Evolution of the ca. 1.9 Ga Taltson magmatic zone, N.W.T.:

A Nd isotope perspective

by

Réginald J. Thériault

Thesis submitted to
the School of Graduate Studies and Research
in partial fulfillment of the requirements for the M.Sc.
degree in Geology

University of Ottawa
Ottawa-Carleton Geoscience Centre

NOTICE

The quality of this microform is heavily dependent upon the quality of the original thesis submitted for microfilming. Every effort has been made to ensure the highest quality of reproduction possible.

If pages are missing, contact the university which granted the degree.

Some pages may have indistinct print especially if the original pages were typed with a poor typewriter ribbon or if the university sent us an inferior photocopy.

AVIS

La qualité de cette microforme dépend grandement de la qualité de la thèse soumise au microfilmage. Nous avons tout fait pour assurer une qualité supérieure de reproduction.

S'il manque des pages, veuillez communiquer avec l'université qui a conféré le grade.

La qualité d'impression de certaines pages peut laisser à désirer, surtout si les pages originales ont été dactylographiées à l'aide d'un ruban usé ou si l'université nous a fait parvenir une photocopie de qualité inférieure.

ISBN 0-315-60589-8

Abstract

The Taltson magmatic zone is a north-trending belt of Early Proterozoic granitoids exposed over an area exceeding 18,000 km^2 in the Northwest Territories. It is flanked to the east by the Archean Churchill Province and to the west by the Buffalo Head terrane, a geophysically and chronologically distinct litho-tectonic crustal entity of Archean crustal age overlain by Paleozoic sedimentary rocks. The Taltson zone is contemporaneous and continuous with the Thelon tectonic zone, a continental arc and collisional orogen which lies immediately north of the Taltson magmatic zone.

Three petrologically and chronologically distinct intrusive suites comprise the Taltson zone. These are the 1986 Ma Deskenatlata suite, the 1955 to 1925 Ma Slave suite and the 1935 Ma Konth suite. The Deskenatlata suite is composed of a biotite-hornblende diorite to granite suite whose major and trace element chemistry supports derivation by arc magmatism. Initial ϵ_{Nd} values for the Deskenatlata suite range from -2.7 to -3.6.

The Slave and Konth suites are leucocratic granitoids which contain numerous xenoliths of dominantly pelitic high

grade paragneiss and display S-type granite mineralogy which commonly duplicates that of the pelitic gneisses. Bulk rock chemistry for the Konth suite is consistent with a homogeneous crustal magma source whereas the Slave suite is compositionally more heterogeneous. Initial ϵ_{Nd} values for the Konth suite cluster within -4.7 and -5.6 and are completely overlapped by the -4.1 to -5.8 range of the pelitic xenoliths. The Slave suite has initial ϵ_{Nd} values ranging from -4.8 to -7.5, overlapping the ϵ_{Nd}(1.94 Ga) values of the western Churchill Province and the pelitic xenoliths.

Compatible with the evolution of the Thelon zone, the Deskenatlata suite is considered as continental arc-derived granitoids resulting from eastward subduction of oceanic lithosphere beneath the Churchill Province. The Slave suite is regarded as the result of melting of various segments of heterogeneous Archean crust whereas the Konth may have evolved exclusively from melting of pelitic metasediments. Generation of the Slave and Konth suites may have resulted from collision of the Buffalo Head terrane and the Churchill Province.

Sommaire

La zone magmatique Taltson comprend une ceinture de granitoïdes d'âge protérozoïque inférieur qui s'allonge dans une direction nord et qui recouvre plus de 18,000 km^2 dans les Territoires du Nord-Ouest. Cette zone est bornée à l'est par la province archéenne de Churchill et à l'ouest par le terrain Buffalo Head, un segment de croûte archéenne qui est géophysiquement et chronologiquement distinct et présentement recouvert de sédiments paléozoiques. La zone Taltson est contemporaine et continue avec la zone tectonique Thelon au nord, qui elle comprend un arc continental et une orogène collisionelle.

Trois suites pétrologiquement et chronologiquements distinctes composent la zone Taltson. Celles-ci sont: la suite Deskenatlata (1986 Ma), la suite de l'Esclave (1955 à 1925 Ma) et la suite Konth (1935 Ma). La suite Deskenatlata est composée de diorites à biotite et hornblende dont les éléments majeurs et traces suggèrent une origine par un arc magmatique. Les valeurs initiales ϵ_{Nd} de la suite Deskenatlata vont de -2.7 à -3.6.

Les suites de l'Esclave et Konth sont toutes deux composées de granitoïdes leucocrates avec une minéralogie de

type S et de nombreux xénolites de gneiss surtout pélitiques et de haut grade. La géochimie suggère pour la suite Konth une source crustale homogène, alors que la suite de l'Esclave est plus hétérogène. Les valeurs initiales ϵ_{Nd} de la suite Konth vont de -4.7 à -5.6 et sont complètements encaissées par les valeurs des xénolites pélitiques qui eux vont de -4.1 à -5.8. La suite de l'Esclave possède des valeurs initiales ϵ_{Nd} de -4.8 à -7.5 qui recouvrent les valeurs ϵ_{Nd}(1.94 Ga) des gneiss de l'ouest de la province Churchill et des xénolites pélitiques.

La suite Deskenatlata est considérée comme le produit d'un arc continental associé à une subduction de croûte océanique sous la province Churchill. Ceci est compatible avec les modèles suggérés pour la zone Thelon au nord. La suite de l'Esclave résulte de la fusion de plusieurs segments hétérogènes de croûte archéenne alors que la suite Konth résulte peut-être exclusivement de la fusion de métasédiments pélitiques. Les suites de l'Esclave et Konth sont possiblement les produits d'une collision survenue entre le terrain Buffalo Head et la province Churchill.

Table of contents

List of Figures

List of Plates

Acknowledgements

Sincere thanks are extended to Dr. A. Lalonde, principal adviser, for having accepted to supervise this project. His enthusiasm and counselling on all aspects of this work have rendered this study an enjoyable and fruitful experience.

The Geological Survey of Canada is thanked for providing field support and isotopic analytical facilities. XRF analyses were made possible through NSERC grant # A1437 to Dr. A. Lalonde. This research would not have been possible without samples and impeccable geological maps provided by Dr. H. Bostock. Dr. O. van Breemen initiated the project and made available laboratory facilities for isotopic analyses. I am greatly indebted to Dr. E. Hegner for having taught me state of the art skills in isotopic analysis and data interpretation. Discussions with and a review of the manuscript by Dr. F. Dudas clarified ambiguities of data interpretation and directed me to pertinent literature.

Endless patience and moral support from my wife, Andrée were central to the successful completion of this project.

Introduction

Neodymium isotopic studies of Precambrian orogenic belts have contributed immensely to the understanding of the tectonic evolution of continents and the growth of continental crust, which can be viewed as the result of addition of new materials differentiated from the mantle and mechanical assembly of pre-existing crustal entities. The similar geochemical behaviour of the samarium-neodymium pair and the long half-life of the radioactive parent isotope ^{147}Sm make the Sm-Nd system ideal for identifying crustal and mantle contributors to the products of crustal growth and for retracing the tectonic processes by which the continents accreted.

This study is primarily a regional scale Nd isotopic survey of the granitoid intrusive suites of the Early Proterozoic Taltson magmatic zone and of its proximal gneisses exposed in the Northwest Territories. The objectives of the study are two-fold: 1) to reconstruct the petrogenetic history of the intrusive suites of the Taltson zone, placing emphasis on potential source materials and, 2) to identify the role of the Taltson magmatic zone in the framework of regional Precambrian tectonics. As a first chapter, a synthesis of current knowledge of the tectonics of the northwestern

Canadian Shield and a general overview of the geology of the study area are presented. This is followed by petrographic and bulk rock chemistry characterization of the granitoid suites of the Taltson magmatic zone. In the following chapter, Sm-Nd isotope principles and systematics are reviewed, procedures for isotopic analysis are discussed and data for the different lithologies of the study area are presented. Special attention is brought to lithologies which, by field relationships, appear as potential source rocks to the granitic suites of the Taltson zone. Finally, in the concluding chapter, the petrogenesis of the intrusive suites is summarized and tectonic implications are contemplated.

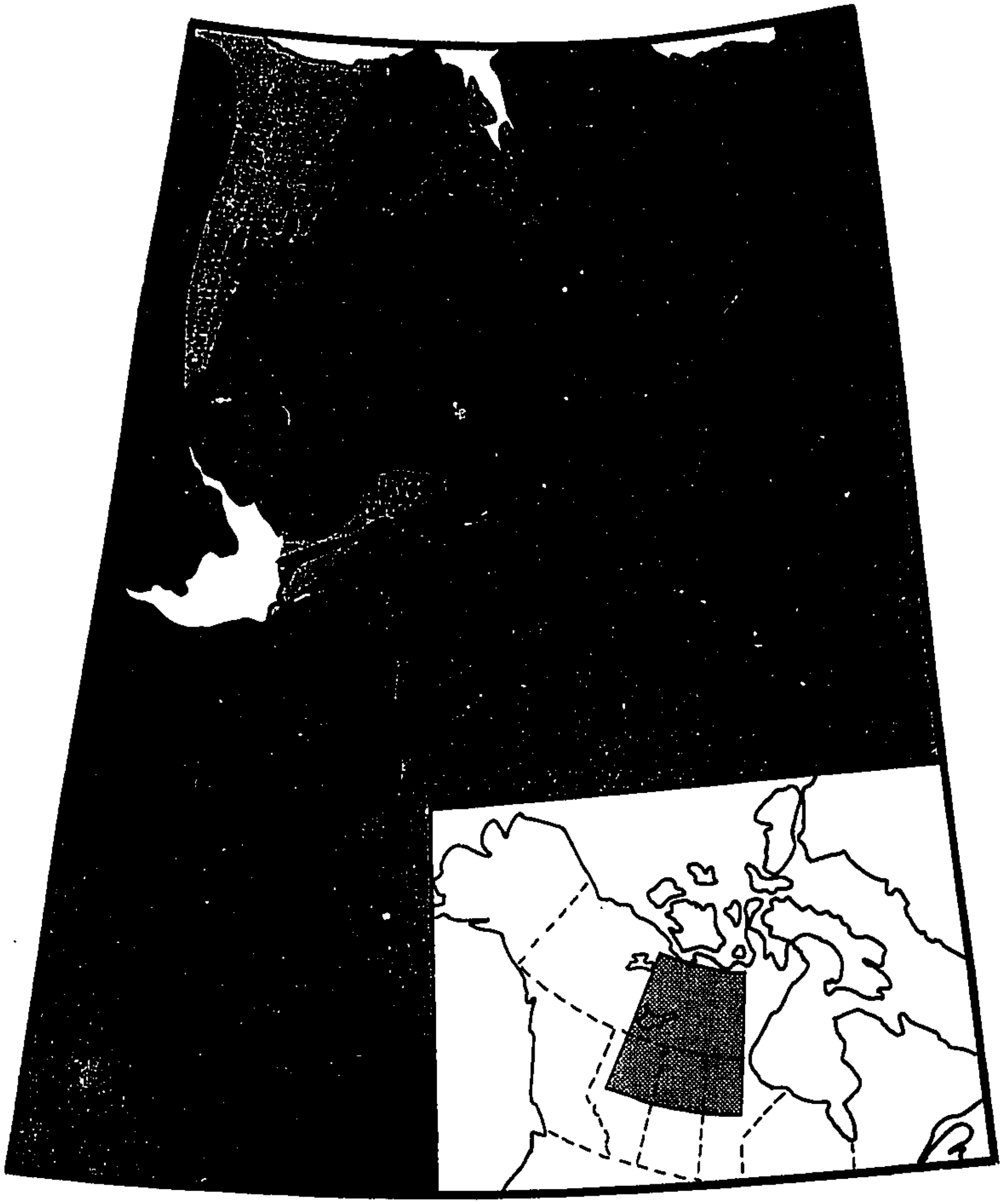
Chapter 1: Regional geology

1.1 Tectonic setting

In the northwestern Canadian Shield, three cratonic blocks of Archean crustal age pertain to this study (Fig. 1). These are the well exposed Slave and Churchill Provinces and the Buffalo Head terrane, the latter being entirely overlain by Paleozoic sedimentary cover.

The Slave Province consists of plutonic-metamorphic terranes which accreted 2.7 to 2.5 Ga ago (Padgham, 1987; Mortensen et al., 1988; van Breemen and Henderson, 1988) by virtue of compressional tectonics (Kuskey, 1989). Nd crust formation ages for the Slave Province are in the vicinity of 2.7 to 3.3 Ga (Dudas, 1989; E. Hegner, pers. comm., 1988). A Nd model age of 4.0 Ga has been obtained from the Exmouth terrane, an outlier of the Slave Province found as basement to the Wopmay orogen (Bowring et al., 1989). The Slave Province is bounded to the west by the 1.9 to 1.8 Ga Wopmay orogen (Coronation Supergroup, Great Bear and Hottah arcs) (Hoffman, 1980; Hoffman and Bowring, 1984; Hildebrand and Bowring, 1984) and to the east by the 2.0 to 1.9 Ga Thelon orogen (Henderson et al, 1982, 1987; van Breemen et al., 1987a, 1987b).

Figure 1: Map of major tectonic elements of the northwestern Canadian shield. Cratonic blocks of Archean crustal age are Buffalo Head terrane, Churchill Province and Slave Province. The latter is o v e r l a i n b y sedimentary thrust and fold belts: Coronation Supergroup, Goulburn Supergroup and Great Slave Supergroup. The Thelon-Taltson zone is truncated by the Snowbird tectonic zone (Stz) and the Great Slave Lake shear zone (GSLsz). The western limit of exposed Precambrian is delineated by the dashed line. Area of study is outlined in red.



The Churchill Province has been subdivided by Hoffman (1988) into a northern segment (Rae Province) and a southern segment (Hearne Province). The Rae and Hearne segments are divided by the mainly subsurficial Snowbird tectonic zone, a 3000-km long northeast-trending structural discontinuity which is evident on gravity gradient and magnetic anomaly maps (Sharpton et al.,1987). Of greater significance to this study is the Rae segment, which extends eastward to New Québec and northward into the Arctic archipelago. The Rae segment is dominated by felsic gneisses and plutonic rocks ranging in age from 2.9 to 2.6 Ga with relics of older, 3.1 to 2.9 Ga gneisses (Hoffman, 1989).

The Buffalo Head terrane is a dominantly magmatic terrane overlain by Paleozoic sedimentary rocks of the western interior platform. It is characterized on gravity and magnetic anomaly maps by the lack of a consistent internal fabric, in sharp contrast with the Taltson zone which displays strong north-trending gravity and magnetic patterns east and west of the Buffalo Head terrane (Ross et al., in prep.). The Great Slave Lake shear zone and the Snowbird tectonic zone bound the Buffalo Head terrane to the north and south respectively. Dating of zircons of drill cores from the Buffalo Head terrane has yielded distinct crystallization ages falling in the 2.3 to 2.0 Ga bracket, distinctly older than the Taltson magmatic zone. Nd crust formation ages approximating 2.7 Ga are characteristic of the Buffalo Head terrane (Thériault and Ross, 1990).

A total dextral displacement of 700 km along the northeast-trending Great Slave Lake shear zone (Hoffman, 1987) and the presence of the conjugate Bathurst and McDonald faults transecting the Thelon tectonic zone have lead to the postulation of eastward convergence and collision, followed by indentation of the Slave Province into the Churchill Province (Gibb, 1978; Gibb et al., 1983; Hoffman 1988). Evidence in support of this theory is as follows. The 80 to 100 km wide Thelon tectonic zone, composed of highly deformed 2.0 to 1.9 Ga (van Breemen et al., 1987b) dioritic to granitic plutons lying between the Slave and Churchill Provinces (Henderson et al., 1982) is inferred to represent arc magmatism resulting from eastward subduction of oceanic crust beneath the Churchill Province as well as syn- and post-collisional magmatism (Hoffman et al., 1986; Hoffman, 1988). The westerly-verging thrust-fold belts and foreland basins in the Goulburn and Great Slave Lake Supergroups are believed to be related to the Thelon orogen (Hoffman, 1988, 1989). In the Goulburn Supergroup, drowning of the shallow shelf Kimerot platform at 1.967 Ga (Bowring and Grotzinger, 1989) by southeasterly-derived detritus (Bear Creek foredeep)

(Grotzinger and McCormick, 1988) closely estimates the Slave-Churchill collision. Granulite grade metamorphism, dated in the interval 2.0 to 1.95 Ga (van Breemen et al., 1987a, 1987b) is interpreted as the result of collision between the Slave and Churchill Provinces. The indentation of the cold and rigid Slave Province into the hot and ductile Churchill Province was accommodated by the conjugate Bathurst and McDonald faults and by the uplift and northward translation of the Queen Maude uplift of the western Churchill Province. Paired gravity anomalies in the eastern Slave and western Churchill Provinces indicate crustal thickening of the eastern portion of the indenting Slave Province (Gibb et al., 1983; Henderson et al., 1987).

South of the McDonald fault, the Taltson zone appears to be coeval to the Thelon zone although the former is less deformed and metamorphosed to a lesser grade. The Taltson zone extends beneath the subsurface of the Province of Alberta and is truncated by the Snowbird tectonic zone (Hoffman, 1989; Ross et al.,in prep.).

Magnetic anomalies distinct to the Thelon zone and Queen Maud uplift can be traced northward to Boothia peninsula (Hoffman, 1989).

1.2 General geology of the Taltson magmatic zone and proximal gneisses of the Churchill Province

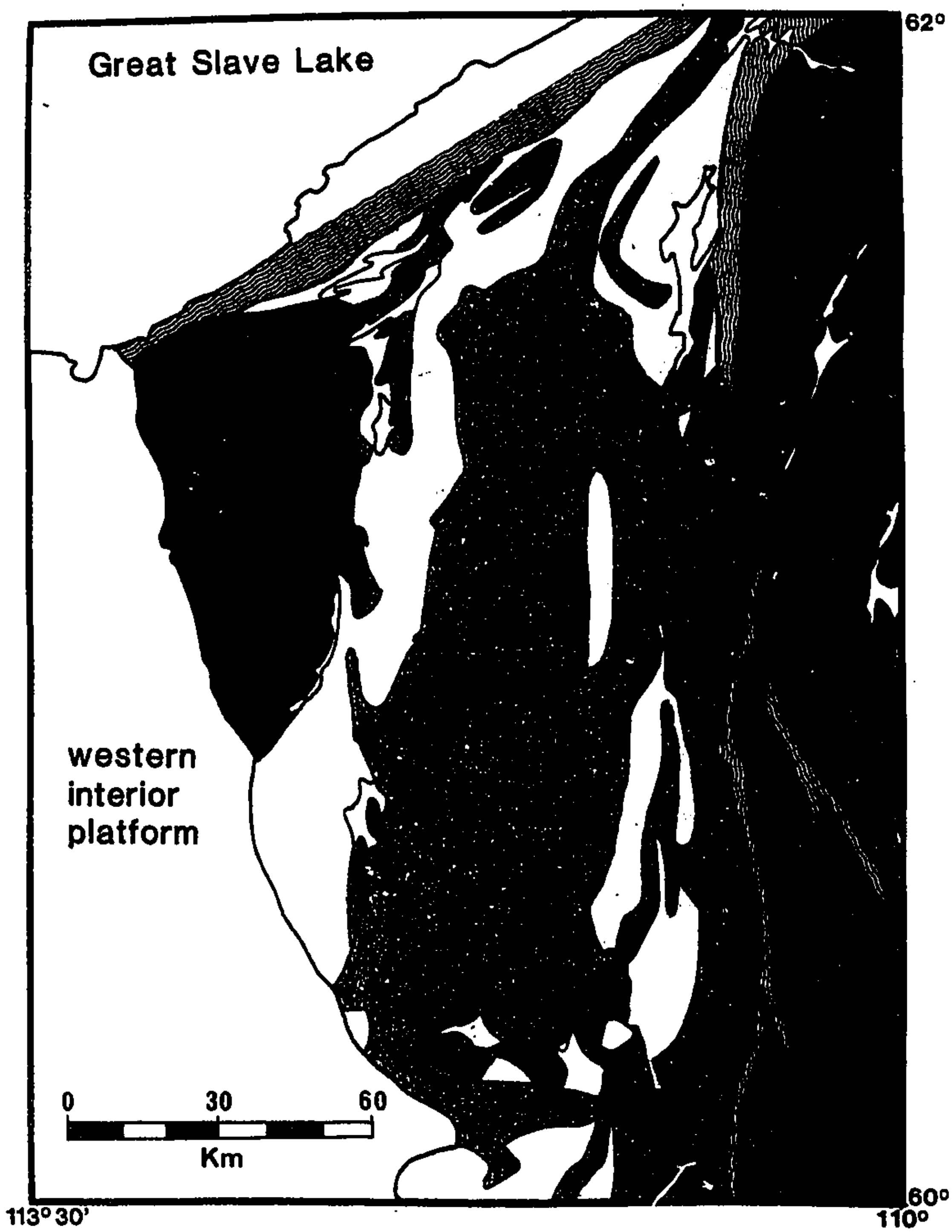
Two major lithologic packages relevant to the study are described below. The first package includes gneisses belonging to the western part of the Rae segment of the Churchill Province whereas the second encompasses rocks comprising the Taltson magmatic zone (Fig. 2). The Taltson magmatic zone and Churchill Province are separated by a north-trending belt of mylonitic rocks. The rock units are presented in chronologic order. Unless stated otherwise, all ages quoted are based on U-Pb isotopic analyses on zircon and/or monazite. Detailed geology and specific localities mentioned in the text are shown on the geological and sample location maps of Appendix III.

1.2.1 Gneisses of the Churchill Province

Bostock and Loveridge (1988) recognize two distinct gneiss terranes in the Churchill Province immediately east of the Taltson magmatic zone. These are referred to as the eastern granitic and western mixed gneisses (Bostock and Loveridge, 1988).

The eastern gneisses constitute a poorly mapped terrane of mostly granitic gneisses to the north and east of the western mixed gneisses. The dominant rocks are biotite-,

Figure 2: Generalized map of major lithologies of the Taltson magmatic zone and proximal gneisses exposed in the Northwest Territories.
Brown: mixed gneisses of the Churchill Province;
Grey: granitic gneisses of the Churchill Province;
Green: mainly pelitic paragneisses of upper amphibolite to granulite grade amidst intrusive rocks of the Taltson zone, and of sub-greenschist grade overlying Churchill gneisses;
Red: Deskenatlata intrusive suite;
Yellow: Slave intrusive suite;
Orange: Konth intrusive suite;
Wavy pattern: mylonites.


Great Slave Lake
western
interior
platform
0
30
60
Km
62°
60°
113° 30'
110°

hornblende- and potassium feldspar-rich granitic gneisses with varying proportions of mafic inclusions. These rocks are commonly intruded by granite pegmatites. Metamorphic grade is lower amphibolite and greenschist facies and deformation is dominantly brittle (Bostock et al., 1987). A north-trending band of sub-greenschist grade greywacke and mudstone overlies the eastern granitic gneisses at Hill Island Lake (Bostock, 1984) (c.f. Appendix III). These metasedimentary rocks are intruded along their western margin by muscovite-bearing granitoids and pegmatites.

The western mixed gneisses form a longitudinal, northward-tapering wedge between the eastern gneisses and the Taltson magmatic zone. The western gneisses are extremely variable and may be granitic, pelitic or mafic. These deformed gneisses have undergone north-trending ductile shear and have been retrograded to greenschist facies (Bostock et al., 1987; Bostock and Loveridge, 1988). Numerous granitic plutons varying in age from 1935 Ma (Bostock et al., 1987) to 2334 Ma (Bostock and Loveridge, 1988) intrude the mixed gneisses.

1.2.2 Rocks of the Taltson magmatic zone

Three chronologically and petrographically distinct intrusive suites comprise the bulk of the exposed Taltson magmatic zone. These are the Deskenatlata, the Konth and the Slave intrusive suites. The petrography of these three suites is only outlined below, along with the other geological units of the area. The detailed petrography of the Taltson granitoid suites is found in the next chapter. Dominantly pelitic metasedimentary gneisses are scattered throughout the area and occur mostly as xenoliths in the intrusive suites. Amphibolitic gneisses are present in lesser amounts and occur mostly in the western region of the study area as xenoliths in the Deskenatlata intrusive suite. A regional metamorphic gradient is not recognizable although mineral assemblages in paragneiss xenoliths suggest that these have undergone upper amphibolite to granulite grade metamorphism (Bostock, 1987; Bostock 1988; Bostock et al., 1987; Culshaw, 1984).

1.2.2a Deskenatlata intrusive suite

The Deskenatlata intrusive suite, the western most of the three suites, is dominantly granodioritic and is exposed over an area of approximately 2600 km^2. It is bounded to the north and west by the Great Slave Lake shear zone, to the south and west by Paleozoic cover which extends into Alberta and to the east by the Slave intrusive suite. Rocks of the Deskenatlata suite are distinguished by a generally massive texture and I-type (Chappell and White, 1974) granite mineralogy (Plate 1). They are generally medium grained and equigranular. Typically, the phases accompanying quartz, plagioclase and potassium feldspar are biotite and hornblende, with chlorite dominating locally. Titanite, magnetite and hematite are commonly observed as accessory phases.

Xenoliths of amphibolitic and pelitic gneisses are abundant in the eastern part of this intrusive suite, where north-trending planar deformation is intense (Bostock, 1981; Bostock et al., 1987). The xenoliths range in size from a few centimetres to more than a metre in diameter and show partial to almost complete resorption into the surrounding plutonic rock. Xenoliths of amphibolite are more abundant than those of pelitic paragneiss. An age of emplacement of 1986 Ma for the Deskenatlata suite has been determined by Bostock et al. (1987).

The Gagnon Lake granodiorite, a large intrusive body resembling the Deskenatlata in mineralogy, lies immediately east of the mylonites separating the Taltson magmatic zone from the gneisses of the Churchill province. A crystallization age for this body is yet to be determined.

Plate 1: Medium-grained, massive Deskenatlata granodiorite.

1.2.2b Slave intrusive suite

Exposed in the Northwest Territories over an area of about 6500 km^2, the Slave intrusive suite forms north-trending parallel segments. The largest of these segments is bounded to the north by the Great Slave Lake shear zone, to the south by Paleozoic cover, to the west by the Deskenatlata intrusive suite and to the east by the Konth suite. Smaller segments of the Slave suite are found in the eastern and southern sectors of the Konth suite. Contacts between the Slave and Konth suites are often gradational (Bostock, 1982). Foliation, defined by flattening of quartz and feldspar grains, is most pronounced proximal to mylonites and shear zones in the eastern portion of the Deskenatlata suite and the western margin of the Churchill Province. The foliation is generally parallel to the mylonites and shear zones.

Rocks of the Slave suite are mostly medium-grained and equigranular. Their mineralogy typically includes biotite, chlorite, garnet, sillimanite, andalusite and cordierite (Bostock, 1982; 1987; 1988; Bostock et al., 1987) (Plate 2). These minerals are irregularly distributed throughout the suite and, in hand specimen, generally do not appear to have grown from pre-existing mineral phases. Occurrences with coarse-grained, potassium feldspar are often difficult to

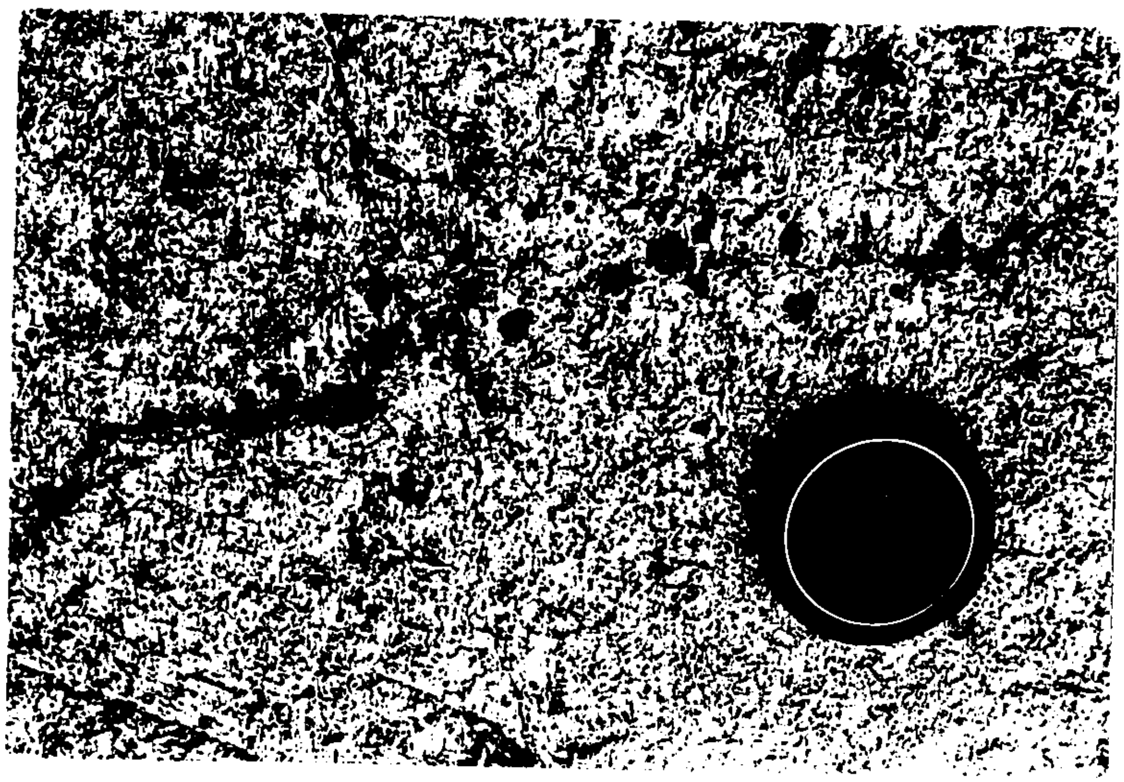


Plate 2: Coarse-grained, foliated Slave granite with garnet xenocrysts. Lens cap is 6 cm in diameter.

distinguish from the Konth suite (described below) since both rock types display similar peraluminous accessory phases.

Mainly pelitic metasedimentary xenoliths, with subordinate quartzo-feldspathic members, ranging in size from a few centimetres to tens of square kilometres are found in the Slave intrusive suite. Remnants of primary sedimentary structures, such as graded bedding (Plate 3), are commonly preserved within these. The xenoliths display varying amounts of resorption, from unresorbed to almost completely resorbed, suggesting assimilation of sedimentary material by the granitic magmas.

The Slave suite has yielded ages of crystallization of 1955 Ma (Bostock et al., 1987) and 1925 Ma (H. Bostock, pers comm., 1989). Discontinuous remnants of a similar rock type continue south of the Alberta-Northwest Territories border where they have been called the Slave granite (Godfrey and Langenberg, 1978).

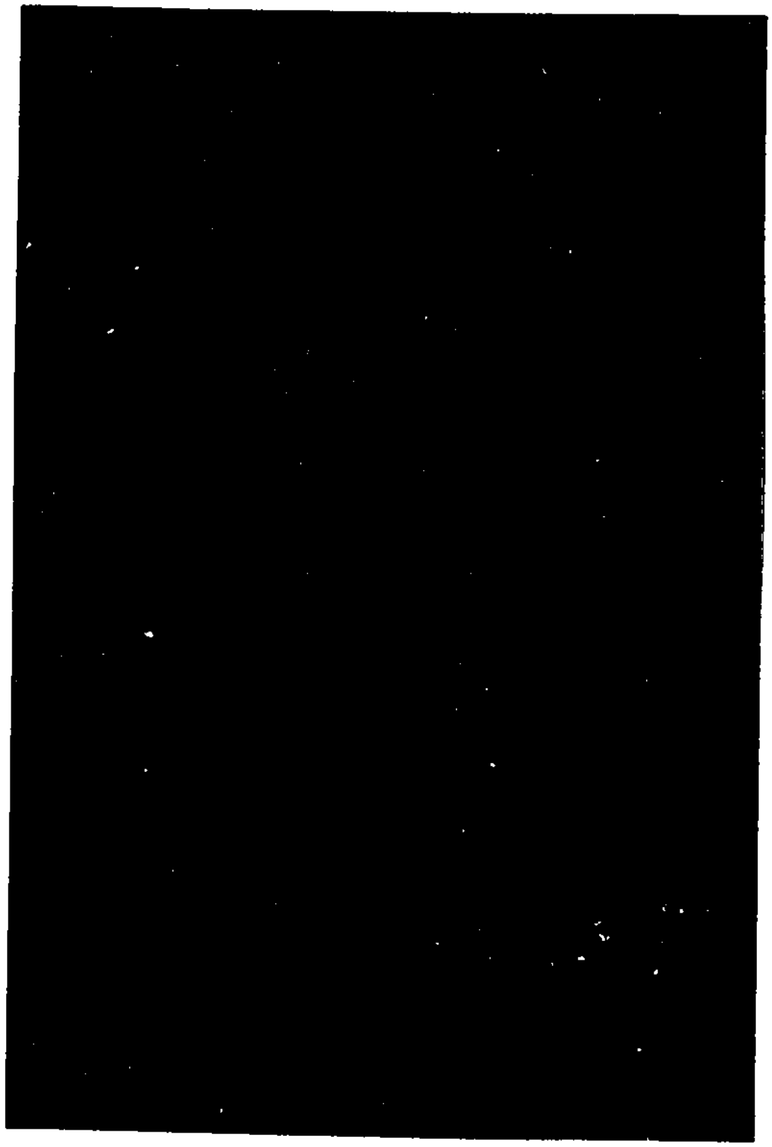


Plate 3: Preserved graded bedding in an interlayered pelitic and quartzofeldspathic paragneiss xenolith in the Slave suite.

1.2.2c Konth intrusive suite

The Konth intrusive suite, exposed over an area exceeding 9100 km^2, is the largest intrusive suite in the Taltson magmatic zone. It is bounded to the north by the Great Slave Lake shear zone, to the south by Paleozoic cover, to the west by the main body of the Slave intrusive suite and to the east by north-trending mylonite belts which define the boundary between the Taltson magmatic zone and the Churchill Province (Bostock, 1988; Bostock et al., 1987; Bostock and Loveridge, 1988; Culshaw, 1984). Although it is generally coarser-grained and richer in potassium feldspar than the Slave suite, the Konth suite resembles the Slave suite in mineralogy and metasedimentary xenoliths. Similar to the Slave suite, mineral phases in the Konth suite are not systematically distributed and are apparently not products of metamorphism of earlier phases. A diagnostic feature of the Konth suite is the presence of potassium feldspar megacrysts which reach 3 or 4 cm in length in an equigranular fine to medium-grained matrix. The foliation, defined by the planar orientation of megacrysts, varies in intensity and generally strikes north with steep to moderate easterly dips (Bostock et al, 1987). Similar to the Slave suite, the Konth suite is emplaced into, and incorporates multiple lenses of chiefly pelitic paragneiss (Plate 4).

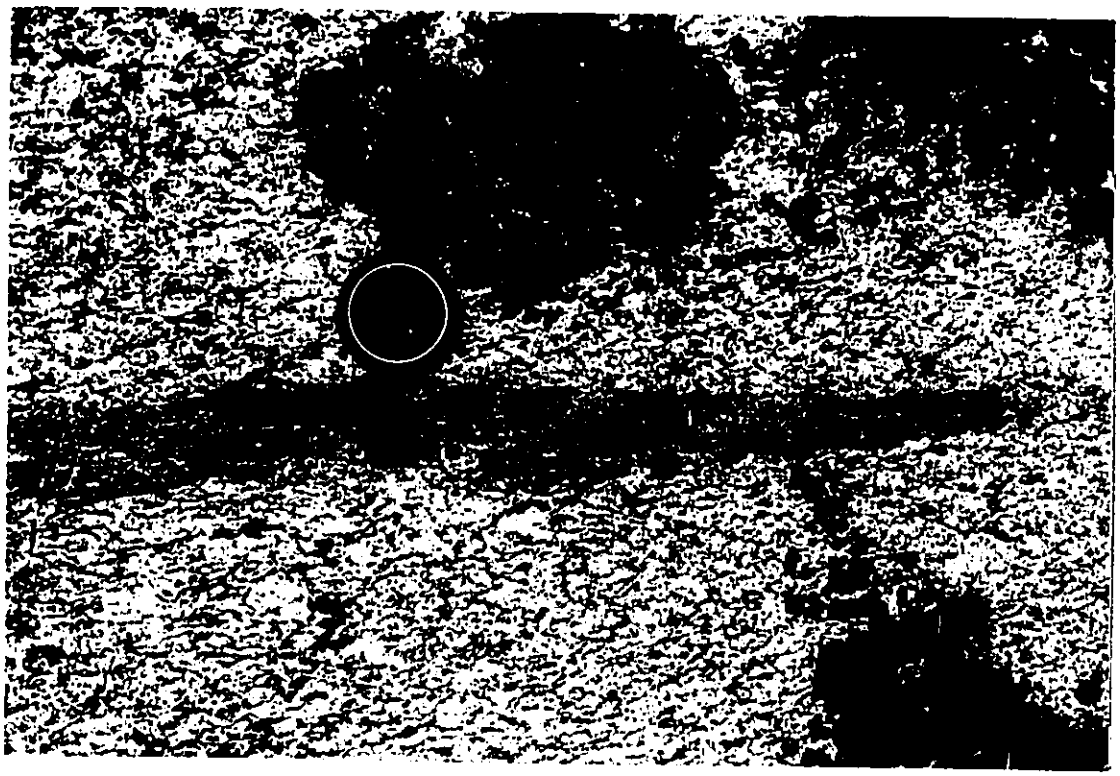


Plate 4: Megacrystic Konth syenogranite and pelitic paragneiss xenolith.

Numerous ages of crystallization have been obtained for the Konth suite. These are 1935 Ma for the northwest zone of the Konth intrusive suite (Bostock et. al, 1987), 1938 Ma for the southwest zone, 1936 Ma and a tentative age of 1922 Ma for the central zone (Bostock and Loveridge, 1988).

1.2.3 Nonacho group

The Nonacho basin constitutes a structure infilled by dominantly terrigenous clastic sedimentary rocks which unconformably overly mixed and granitic gneisses northeast of the Taltson magmatic zone. The coarse nature of the sediments, development of cycles up to thousands of metres thick, the presence of conglomerates and sandstones and soft-sediment deformation all indicate that syn-depositional faulting and deformation took place. The Nonacho Group is severely deformed along its western margin where it becomes incorporated in north-trending mylonites (Aspler, 1985; Bostock et al., 1987).

1.2.4 Mylonites

Zones of north-trending mylonite and faults are predominant along the eastern edge of the Taltson magmatic zone and the western edge of the Churchill Province (Bostock, 1982, 1987, 1988, Bostock et al., 1987, Culshaw, 1984). The largest of these mylonites is about 1 kilometre wide and is located along the western shore of Lady Grey Lake (c.f. Appendix III), east of the Konth intrusive suite, and then splays into different segments to join the Allen Fault zone in Alberta (Bostock, 1987; Bostock et al., 1987). A second major mylonite belt extends southeast from Lady Grey Lake into the Churchill Province. A crystallization age of 1906 Ma on the Benna Thy monzogranite, a small intrusion between mylonites at the boundary of the Taltson magmatic zone and the Churchill craton has provided a minimum age for the shearing (Bostock and Loveridge, 1988). Less prominent mylonite and fault zones are found in the western part of the study area, where they trend northward along the eastern edge of the Deskenatlata intrusive suite (Bostock, 1981, 1986).

1.2.5 Sparrow dykes

Gabbro dykes of the Sparrow swarm are common throughout the study area. These are generally less than a meter thick, have a southeasterly strike and a vertical dip (Bostock, 1982, 1987). Sparrow dykes intrusive into sediments of the Nonacho group have been dated at about 1700 Ma by the K-Ar method (McGlynn et al., 1974).

Chapter 2: Petrography

2.1 Introduction

Over sixty thin sections from the Deskenatlata, Slave and Konth intrusive suites were examined. A synthesis of these observations is presented in the following pages. Because this study deals with the petrogenesis of the granitic rocks of the Taltson zone, petrographic descriptions of their many potential Churchill Province parent rocks are not presented. Exception is made for the paragneiss xenoliths engulfed by the Slave and Konth suites, as field observations show intrinsic relationships between granitoids and xenoliths and petrographic examination provides valuable insight on the granitoid-paragneiss association.

2.2 Deskenatlata intrusive suite

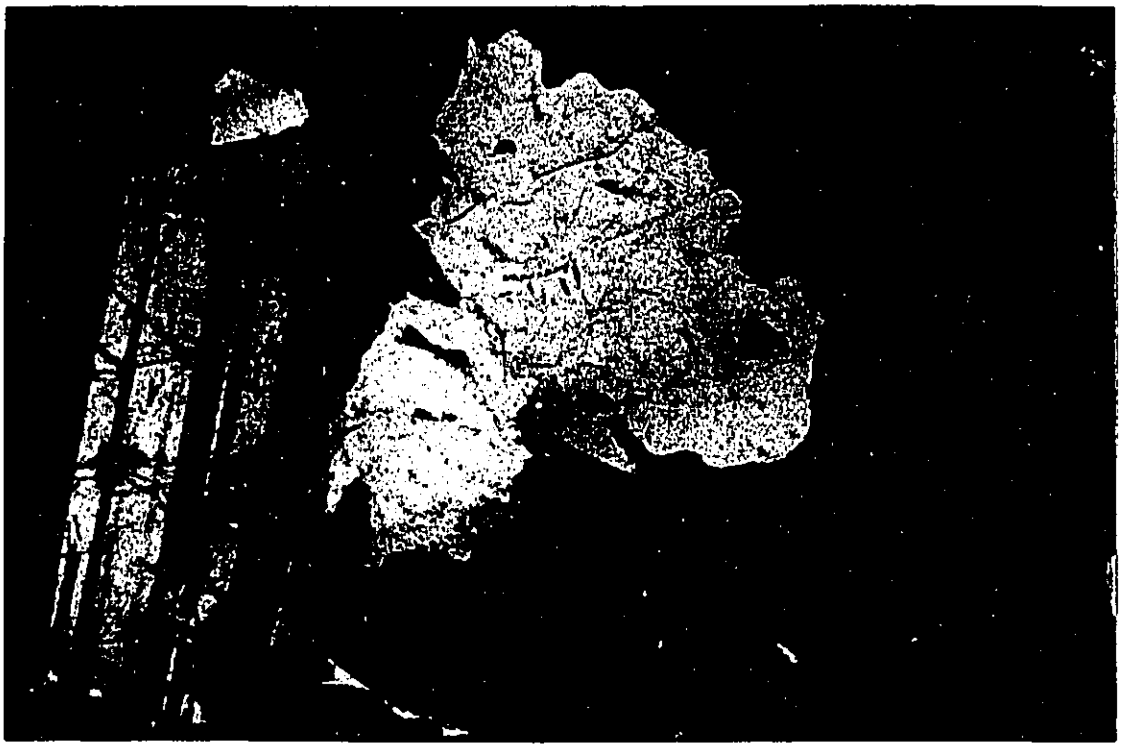
The Deskenatlata intrusive suite is dominantly granodioritic and ranges compositionally from quartz diorite to granite. Rocks of the suite are generally medium to coarse-grained, massive and equigranular with little evidence of strain.

Quartz, whose modal percentage varies from 10 to 30%, is usually inclusion-free and commonly has uniform extinction although recrystallized finer-grained, strained quartz is observed in the minority of cases. Quartz poikiloblasts and rutile needles occur in biotite (Plate 5). Plagioclase (An_{30}) is usually present in amounts of 15 to 25%, occurs as coarse to medium grains, is anhedral to subhedral and shows some internal zoning. Anhedral to subhedral potassium feldspar is mainly microcline and perthitic exsolution is pervasive. Potassium feldspar is commonly present in amounts of 10 to 15% and rarely exceeds 20%. Feldspars exhibit various extents of sericitic alteration.

Medium-grained brownish-red to green subhedral to euhedral biotite is the dominant mafic phase and comprises up to 20% of the most mafic members of the Deskenatlata suite. Biotite contains inclusions of quartz, rutile, apatite and zircon. Green and brown hornblende is present locally and appears to replace clinopyroxene (Plate 6). Amphibole occurs in the more mafic members of the Deskenatlata suite in amounts of 5 to 15%. Minor to extensive alteration of the mafic silicate phases to chlorite is common. Apatite, present in abundances of up to 5%, titanite and zircon are minor constituents of the Deskenatlata suite.

Plate 5: Quartz-plagioclase-biotite assemblage in Deskenatlata granodiorite under crossed-polars. Note acicular rutile in biotite. Crossed polars, X 50.

Plate 6: Clinopyroxene altered to hornblende in Deskenatlata granodiorite. Crossed polars, X 50.



2.3 Slave intrusive suite

The composition of the Slave suite varies from granodiorite to syenogranite, with monzogranite being the most common rock type. The rocks are medium to coarse-grained, generally hypidiomorphic and show variability in degree of alteration. The foliation varies in intensity and is defined by the elongation of coarse potassium feldspar and quartz grains and the parallel alignment of phyllosilicates. Locally, fine-grained quartz- and feldspar-rich matrix surrounds coarse grains of quartz and potassium feldspar.

Fine to coarse-grained quartz is a major mineral constituent of the Slave suite and varies in abundance from 25 to 50%. It shows extensive undulose extinction and is also the major constituent of the matrix. Abundant, small fluid inclusions are visible in the coarsest quartz grains. Quartz is commonly present as myrmekite (Plate 7). Potassium feldspar exhibits perthitic exsolution or microcline twinning and is present in abundances ranging from 30 to 70%. Megacrysts of potassium feldspar occur in the coarsest rocks. Plagioclase (An_{17}) occurs as fine to medium grains peripheral to potassium feldspar, is antiperthitic and shows no zoning. Plagioclase comprises 20 to 40% of this rock type. Feldspars are variably altered to sericite. Fine-grained, quartz and feldspar-rich matrix commonly surrounds coarse quartz and potassium feldspar

Plate 7: Fine to medium-grained biotite and spinel (isotropic) and myrmekite interstitial to coarse grains of quartz and alkali feldspar in Slave granite. Crossed polars, X 50.

grains. The matrix generally has a granular texture and typically grain boundaries form 120° angles.

Bright reddish-brown to orange fine to medium-grained biotite often occurs in clots and is commonly chloritized. Fine grained chloritized biotite commonly occurs as parallel wisps in the quartzo-feldspathic matrix. Locally, garnet and/or dark green spinel (gahnite?) are associated with biotite. Garnet and spinel are abundant in amounts up to 10% and are not idiomorphic. Spinel is commonly rimmed by an unidentified, anisotropic and colourless mineral. Medium to coarse-grained anhedral cordierite, whose modal abundance ranges up to 10%, displays cyclic twinning (Plate 8) when not altered to pinite, contains abundant quartz inclusions and frequently occurs proximal to pelitic paragneiss xenoliths. Garnet and cordierite do not appear to replace pre-existing mineral phases. Orthopyroxene is present in minor amounts as fine to medium anhedral grains. Medium grained, euhedral sillimanite appears to be primary and is not subordinate to other phases. Fibrolitic sillimanite is present in lesser amounts. Zircon, monazite and apatite are generally fine-grained minor phases.

Plate 8: Twinned cordierite, coarse-grained quartz and alkali feldspar and fine-grained leucocratic minerals in Slave granite. Crossed polars, X 50.

2.4 Konth intrusive suite

The Konth intrusive suite is compositionally restricted to syenogranite. It is characterized by megacrysts of potassium feldspar and quartz. The mineralogy of the Konth suite approximates that of the Slave suite (Plate 9). Various amounts of strain are exhibited in unfoliated to highly foliated specimens. The development of an intense foliation is most conspicuous to the east of the study area where the Konth suite is adjacent to north-trending mylonites. Megacrysts are typically surrounded by fine-grained matrix similar to that described for the Slave suite. The proportion of matrix is greater in the Konth suite than it is in the Slave suite.

Megacrysts of anhedral to subhedral perthite and quartz can reach up to 4 cm in length. Potassium feldspar commonly comprises 40% of this suite whereas quartz is usually present in amounts of 20 to 25%. Inclusions of quartz, plagioclase, microcline and biotite are common in the potassium feldspar megacrysts which occasionally are extensively altered to sericite. Quartz megacrysts contain abundant fluid inclusions, show variable extents of undulose extinction and are commonly polycrystalline, preserving recrystallized aggregates of finer quartz grains displaying grain boundaries at 120°. Myrmekitic quartz is common. Fine to medium grains of plagioclase (An_{17})

Plate 9: Biotite, orthopyroxene around spinel (isotropic), sillimanite and perthite in Konth syenogranite. Crossed polars, X 50.

are often peripheral to potassium feldspar and are seldom in excess of 5% of the mode.

Biotite, present in amounts of up to 10%, is medium to coarse-grained, euhedral, bright orange to rust in colour (Plate 10) and variably altered to chlorite. The biotite does not appear to be a late alteration product and contains inclusions of zircons and monazites with pleochroic halos. Anhedral, coarse to medium grains of garnet and dark green spinel are often proximal to or in contact with biotite. As in the Slave suite spinel is typically rimmed with an unidentified mineral phase. When present, garnet and spinel can each constitute up to 10% of the mode. Anhedral, medium-grained, twinned cordierite, commonly altered to pinite, is present in amounts up to 7%. Commonly disseminated medium grains of euhedral sillimanite are present in abundances rarely exceeding 5%. Subhedral to anhedral pleochroic orthopyroxene occurs locally in abundances of up to 2 or 3%. Zircon, monazite and apatite are minor phases.

Plate 10: Orange-red biotite, dark green spinel and disseminated sillimanite in Konth syenogranite. Crossed polars, X 50.

2.5 Paragneiss xenoliths in the Konth and Slave suites

Mainly pelitic paragneiss xenoliths, varying in size from a few centimetres to over 10 kilometres in length, are intruded and exhibit varying degrees of resorption by the Konth and Slave suites. The gneisses are typically pelitic with subordinate quartzo-feldspathic members although metavolcanic rocks are reported by Bostock (1981, 1986) to occur mainly near Thubun and Tsu Lakes (c.f. Appendix III) immediately east of the Deskenatlata intrusive suite. Metamorphic grade is of amphibolite and granulite facies (Culshaw, 1984; Bostock, 1982, 1986, 1987, 1988).

Pelitic paragneisses are fine- to medium-grained, equigranular, granoblastic and are commonly compositionally layered from pelitic to quartzo-feldspathic. Quartz, perthite or microcline and plagioclase of variable anorthite content comprise matrix material interstitial to coarser grains of peraluminous minerals. Quartz and feldspar can also be porphyroblastic and their occurrence is most common in leucocratic layers in the paragneiss. Euhedral orange to rusty brown biotite and muscovite are commonly coexistent. Anhedral garnet with inclusions of quartz is associated with dark green spinel and biotite (Plate 11). Patchy cordierite grains are porphyroblastic and exhibit well developed cyclic twinning (Plate 12). Sillimanite commonly occurs as disseminated euhedral medium grains (Plate 13). Orthopyroxene is subhedral and pleochroic. Rounded zircon and monazite grains are proper to quartzo-feldspathic members.

Plate 11: Garnet, spinel and red biotite in pelitic paragneiss. Plane polarized light, X 50.

Plate 12: Green spinel and euhedral sillimanite in metapelite. Plane polarized light, X 100.

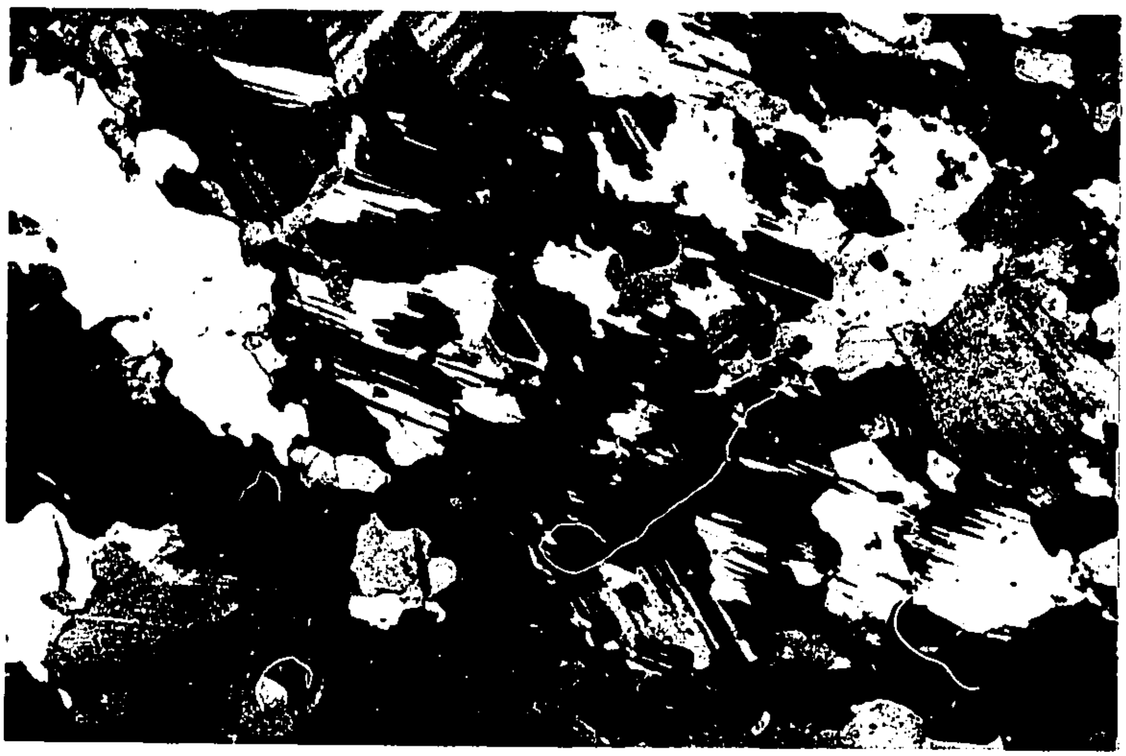


Plate 13: Twinned cordierite grain and spinel in metapelitic xenolith. Crossed polars, X 50.

2.6 Discussion

The three intrusive suites of the Taltson magmatic zone can be classified into two compositional categories. The first category, comprised solely by the Deskenatlata intrusive suite, is characteristically more mafic than the second category and displays little evidence for the incorporation of a sedimentary precursor. The granodioritic composition, the absence of aluminosilicate phases, the zoned feldspars, equidimensional euhedral to subhedral grains and granular texture are suggestive of derivation from igneous sources at depth.

The Slave and Konth intrusive suites form the second compositional category. In contrast with the Deskenatlata suite, the Slave and Konth suites are characterized by garnet, spinel, sillimanite, cordierite and monazite. The similarity in mineral assemblages of paragneiss xenoliths and Konth and Slave suites is striking. The dark green colour and rounded, anhedral habit and size of the spinel is the same in xenoliths and granitoids. The spinel in the paragneiss xenoliths differs from that in the Konth and Slave suite in that the former is not rimmed by another mineral phase. Cordierite in the xenoliths has identical looking cyclic twinning, quartz inclusions and grain size as the cordierite in the Slave and Konth suites. The habit of the sillimanite in the paragneisses is the same as in the two leucocratic granitoid suites. The quartz and potassium feldspar porphyroblasts in the xenoliths are reminiscent of the megacrysts which characterize the Konth. The peraluminous phases in the Konth and Slave suites are not considered to be the result of post-crystallization metamorphism. This is primarily due to the lack of a metamorphic zonation on a regional or local scale. Secondly, biotite, sillimanite, cordierite and garnet are not intergrown with and do not appear to be subordinate to earlier phases. Euhedral, medium-grained sillimanite may have grown as a primary phase or may be restitic material from ultra-metamorphosed and melted pelitic paragneisses, whose remnants exist as xenoliths and xenocrysts. The medium grain size and euhedral habit of the sillimanite are also compatible with uninhibited growth in a melt. Other xenocrystic and/or primary magmatic phases in the Konth and Slave suites may be biotite, spinel, garnet, cordierite monazite and orthopyroxene.

Garnet, sillimanite, cordierite and spinel have been shown to be common primary magmatic or restitic phases in many leucogranites worldwide; notably in the Himalaya (Foord, 1977; Gogte and Ramana, 1982), in the Lachland fold belt of Australia (White and Chappell, 1977; 1988) and in the Hercynian belt of Spain (Corretge et al., 1977; Lorenzoni et al., 1979). Furthermore, biotite, sillimanite, garnet, spinel, cordierite and orthopyroxene are all mineral phases which can coexist with a water-saturated granitic melt (Clarke, 1981; Clemens and Wall, 1981).

Chapter 3: Major and trace element geochemistry

3.1 Methods

A total of fifty one samples from the Deskenatlata, Slave and Konth intrusive suites were analyzed for major and trace elements. Tables of results are shown in Appendix I. Major elements are reported as weight % oxides whereas trace elements are reported in ppm.

The major and trace elements were analyzed on a Philips PW1410 automatic sequential X-ray fluorescence (XRF) spectrometer. Glass discs were prepared by fusing a mixture of 1.5 g of sample powder with 4.5 g of Li_2BO_7 and 0.5 g of $LiCO_3$. Duplicate and standard samples were run for precision and accuracy. The precision for the major elements is estimated to be within 2% while that of trace elements is approximately 10%. Ferrous and ferric iron determinations were carried out by the titration method of Wilson (1960).

3.2 Major element variations

The granitic rocks of the Taltson magmatic zone display a considerable compositional range in which the Deskenatlata, Slave and Konth suites occupy distinct domains. The more mafic character of the Deskenatlata is reflected by its lower range of SiO_2 contents (from 58.72% to 74.42% with a mean of

68.61%). The Deskenatlata SiO_2 values fall within the range typical of granodiorites worldwide (LeMaitre, 1976; Debon and LeFort, 1983).

The Slave and Konth suites display generally higher silica contents compared to the Deskenatlata. Slave suite SiO_2 values range from 67.65% to 75.93 % with a mean of 73.28% while values for the Konth suite fall between 66.20% and 75.28% with a mean of 71.69%. Also fundamental to the general geochemical characterization of the Taltson magmatic zone granitoids are variations in Fe_{tot} (Fig.3), MgO (Fig.4) and (K_2O + Na_2O) (Fig.5). The Deskenatlata suite's higher range of Fe_{tot} (1.10% to 7.30%) and MgO (0.02% to 2.75%) contrasts with the Slave and Konth's lower Fe_{tot} (0.90% to 3.74% for the Slave and 0.71% to 4.60% for the Konth) and MgO (0.00% to 1.51% for the Slave and 0.01% to 0.89% for the Konth). In terms of total alkali contents, the range of (K_2O + Na_2O) values for the Deskenatlata, Slave and Konth suites are 5.77% to 8.74%, 5.88% to 8.89% and 7.50% to 9.66% respectively. Although there is overlap in the (K_2O + Na_2O) content of the three suites, a progressive trend toward alkali enrichment is observed from the Deskenatlata (average 7.19%) to the Slave (average 7.96%) and the Konth (average 8.62%), compatible with an increasing metasedimentary contribution from the Deskenatlata to the Konth suites.

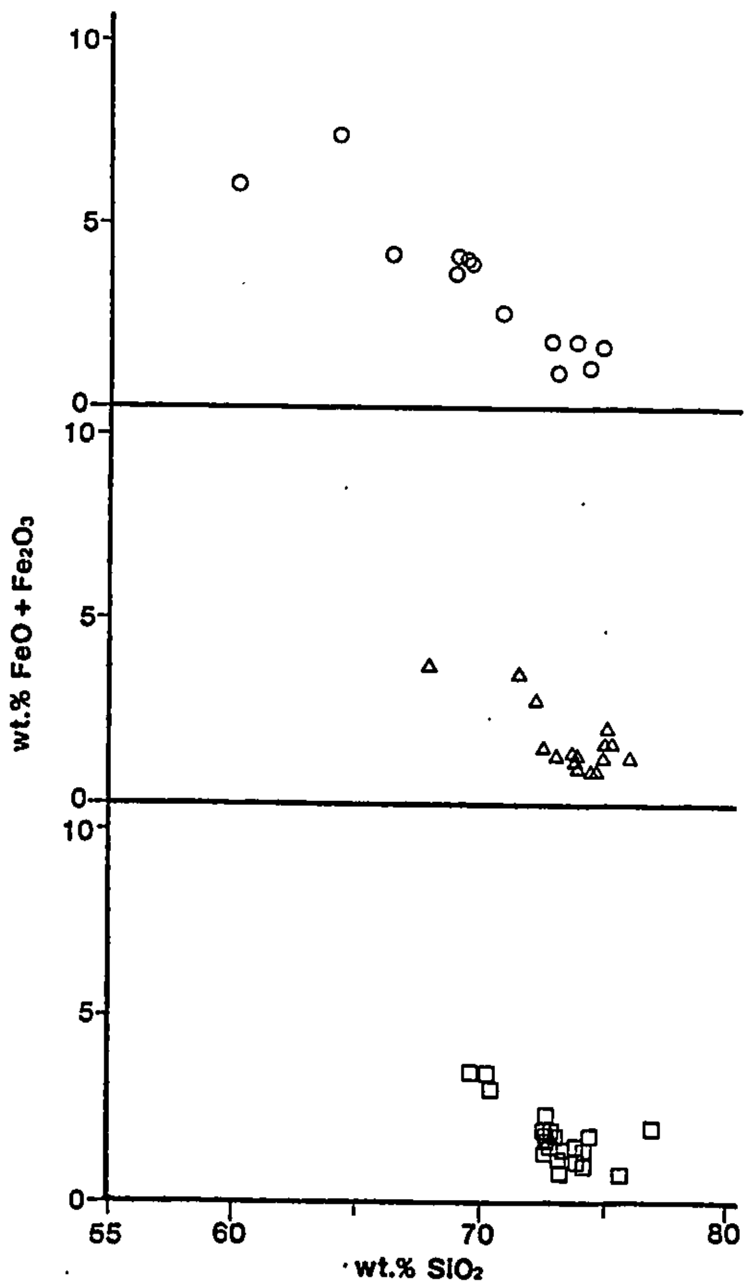


Figure 3: $(Fe_2O_3 + FeO)\%$ vs $SiO_2\%$ for Deskenatlata (circles), Slave (triangles) and Konth (squares) intrusive suites.

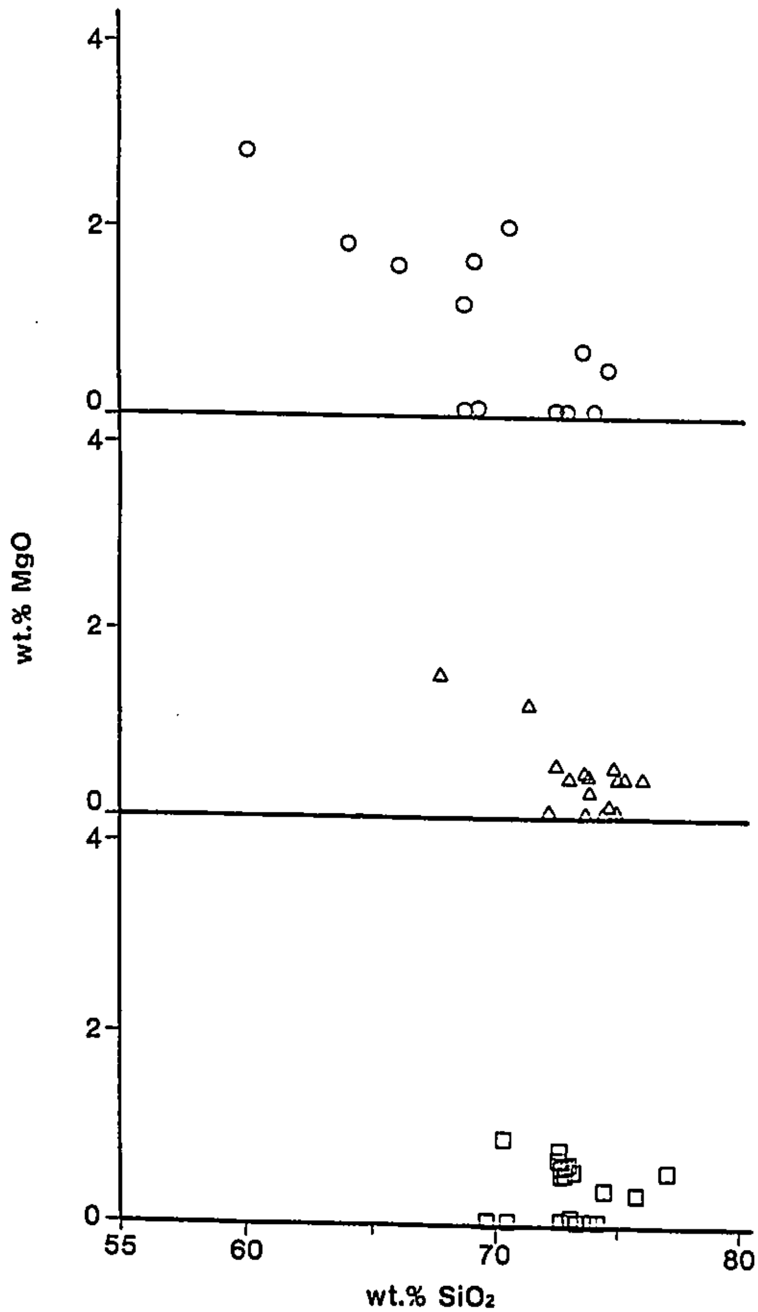


Figure 4: MgO% vs SiO_2% for Deskenatlata (circles), Slave (triangles) and Konth (squares) intrusive suites.

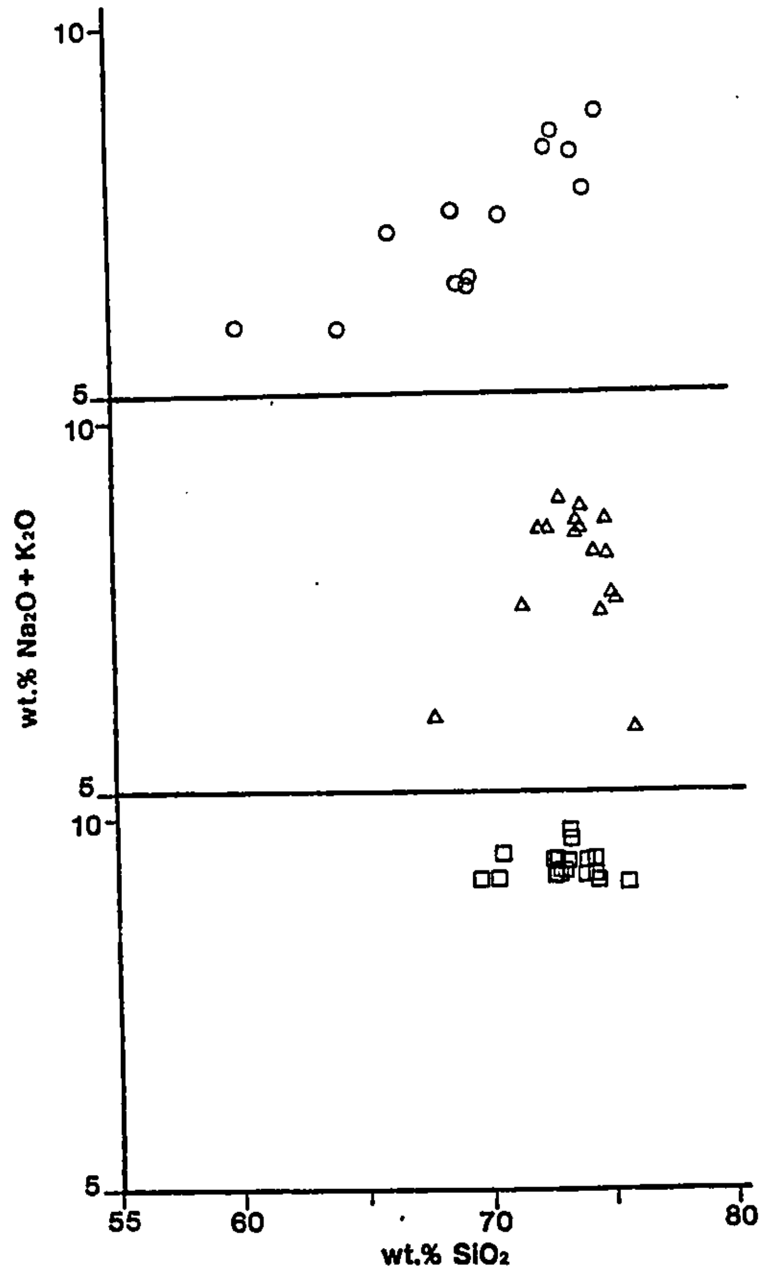


Figure 5: $(K_2O + Na_2O)\%$ vs $SiO_2\%$ for Deskenatlata (circles), Slave (triangles) and Konth (squares) intrusive suites.

Each intrusive suite has distinct ranges of CaO abundances. For the Deskenatlata suite, CaO values span from 0.74 to 4.84%. CaO falls in the 0.71 to 2.77% range for the Slave suite and in the 0.61 to 1.39% range for the Konth suite. Variations in CaO with respect to Na_2O in granitoids have been correlated with tectonic environment (Maniar and Piccoli, 1989). They observe an increase in Na_2O/CaO with increasing influence of continental crust in the petrogenesis of granitoids. Furthermore, these authors report that Na_2O/CaO approximates 1 in island arc granites, seldom exceeds 4 in continental arcs and generally ranges from 2 to 10 in continent-continent collision-derived granitoids. Except for two data points lying within the collision-derived granite field, the Na_2O/CaO ratios (Fig. 6) for the Deskenatlata suite are less than 2 and three data points have values less than 1. This set of values is spread over Maniar and Piccoli's (1989) range of Na_2O/CaO ratios for island arc and continental arc granites. The Slave suite also displays continental arc Na_2O/CaO ratios which are less than 4. All but three Slave suite data points plot within the area for which collisional and continental arc granites overlap, indicative of derivation from crustal sources. Values for the Slave suite are generally more elevated than those for the Deskenatlata, suggesting a lesser involvement

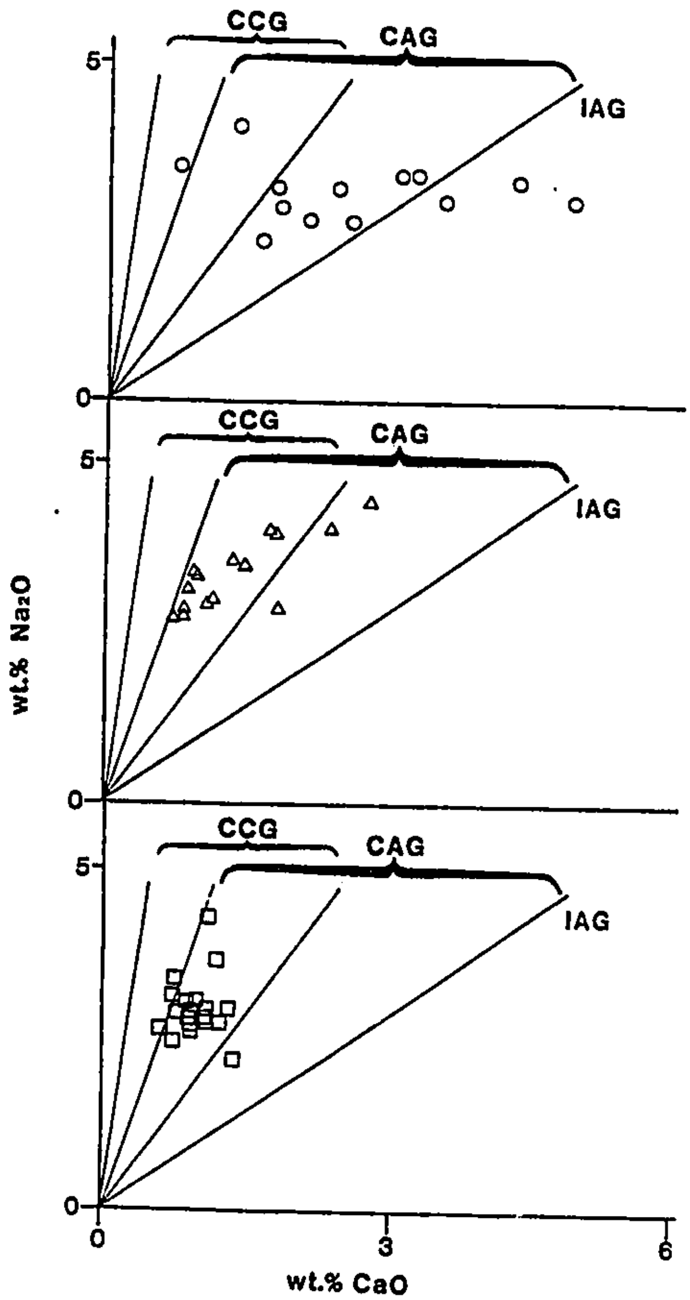


Figure 6: Na_2O% vs CaO% for Deskenatlata (circles), Slave (triangles) and Konth (squares) intrusive suites. Continent collision granite (CCG) field is bounded by Na_2O/CaO slopes of 2 and 10. Continental arc granite (CAG) field is bounded by slope of 4 and island arc granite (IAG) slope of 1 (after Maniar and Picolli, 1989).

of mantle-derived material in the petrogenesis of the Slave suite compared to the Deskenatlata. Konth suite Na_2O/CaO ratios cluster near the 3.0 value within the continental arc and collisional granite fields. Such tight grouping reflects a degree of homogeneity not observed in the other two intrusive suites. Although the Konth's values are ambiguous in terms of tectonic discrimination, dominance of homogeneous crust in the petrogenesis of the Konth is suggested.

Illustrated on Figure 7 are the A/CNK [molar($Al_2O_3/CaO+Na_2O+K_2O$)] vs %SiO_2 for the three intrusive suites of the Taltson zone. All three suites are peraluminous as most A/CNK indices fall above 1.0. The peraluminosity of the three suites is reflected by the normative corundum (c.f. Appendix II) in all three rock suites. The A/CNK indices for the Deskenatlata suite range from 0.90 to 1.24, and average 1.07. High peraluminosity is unexpected for the Deskenatlata suite which does not petrographically or geochemically manifest an important metasedimentary precursor. In contrast with the Deskenatlata suite, the granodioritic western batholiths of the Peninsular Ranges display similar bulk geochemical features to the Deskenatlata suite and typically have A/CNK values of 0.9 (Bateman and Dodge, 1970; Bateman, 1983).

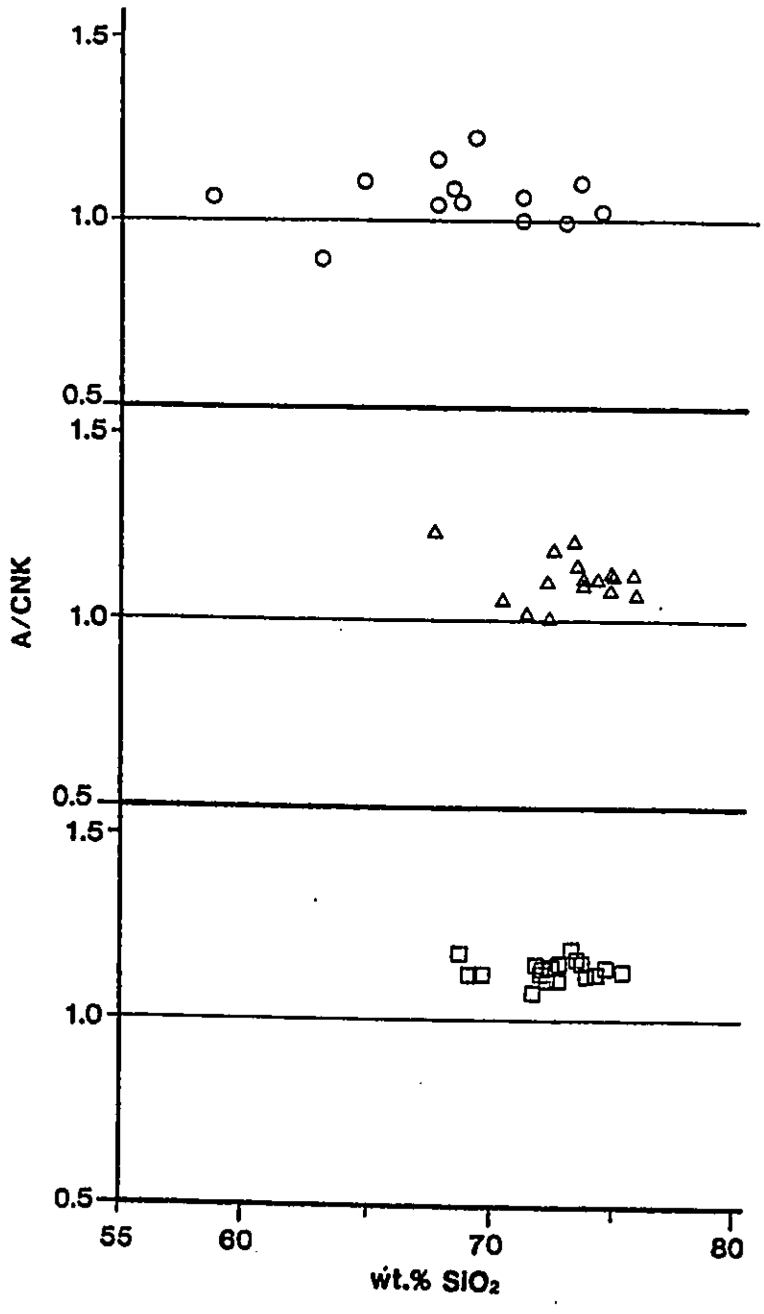


Figure 7: Molar $Al_2O_3/CaO+Na_2O+K_2O$ (A/CNK) vs SiO_2% for Deskenatlata (circles), Slave (triangles) and Konth (squares) intrusive suites.

The Deskenatlata suite is not as peraluminous as the other two suites. The Slave suite yields A/CNK indices ranging from 1.01 to 1.24 and an average of 1.12. The Konth intrusive suite's A/CNK values cluster within the 0.99 to 1.19 bracket and average 1.12. High peraluminosity is expected for granitic rocks exhibiting an "S-type character" (Chappell and White, 1974; Pitcher, 1982; White and Chappell, 1988) such as the Slave and Konth suites, which are mineralogically peraluminous and which have clearly incorporated, to varying extents, enclaves of pelitic paragneiss of mappable dimensions.

3.3 Trace element variations

Based on trace element variations, empirical geochemical classifications of granitoids into distinct tectonic environments has been proposed by Pearce et al. (1984). The classification scheme is based on a data base containing over 600 trace element analyses of granitic rock samples from well-established tectonic settings. The method of Pearce et al. (1984) has been recently applied to Tertiary continental arc volcanic rocks and related granitic batholiths of New Mexico (Lipman, 1988), Early Proterozoic arc and collisional granitoids of Wopmay orogen (Lalonde, 1989) and Mid-Proterozoic anorogenic granites of southwest U.S.A. (Anderson and Bender, 1989).

Figure 8 illustrates the distribution of data for all three intrusive suites on a Rb vs (Y+Nb) discrimination diagram developed by Pearce et al. (1984). The granitic rocks are classified as oceanic ridge granites (ORG),volcanic arc granites (VAG), within-plate granites (WPG) and syn-collisional granites (COLG). On this figure, the VAG field is essentially exclusive to the Deskenatlata and some of the Slave suite. The COLG field accommodates the remainder of the Slave data and the Konth. Some data for the three suites plot in the WPG field, reflecting enrichment in Y and Nb independently of Rb content. It is pertinent to note that the data for the Deskenatlata are distributed in the Rb-rich area of the VAG field. This suggests that a juvenile component introduced by arc magmatism may be present in the Deskenatlata, but that it is largely attenuated by a Rb-enriched component. The Slave suite data shows dispersion into the VAG and COLG fields, suggesting that its source is heterogeneous relative to the other two intrusive suites, and that components of juvenile and evolved material are incorporated in its magmas. The data for the Konth intrusive suite lie mainly in the COLG field, implying that its protolith was essentially Rb-rich continental crust with no influence of juvenile material.

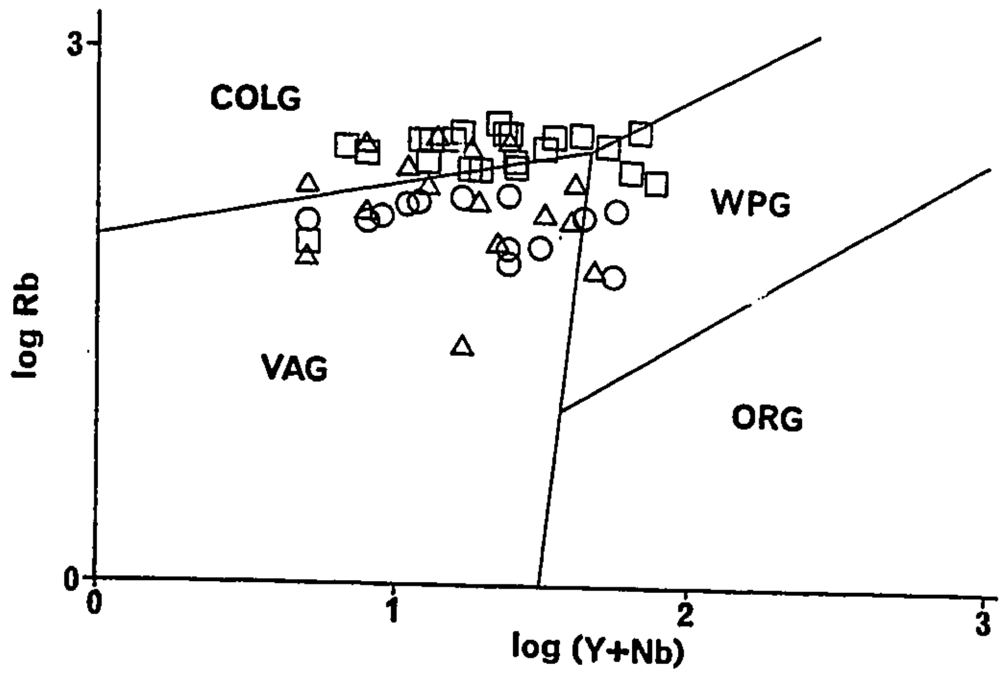


Figure 8: log Rb vs log (Y+Nb) discrimination diagram (after Pearce et al., 1984) for Deskenatlata (circles), Slave (triangles) and Konth (squares) intrusive suites. VAG = volcanic arc granites; COLG = syn-collisional granites; WPG = within-plate granites; ORG = oceanic ridge granites.

Figure 9 illustrates the range of Rb and Sr abundances for the three intrusive suites of the Taltson zone. Lines defining Rb/Sr ratios of depleted mantle, upper crust and lower crust (Taylor and McClennan, 1985) are superimposed on the data points. Lower Rb/Sr values are inherent to the Deskenatlata suite, suggesting a greater involvement of depleted mantle or lower continental crust in the genesis of the Deskenatlata relative to the other two intrusive suites. The trend of the Deskenatlata suite toward more elevated Rb/Sr ratios may be due to contamination of these magmas upon the incorporation of metasediments, accounting for the peraluminosity of this suite.

The data for the Slave suite scatter over a broad spectrum of Rb/Sr ratios (from 0.16 to 4.5) and overlap regions covered by the Deskenatlata and the Konth suites. The Rb/Sr ratios of the Slave suite are consistent with incorporation of a variety of protoliths varying from lower crust or depleted mantle of low Rb/Sr ratios to upper crust with more elevated Rb/Sr.

The Konth Rb/Sr ratios range from 0.5 to 2.5 and cluster near the Konth average of 2.5. This implies derivation from a homogeneous, upper crustal source.

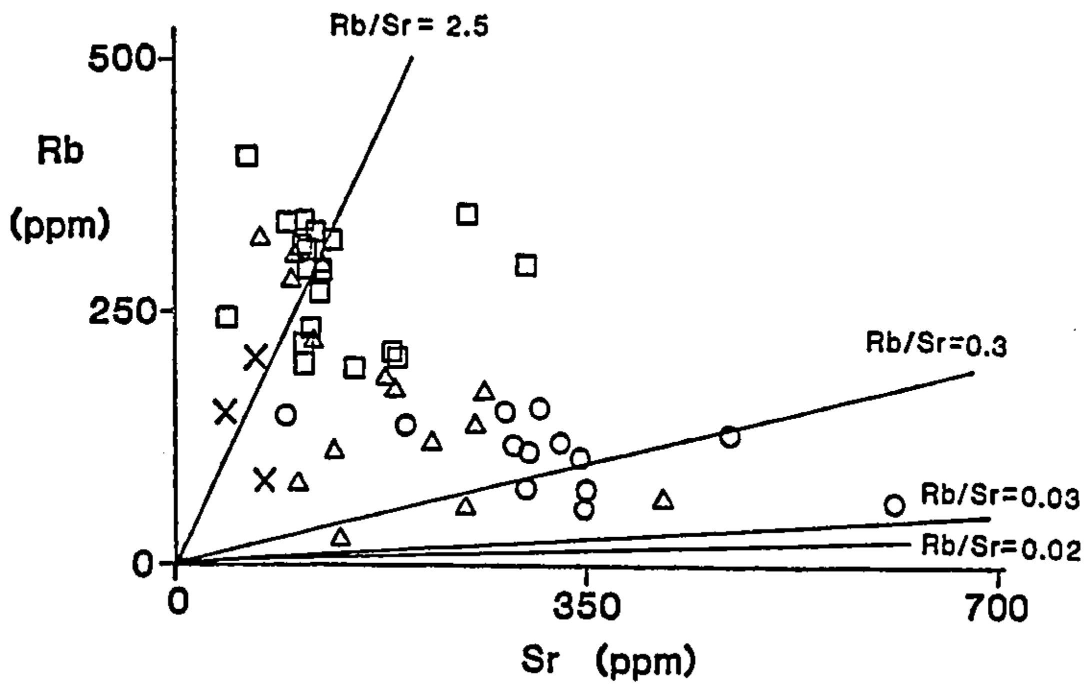


Figure 9: Rb vs Sr diagram for Deskenatlata (circles), Slave (triangles), Konth (squares) intrusive suites and pelitic paragneisses engulfed by Slave and Konth (crosses). Lines corresponding to Rb/Sr ratios for depleted mantle (0.03), lower crust (0.02) and upper crust (0.3) are from Taylor and McClennan (1985). Line repesenting Rb/Sr = 2.5 is based on average of Konth suite.

3.4 Discussion

The geochemical data presented in this chapter leave little doubt as to the affinity of the Taltson zone granitoids for crustal sources. The granitic compositions, high peraluminosity, general tendency toward continental arc and syn-collisional fields on major and trace element discrimination diagrams and generally elevated Rb/Sr ratios all point to an important ensialic crustal component in the composition of the Deskenatlata, Slave and Konth intrusive suites.

Each intrusive suite has, nonetheless, distinct geochemical features which echo its petrogenetic evolution and thus, constitute the compositional asymmetry across the Taltson magmatic zone. The Deskenatlata suite is characterized by lower silica and alkali contents, greater abundances of Mg and Fe, very slightly lower peraluminosity, island arc and continental arc-like Na_2O/CaO ratios, affinity for the Rb-rich area of the VAG field on a Rb vs (Y+Nb) plot mantle and tendency to lower crust Rb/Sr values. The Deskenatlata suite appears to bear a depleted juvenile component that is not as strongly recognized in the Slave and Konth suites. Along with its more mafic geochemical composition, the Deskenatlata's affinity to the volcanic and continental arc fields and generally low Rb/Sr ratios support the interpretation that the

Deskenatlata magmas may have originated as lower, underplated-crust derived magmas containing an unspecified, but subordinate amount of mantle material. Another plausible explanation for the generation of the Deskenatlata magmas is melting of older igneous rocks of a more metaluminous composition (Chappell and Stephens, 1988).

The Deskenatlata suite nevertheless displays a geochemical affinity for an evolved continental crust component by its peraluminosity and trend toward upper crustal Rb/Sr ratios. The low abundance of metasedimentary xenoliths in this suite relative to the Konth and Slave suites, can be explained by its greater ability for assimilation. This could be caused by higher liquidus temperatures as suggested by the higher An-content of the plagioclase and by the presence of amphibole in the Deskenatlata suite.

The Slave intrusive suite exhibits a greater crustal signature in its geochemical data compared to the Deskenatlata suite. This is indicated by higher SiO_2, K_2O+Na_2O and A\CNK values as well as lower MgO and Fe_{tot} contents. Furthermore, the presence of Slave suite data in the COLG field of the Rb vs (Y+Nb) plot, tendency toward continental arc and collisional granite on a Na_2O/CaO diagram and Rb/Sr ratios ranging well into enriched crust values suggest a greater proportion of crust in the protolith of the Slave suite relative to the

Deskenatlata suite. A feature unique to the Slave suite is the dispersed distribution of its data on Rb vs (Y+Nb) and Rb vs Sr diagrams. This is indicative of heterogeneity in source material. Thus, the Slave intrusive suite may be the result of melting of various segments of ensialic crust, from the base of the crust- which may have interacted with juvenile material -to shallower levels where metapelites reside. The Slave suite can be considered as the product of a later mid to upper crust-consuming generation of magma, which followed the Deskenatlata event: an earlier form of magmatism with greater amounts of basal crust and depleted mantle.

The elevated silica and alkali contents, high peraluminosity and low magnesium and iron abundances of the Konth suite are compatible with derivation from a crustal source. The position of the Konth data on Na_2O/CaO and Rb vs (Y + Nb) tectonic discrimination diagrams clearly indicates the dominance of a crustal source in the genesis of the Konth suite. An obvious source for the Konth magmas, as strongly suggested by field observations and petrography, are the pelitic metasedimentary xenoliths which host the suite.

The intrusive suites of the Taltson magmatic zone display compositional asymmetry with respect to crystallization age and, to a certain extent, geographic location of each individual intrusive suite. The 1986 Ma Deskenatlata suite, the oldest and westernmost suite, is the most compositionally juvenile of the three suites and may be comparable with subduction-derived calc-alkaline batholiths, notably the western Peninsular range of the southwestern U.S.A. (Silver and Chappell, 1988) and the pre-India-Eurasia collision Transhimalayan (LeFort, 1975; Pitcher, 1982; Debon et al., 1986).

East of the Deskenatlata suite lies the 1925 to 1955 Ma Slave monzogranitic suite whose geochemistry reflects compositional variation and prevalence of evolved continental crust in its petrogenesis. Coeval with Slave suite plutonism, the 1935 Ma Konth syenogranitic suite exhibits geochemical features which are consistent with derivation from a single crustal protolith with no distinguishable presence of a primitive component. The Slave and Konth suites are comparable to other well-studied leucogranites intrinsically related to surrounding paragneisses, notably the Himalayan leucogranites (Vidal et al., 1982; France-Lanord and LeFort, 1988), the Hercynian leucogranites of western Europe (Lorenzoni et al., 1979; Orsini, 1979; Harris et al., 1986) and "S-type" granites of the Lachland Fold Belt (White and Chappell, 1988).

Compositional asymmetry related to time and location of plutonism is documented in many plutonic belts (e.g Andes, Rogers and Hawkesworth, 1989; Peninsular Range, Silver and

Chappell, 1988; Himalayas, Debon et al., 1986) where progressive contribution of continental crust correlates with belt evolution. Particular to the Taltson zone, the transition from the subduction-related character of the Deskenatlata to the collisional aspects of the Slave and Konth suites is remarkably analogous to the pre-collision arc-related Transhimalayan granitoids and syn-collisional North, Upper and Lesser Himalayas (Debon et al., 1986).

Chapter 4: Sm-Nd isotope geochemistry

4.1 Introduction

The Sm-Nd isotopic evolution of the intrusive suites of the Taltson magmatic zone and proximal gneisses is central to the elucidation of the petrogenetic history and, ultimately, the tectonic significance of the Taltson zone. Sm-Nd isotopes provide an insight, practically unaffected by the ambiguities of chemical mobilization in the crust, into the evolutionary history of the Taltson zone granitoids and associated gneisses. This chapter discusses Sm-Nd principles and systematics, analytical techniques and presents data from analyses of thirty two samples representing the three intrusive suites, xenolithic material within these suites and Archean gneisses of the Churchill Province.

4.2 Sm-Nd principles and systematics

Sm and Nd are both light rare earth elements with similar valencies (+3) and ionic radii (1.08 Å for Nd and 1.04 Å for Sm). The Sm-Nd pair are relatively inert to partitioning by crustal geological processes in comparison with other element pairs with greater differences in charge and ionic radii (e.g. Rb and Sr). Sm and Nd are fractionated with respect to each other by partial melting and fractionation of mafic, depleted mafic, depleted mantle into more felsic material. Because Sm has a slightly smaller ionic radius than Nd, it has a tendency to remain in the mafic residue whereas Nd is preferentially incorporated in the melt fraction. One of the isotopes of Sm (^{147}Sm) is radioactive and decays by alpha emission to a stable isotope of Nd (^{143}Nd). The long half life of ^{147}Sm ($T_{1/2}$ = 1.06 Ga, $\lambda = 6.54 \times 10^{-12}\ y^{-1}$), combined with the similar geochemical behaviour of Sm and Nd in the lithosphere, make the ^{147}Sm-^{143}Nd isotopic system particularly appealing for addressing questions of long term crustal evolution. In order to show the evolution of ^{147}Sm and ^{143}Nd with time, relative abundances of ^{147}Sm and ^{143}Nd are expressed as ^{147}Sm/^{144}Nd and ^{143}Nd/^{144}Nd. ^{144}Nd is the denominator because 1) it is stable and therefore does not vary in abundance with time and, 2) can be measured accurately because it comprises an important proportion (23.85%; Faure, 1986) of Nd in nature.

Sm-Nd isotopic studies are based on the assumption that continental crust and mantle formed by partial melting of a undifferentiated, chemically uniform chondritic earth approximately 4.6 Ga ago (DePaolo, 1988). Partial melting of the chondritic uniform reservoir (CHUR) resulted in the formation of a light rare earth enriched (LREE) crust and a residual light rare earth depleted mantle (DM). Differentiation caused CHUR to have a Sm/Nd ratio lower than that of the depleted mantle but higher than that of the enriched crust. As a consequence, CHUR, the depleted mantle and the enriched crust followed different $^{143}Nd/^{144}Nd$ evolutionary trends over time. It is assumed that all rocks forming the continental crust were derived by chemical fractionation processes from the mantle (DePaolo, 1988). It is possible to calculate for a sample of continental crust its age of extraction from a depleted mantle source. This is done by measuring the sample's present-day $^{143}Nd/^{144}Nd$ and $^{147}Sm/^{144}Nd$ and extrapolating the $^{143}Nd/^{144}Nd$ evolution curve of the sample to a point of intersection with the Nd isotopic evolution curve of the depleted mantle. Such an age, commonly referred to as an Sm-Nd model age or T_{DM} age meaning time of extraction from the depleted mantle reservoir, can be calculated according to the equation

$$T = \lambda^{-1}[\ln[1 + (0.51315 - {}^{143}Nd/{}^{144}Nd)/(0.2138 - {}^{147}Sm/{}^{144}Nd)]]$$

Eq. 1 (from Miller et al., 1986)

where T is the model age, $^{143}Nd/^{144}Nd$ and $^{147}Sm/^{144}Nd$ are the measured present-day values for the sample. The constants 0.51315 and 0.2138 are the present-day values for $^{143}Nd/^{144}Nd$ and $^{147}Sm/^{144}Nd$ (Goldstein et al., 1984) for the depleted mantle assuming the latter's $^{143}Nd/^{144}Nd$ evolved linearly since its initial formation from CHUR 4.6 Ga ago.

The $^{143}Nd/^{144}Nd$ of geologic materials can be compared for any time T to that of CHUR by means of the epsilon (ϵ_{Nd}) notation where

$$\epsilon_{Nd(T)} = [(^{143}Nd/^{144}Nd_{T\ sample})/(^{143}Nd/^{144}Nd_{T\ CHUR}) - 1] \times 10^4 \quad \text{Eq.2}$$

$^{143}Nd/^{144}Nd_T$ are calculated by means of the equation

$$^{143}Nd/^{144}Nd = {}^{143}Nd/^{144}Nd_{T=0} - {}^{147}Sm/^{144}Nd_{T=0}(e^{\lambda T} - 1) \quad \text{Eq.3}$$

Present day $^{143}Nd/^{144}Nd$ and $^{147}Sm/^{144}Nd$ values for CHUR are estimated to be 0.512638 and 0.1967 (Jacobsen and Wasserburg, 1980). The ϵ_{Nd} notation amplifies and permits to distinguish the significance of very small differences in $^{143}Nd/^{144}Nd$. $\epsilon_{Nd} = 0$ is assigned to CHUR for any time T. Because Sm/Nd for the continental crust and the depleted mantle differ from each other and from CHUR, ϵ_{Nd} for the crust and depleted mantle diverge from each other and from CHUR with time (Fig. 10). Sm/Nd is usually higher in the mantle than in CHUR. Therefore, the depleted mantle has positive ϵ_{Nd} values. Conversely, the enriched crust has negative ϵ_{Nd} values due to its Sm/Nd being lower than CHUR. In Eq. 2, T is usually the age of formation (or crystallization) of the sample. Many modern workers (e.g. Nelson and DePaolo, 1987; Patchett and Arndt, 1986; Patchett and Kouvo, 1986; Patchett and Ruiz, 1987; Patchett and Todt,

1987) use U-Pb zircon ages for reasons of accuracy. ϵ_{Nd} calculated at the age of formation of a rock is often referred to as the initial ϵ_{Nd}. The ϵ_{Nd} value of a segment of continental crust at any given time is not strictly dependent on the time elapsed from its differentiation from the mantle reservoir. Assimilation of surrounding crust by an intruding magma or mixing of isotopically differing magmas will result in a hybrid magma differing from its source(s) in ϵ_{Nd} and T_{DM} and reflecting the relative contribution of each source.

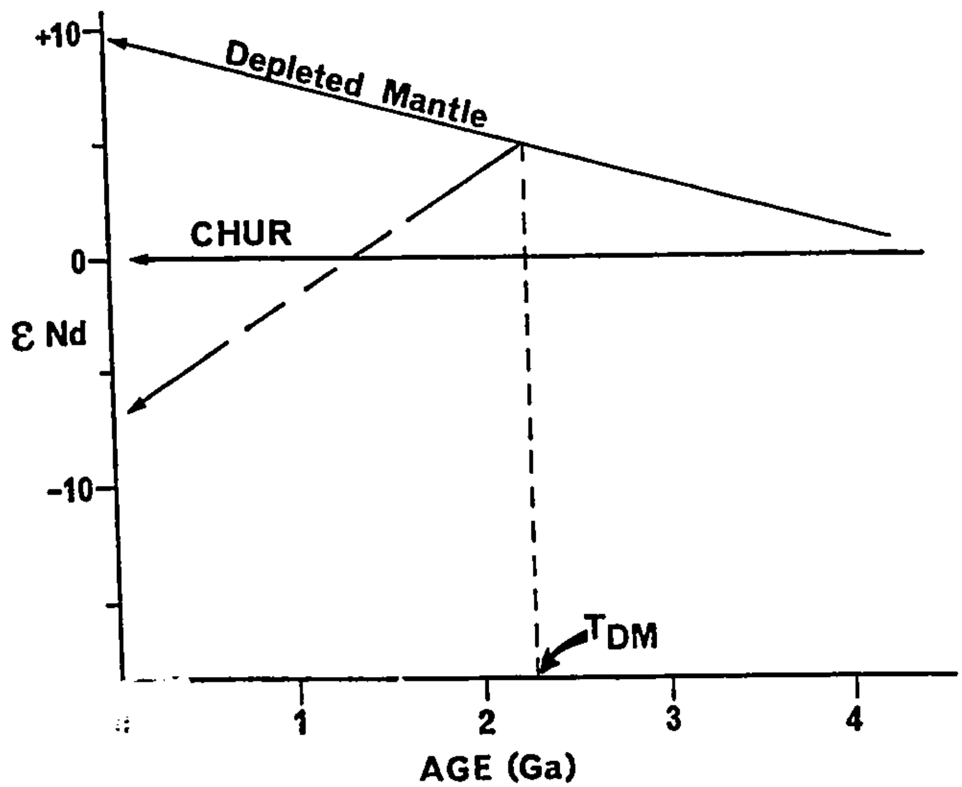


Figure 10: The variability of ϵ_{Nd} with time in depleted mantle and crust. T_{DM} corresponds to the time at which the mantle partially melted from the crust (from DePaolo, 1988).

4.2.1 Limitations of Sm-Nd model ages

The estimation of the time of extraction of LREE-enriched crust from a depleted mantle reservoir hinges on assumptions which are, in the great majority of cases, not verifyable. Firstly, in the calculation of T_{DM}, it is assumed that the depleted mantle reservoir evolved along the Nd isotopic evolution path defined by Eq. 1. The Precambrian mantle was depleted to varying extents (e.g. Shirey and Carlson, 1988; Smith and Ludden, 1989) and, thus, various models for the evolution of the mantle may be considered. Secondly, T_{DM} ages depend on the slopes of the samples' ϵ_{Nd} evolution lines which, in turn, depend on the samples' Sm/Nd ratios. Thus, it is assumed that the samples' Sm/Nd ratios have not changed since extraction from a depleted mantle reservoir and that crustal processes prior to their final crystallization have not caused significant partitioning of Sm and Nd. Crustal rocks typically have $^{147}Sm/^{144}Nd$ ratios close to 0.1 (DePaolo, 1988). Samples whose $^{147}Sm/^{144}Nd$ fall outside the 0.08 to 0.12 range are suspected of having undergone some fractionation of Sm and Nd during their crustal history and are, therefore not taken into consideration in model age estimates.

4.3 Analytical methods

Sm-Nd isotopic analyses were performed at the Geological Survey of Canada. The samples were prepared in the rock crushing facilities whereas the chemistry and mass spectrometry were carried out at the geochronology laboratories. Chemical work was performed in a clean air chemistry laboratory. Isotope dilution was used in the elemental abundance determinations. Isotope dilution, chemical procedures and mass spectrometry are discussed below.

4.3.1 Isotope Dilution

Isotope dilution was used in all isotopic analyses in order to determine isotopic composition and elemental concentration in the same analysis. The method consists of adding to a measured quantity of sample powder a measured quantity of reference solution (spike) whose isotopic composition and concentration of the element to be analyzed are known. The spike is enriched with one of the isotopes of the element. The sample and spike form a isotopically homogeneous mixture during the dissolution of the sample. After chemical separation, the element in the sample-spike mixture is analyzed on a mass spectrometer.

The isotopic composition of the element is expressed as a ratio of two stable isotopes (A and B):

$$(A/B)_{soln} = \frac{A_{sp} + A_{sa}}{B_{sp} + B_{sa}} \quad \text{(Eq. 4, after Webster, 1960)}$$

where A and B are the amounts of isotopes in molar units and soln, sp and sa designate sample-spike solution, spike and sample respectively. The ratio of isotopes A and B can be expressed as

$$R = A/B \quad \text{(Eq. 5)}.$$

Thus, we can write

$$A = RB \quad \text{(Eq. 6)}$$

and substitute Eq. 5 and Eq. 6 in Eq. 4 to give

$$R_{soln} = \frac{R_{sp}\ B_{sp} + R_{sa}\ B_{sa}}{B_{sp} + B_{sa}} \quad \text{(Eq. 7, after Webster, 1960)}.$$

The only unknown in Eq. 7 is B_{sa}. Mass analysis of the sample-spike solution gives R_{soln}. Previous calibration of the spike solution has yielded R_{sp} and B_{sp}. R_{sa} is the ratio of the stable isotopes A and B in nature.

4.3.2 Chemical Procedures

The chemical procedures used in the extraction of Sm and Nd are a modification of those outlined by Richard et al. (1976). Three steps are involved: weighing of sample and mixed spike, dissolution and homogenization of sample with mixed spike, and extraction of Sm and Nd. These steps are reviewed below. Typically, the total procedure blanks are 100 to 300 pg for Nd and 30 to 100 pg for Sm.

4.3.2a weighing of sample and spike

The amount of rock powder weighed is such that about 200 ng Nd were provided for mass analysis. Such an amount of Nd is usually obtained from approximately 200 mg of rock powder. The samples were weighed in PFA teflon screwtop vessels and moistened with approximately 1/2 ml of 16 M HNO_3 which is an oxidant during dissolution. Samples were immediately spiked with a mixed tracer enriched in ^{149}Sm and ^{148}Nd. The spike solution is highly enriched in these isotopes and its isotopic composition has been accurately measured (J.C. Roddick, pers. comm., 1989), thus permitting determination of isotopic composition and concentration on the same sample solution. The amount of spike isotope added to the sample was such that error magnification was minimal on the calculation of the concentration. This was usually achieved by adding an amount of spike solution approximately half the weight of the sample.

4.3.2b sample dissolution

The dissolution process consisted of a first dissolution in TFE teflon bombs on a hot plate and a second, pressure dissolution in TFE teflon bombs in steel jackets (Plate 14).

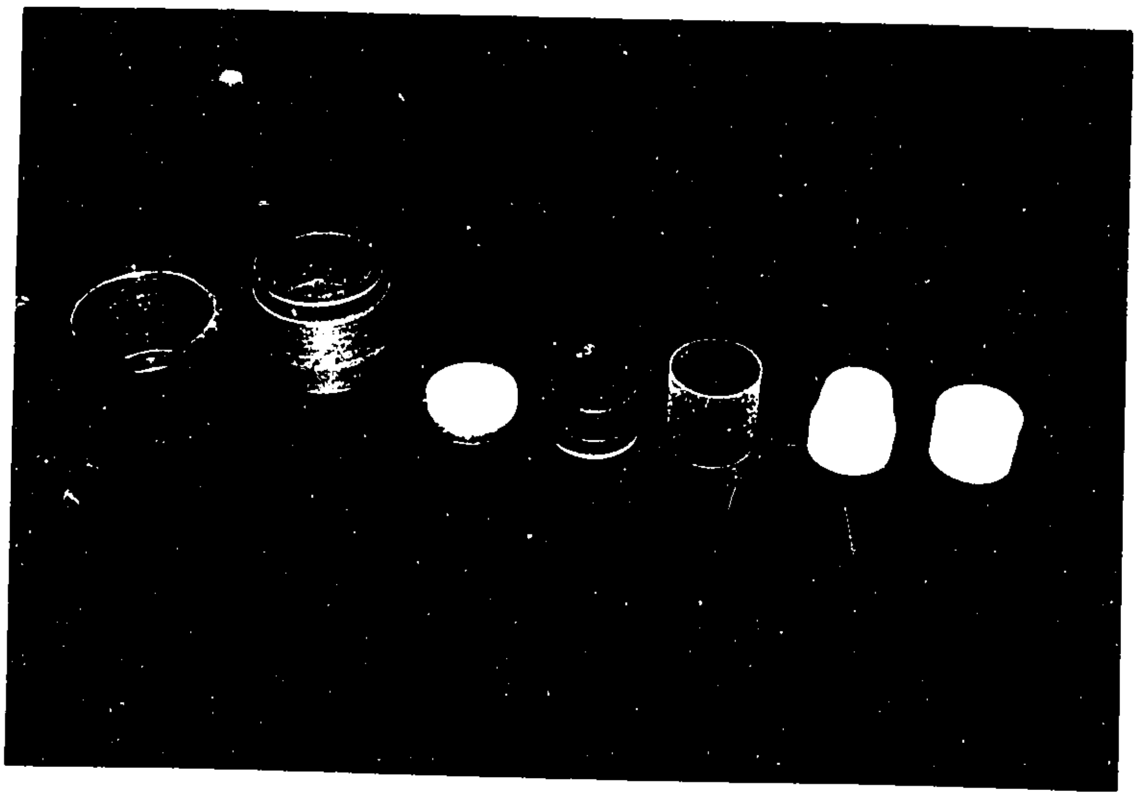


Plate 14: Exploded view of sample dissolution apparatus. From right to left: 1) lid for teflon bomb; 2) teflon bomb which holds sample-spike mixture; 3) plastic sleeve around 1) and 2); 4) and 5) spacers placed above and below 1), 2) and 3); 6) steel jacket which holds 1), 2), 3), 4) and 5); 7) screw-top lid sealing contents of 6).

The first step consisted of adding about 3 ml of 48% HF to the teflon bombs and placing them on a hot plate for at least 12 hours at 150°C. This allowed decomposition of major silicate phases and formation of SiF_4. Sample were then dried at 150°C, volatilizing SiF_4.

The second dissolution step involved taking the dried residues up in 3 ml of HF and 1/2 ml of HNO_3 and placing the bombs in pressure-resistant steel jackets; the samples were decomposed under pressure at 200°C for one week. This procedure ensured complete dissolution of all refractory phases and equilibration of sample and spike. Sample solutions were then dried and fluorides were converted to soluble chlorides by adding up to 20 ml of 6N HCl and heating them at about 80°C for up to four hours. Finally, samples were dried and redissolved in 1 ml of 2.5N HCl.

4.3.2c extraction of Sm and Nd

Extraction of light rare earth elements (LREE) and separation of Sm and Nd were done by elution through two stages of cation exchange columns. The first stage column chemistry served as a method of LREE separation from the sample solutions whereas the second stage colomns separated individual LREE.

Sample solutions of 1 ml were centrifuged to remove possibly undissolved fluorides and pipetted onto first stage columns made of AG50W-X8 cation exchange resin packed in fritted quartz glass tubes (Plate 15). The columns were calibrated such that the REEs were collected as a 30 ml cut of 6.2 N HCl after eluting 117 ml of 2.5 N HCl and 15 ml of 6.2 N HCl. The REE cuts were dried at low heat and the residues were dissolved in 0.4 ml of 0.18 N HCl. The REE solutions were then centrifuged to remove possible resin beads from the first stage columns and pipetted onto second stage columns made of a 10 part teflon powder and 1 part HDEHP (Di(2-ethylhexyl) orthophosphoric acid) mixture packed in fritted quartz glass tubes (Plate 16) which allowed separation of the individual REEs. Elution of 13.6 ml of 0.18 N HCl was followed by collection of Nd in 6 ml of 0.18 N HCl. An additional 4 ml of 0.4 N HCl passed through the columns before Sm was collected in 5 ml 0.4 N HCl.

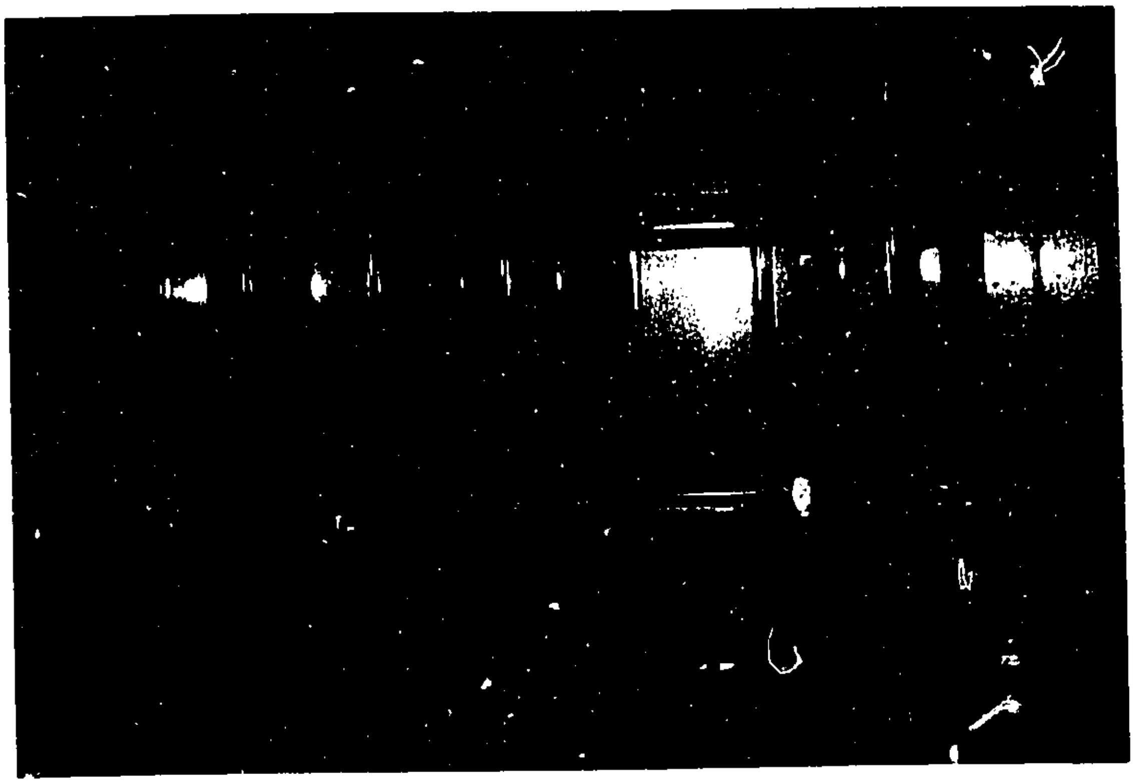


Plate 15: Quartz columns packed with 15 ml of AG50W-X8 cation exchange resin used to extract REEs from sample spike solutions.

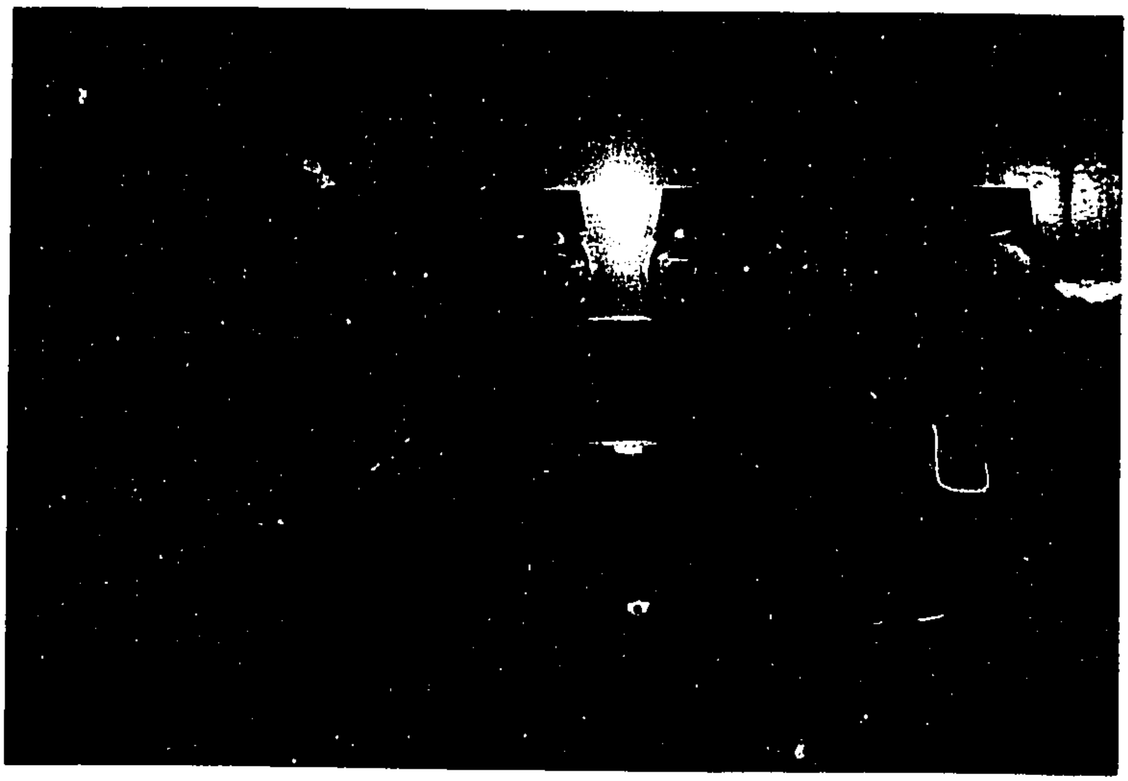


Plate 16: Quartz columns packed with 3 ml of teflon powder and HDEHP mixture used to extract Sm and Nd. Note: yellow anion exchange resin above teflon powder-HDEHP mixture used as filler to allow teflon powder-HDEHP mixture to remain in place.

4.3.3 Mass Spectrometry

Isotopic measurements were made on a Finnigan MAT 261 solid source, thermal ionization mass spectrometer equipped with 6 variable Faraday cups and one fixed collector (Plate 17). The instrument was used in static mode to measure Nd and Sm isotopes. Samples were loaded in 2 μl of H_3PO_4 on evaporation filaments of double Re filament assemblies (Plate 18) which had been outgassed at 2000°C for ten minutes. Loading of samples was carried out in a clean air cabinet.

During analysis of Nd, the ionization filament (Plate 18) was kept at approximately 1900°C and the evaporation filament at 800 to 1000°C, resulting in a ^{144}Nd signal of 1.5 to 3 x 10^{-12} A. Atomic masses 143, 144, 145, 146, 147 and 148 were collected. Mass 147 was monitored to detect and correct for the presence of Sm, one of its isotopes which has an isobaric interference on ^{144}Nd. The ratios were corrected for mass fractionation by normalization to $^{146}Nd/^{144}Nd$ = 0.7219. In static mode, 80 to 100 8-second mass integrations yielded an internal precision for $^{143}Nd/^{144}Nd$ equal or better than 10^{-5}. The external precision is estimated to be better than 2.5 x 10^{-5}. Ten analyses of LaJolla Nd standard yielded a mean $^{143}Nd/^{144}Nd$ of 0.511832 +/- 0.000028. Baseline measurements were done after every 10 integrations and amplifier gain calibrations were done prior to every analysis.

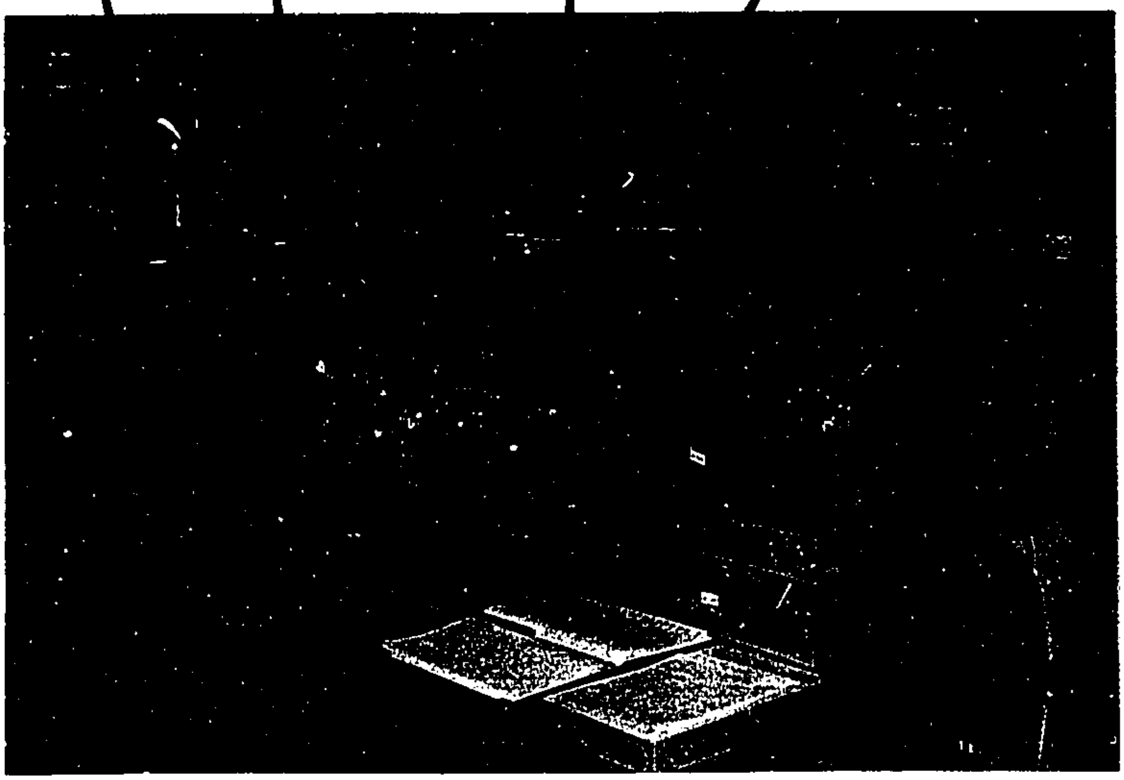
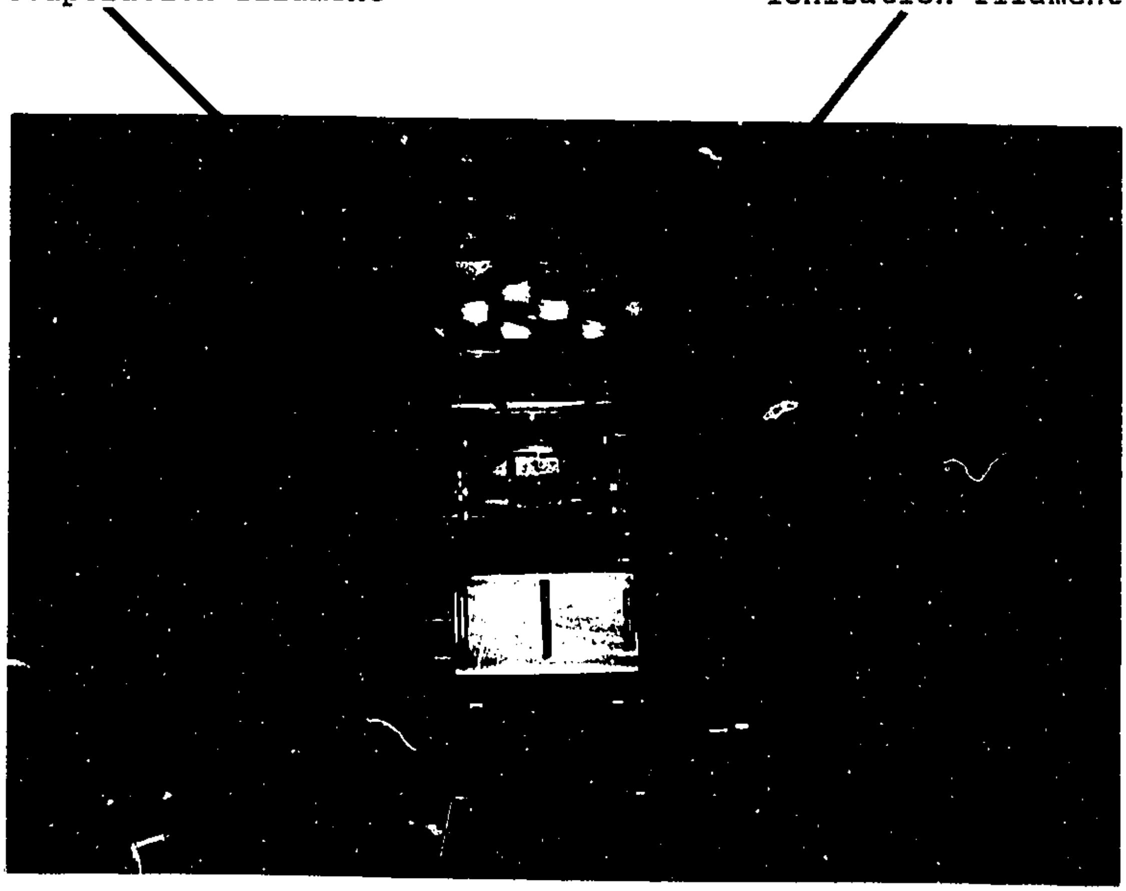


Plate 17: Finnigan-MAT 261 mass-spectrometer. The magazine is placed in the source housing where sample ionization takes place. The ion beam is then accelerated into flight tube by a 10 kV difference of potential. The ion beam is resolved into individual masses by a magnetic field. The individual mass beams are collected in Faraday cups in the multicollector assembly.



<u>Plate 18</u>: Double Re filament assembly mounted on magazine. A shielding plate with slit covers each filament assembly. This prevents cross-contamination during sample ionization.

For analysis of Sm, the ionization and evaporation filaments were brought to temperatures similar to those for Nd. Data was collected when ^{149}Sm was emitting a signal of approximately 4 x 10^{-12} A. Atomic masses 147, 149, 152 and 156 were collected, the latter to monitor CeO which interferes isobarically with ^{152}Sm. The 147/149 ratio was normalized to 147/152 = 0.56081. An analysis typically consisted of 48 8-second mass integrations. Amplifier gain calibrations were done after every three analyses.

4.3.4 Results

Thirty two samples representing the major lithologies of the study area were analyzed. Results are shown in Table 1 and Figs. 11-18. Also included in Table 1 are results of two duplicate analyses (samples 85-BK 703 and 81-BK-838) and from the whole rock standard BCR-1.

ϵ_{Nd} values for the granitic rocks of the Taltson magmatic zone were calculated according to Eq. 2 at their ages of crystallization, namely 1986 Ma for the Deskenatlata suite, 1940 (average of 1955 and 1925 Ma crystallization ages) for the Slave suite and 1935 Ma for the Konth suite (Bostock et al., 1987; Bostock, pers. comm., 1989). Xenoliths in the Konth and Slave suites and Churchill Province gneisses proximal to the Taltson zone, whose ages

Table 1: Results of Sm-Nd isotope analyses for rocks of and proximal to the Taltson magmatic zone. Errors on ϵ_{Nd} are +/- 0.5 ϵ_{Nd} unit. $^{143}Nd/^{144}Nd$ are normalized to the LaJolla isotopic standard solution $^{143}Nd/^{144}Nd$ of 0.511850.

Sample #	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd(2\sigma)$	ϵ_{Nd}	T_{DM} (Ga)
Deskenatlata intrusive suite						
85-BK-702	4.80	19.38	0.1499	0.511849(9)	-3.5	
85-BK-703	9.00	38.14	0.1422	0.511743(8)	-3.6	
85-BK-703	9.02	38.28	0.1424	0.511752(14)	-3.5	
85-BK-704	13.79	83.92	0.0993	0.511205(5)	-3.1	2.58
RT-88-14	1.68	15.66	0.0650	0.510779(8)	-2.7	
RT-88-20	4.27	26.30	0.0981	0.511175(10)	-3.4	2.59
Xenoliths in eastern Deskenatlata						
89-BK-7	5.04	24.65	0.1235	0.511563(11)	-2.8	
89-BK-8	2.70	10.61	0.1541	0.512207(11)	+2.0	
Slave intrusive suite						
80-BK-377	2.84	16.09	0.1068	0.511110(8)	-7.5	2.89
80-BK-978	3.04	21.82	0.0841	0.510838(15)	-7.1	2.70
81-BK-837	4.90	30.66	0.0965	0.511116(6)	-4.8	2.63
87-BK-361	2.49	17.66	0.0852	0.510777(6)	-8.6	2.80
RT-88-23	6.42	39.29	0.0996	0.511069(12)	-6.4	2.76

Sample #	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd (2\sigma)$	ϵ_{Nd}	T_{DM} (Ga)
Konth intrusive suite						
80-BK-574	6.60	52.75	0.0756	0.510843(10)	-5.0	2.53
80-BK-841	6.50	43.45	0.0904	0.511022(12)	-5.1	2.62
81-BK-838	4.82	27.94	0.1042	0.511176(21)	-5.6	2.73
81-BK-838	5.53	31.33	0.1066	0.511210(7)	-5.5	2.74
86-BKM-82	5.97	36.83	0.0979	0.511099(3)	-5.5	2.69
Xenoliths in Konth and Slave						
87-BK-477	8.38	50.56	0.1001	0.511198(8)	-4.1	2.61
RT-88-10	5.01	30.50	0.0993	0.511096(12)	-6.0	2.72
RT-88-12	3.17	17.09	0.1120	0.511328(8)	-4.5	2.68
RT-88-21	6.51	35.32	0.1114	0.511261(12)	-5.6	2.80
RT-88-24	2.48	36.83	0.0948	0.511100(8)	-4.7	2.61

Sample #	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd (2\sigma)$	ϵ_{Nd}	T_{DM} (Ga)
Churchill granitic gneisses						
87-BK-359	3.53	17.49	0.1219	0.511416(6)	-5.2	2.86
87-BK-366	5.35	30.89	0.1046	0.511138(10)	-6.4	2.79
RT-88-5	10.04	63.74	0.0952	0.510865(10)	-9.3	2.92
RT-88-6	7.28	47.91	0.0919	0.510374(11)	-6.6	2.72
RT-88-7	2.65	27.06	0.0591	0.510374(11)	-10.4	
Churchill mixed gneisses						
RT-88-1	3.61	26.45	0.0826	0.510713(8)	-9.2	2.82
RT-88-25	7.21	35.43	0.1230	0.511159(9)	-10.6	
RT-88-27	5.99	43.99	0.0823	0.510643(11)	-10.5	2.89
RT-88-28	6.2	30.9	0.1205	0.510575(9)	-11.6	
Hill Island Lake pelites						
RT-88-2	5.11	28.06	0.1101	0.511334(14)	-4.1	2.64
RT-88-3	9.72	55.41	0.1060	0.511270(17)	-4.1	2.63
Whole rock standard						
BCR-1	6.60	28.92	0.1380	.512620(8)		

White and Patchett (1984) report the following values for BCR-1: Sm = 6.59 ppm, Nd = 28.80 pm, $^{143}Nd/^{144}Nd$ = 0.512647 of emplacement are unknown and by their field relationship are considered potential protoliths to the S-type Taltson granitoids, had their ϵ_{Nd} values calculated at 1940 Ma. The 1940 Ma age was chosen because it represents an intermediate age for the emplacement of the more voluminous and peraluminous (hence possibly crustally derived) Taltson magmas, namely the Slave and Konth intrusive suites. The ϵ_{Nd} values for the xenoliths in the eastern region of the Deskenatlata suite were calculated at the 1986 Ma age of their host suite. The error for the ϵ_{Nd} values is within +/- 0.5 ϵ_{Nd} and has been estimated by duplicate analyses of various samples by staff at the geochronology laboratory of the Geological Survey of Canada. Ages of extraction from a depleted mantle reservoir were calculated by means of Eq. 1.

4.3.4a Deskenatlata intrusive suite

The five samples from the Deskenatlata suite yielded initial ϵ_{Nd} values ranging from -2.7 to -3.6. The T_{DM} age for this suite is approximately 2.6 Ga. (Fig. 11). A broad range of $^{147}Sm/^{144}Nd$ ratios (0.0650 to 0.1499) as well as Nd (15.66 to 83.92 ppm) and Sm (1.68 to 13.79 ppm) abundances is observed in this suite. The similarity in the ϵ_{Nd} values, despite the considerable geographic spacing between sample locations (c.f. Appendix III), suggests an isotopically homogeneous magma source. Source homogeneity is supported by the isochron, defining an age of 1920 +/-45 Ma (2σ error), obtained by plotting $^{143}Nd/^{144}Nd$ against $^{147}Sm/^{144}Nd$ (Fig. 12). The fact that the data points fall on an isochron (MSWD= 1.1) suggests that each sample has evolved from a single, isotopically homogeneous source.

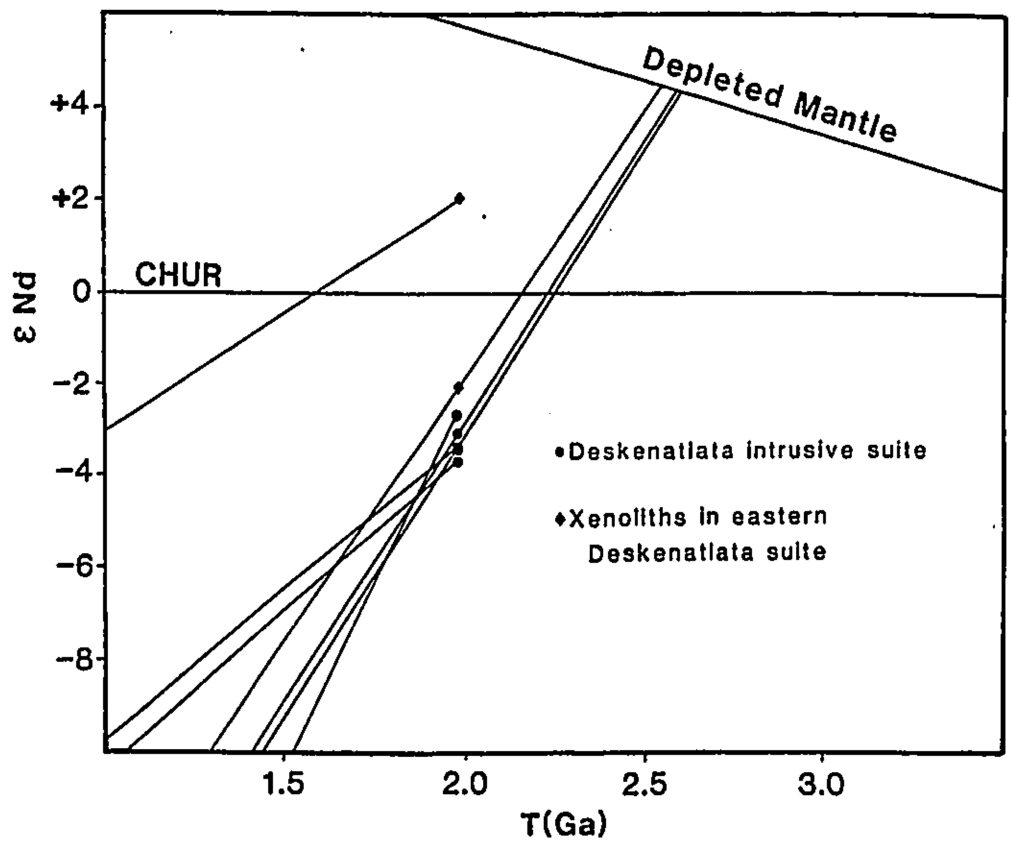


Figure 11: ϵ_{Nd} vs time diagram for Deskenatlata intrusive suite and xenoliths in eastern portion of Deskenatlata suite. Samples with 147Sm/144Nd ratios outside the 0.08 to 0.12 range do not have their evolution lines extrapolated prior to the time of crystallization of the Deskenatlata suite.

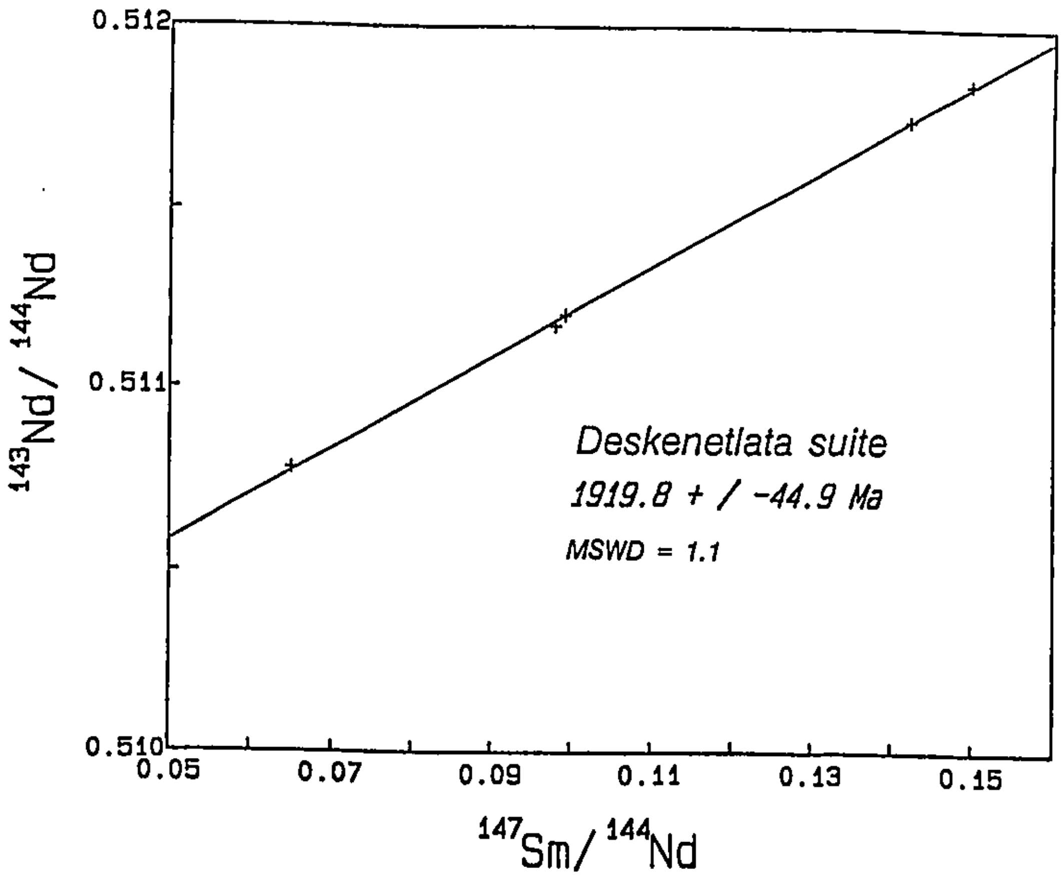


Figure 12: $^{143}Nd/^{144}Nd$ vs $^{147}Sm/^{144}Nd$ diagram for Deskenatlata intrusive suite.

Variations in Sm and Nd concentrations (from 1.68 to 13.79 ppm fcr Sm and 15.66 to 83.92 ppm for Nd) as well as $^{147}Sm/^{144}Nd$ ratios may be the result of crystal fractionation. If fractionation had not taken place, it would be highly coincidental that the Nd isotopic evolution paths for different samples would converge toward the narrow -2.7 to -3.6 ϵ_{Nd} range at the time of crystallization of this suite.

4.3.4b Xenoliths in the eastern Deskenatlata suite

Two samples representing the most common lithologies of xenoliths found in the eastern portion of the Deskenatlata suite were analyzed. The rock types are an amphibolite (89-BK-8) and a metapelite (89-BK-7). ϵ_{Nd} values for the xenoliths were calculated at 1986 Ma in order to compare the Nd isotopic composition of the xenoliths with that of the Deskenatlata suite at the time of emplacement of this intrusive suite. Although the age of the amphibolite and pelite remain unknown, they are clearly older than the intruding Deskenatlata and calculating their ϵ_{Nd} values at 1986 Ma does not constitute an extrapolation of their Nd isotopic evolution prior to their time of deposition. At 1986 Ma the ϵ_{Nd} values for the amphibolite and metapelite were +2.0 and -2.8 respectively (Fig. 11). The ϵ_{Nd} value of +2.0 for the amphibolite is the most juvenile Nd isotopic signature

obtained in the study area. The amphibolitic rocks proximal to the eastern Deskenatlata suite may represent:
1) metamorphosed Early Proterozoic juvenile igneous rocks derived from a LREE-depleted source, or: 2) mafic xenolithic material from the lower crust or upper mantle which was transported by Deskenatlata magmas. The $^{147}Sm/^{144}Nd$ ratio of 0.1541 and the low Sm and Nd concentrations of 2.7 and 10.6 ppm are suggestive of a depleted source for the amphibolite. The metapelite's ϵ_{Nd} value is in the range of values observed for the Deskenatlata suite and is distinctly less radiogenic than other metapelites in the study area. This leads to believe that metapelitic xenoliths found in the Deskenatlata suite are derived from a source similar in Nd signature to the Deskenatlata itself or are the result of mixing older and juvenile sediments.

4.3.4c Slave intrusive suite

The ϵ_{Nd} values for the Slave intrusive suite range from -4.8 to -8.6 and show much greater disparity than those of the Deskenatlata suite, suggesting a less homogeneous magma source for the Slave suite (Fig. 13). The average ϵ_{Nd} value for the Slave suite is -6.8, indicative of a greater overall contribution of older crust than the Deskenatlata suite. The $^{147}Sm/^{144}Nd$ ratios range from 0.0841 to 0.1068. The T_{DM} ages for

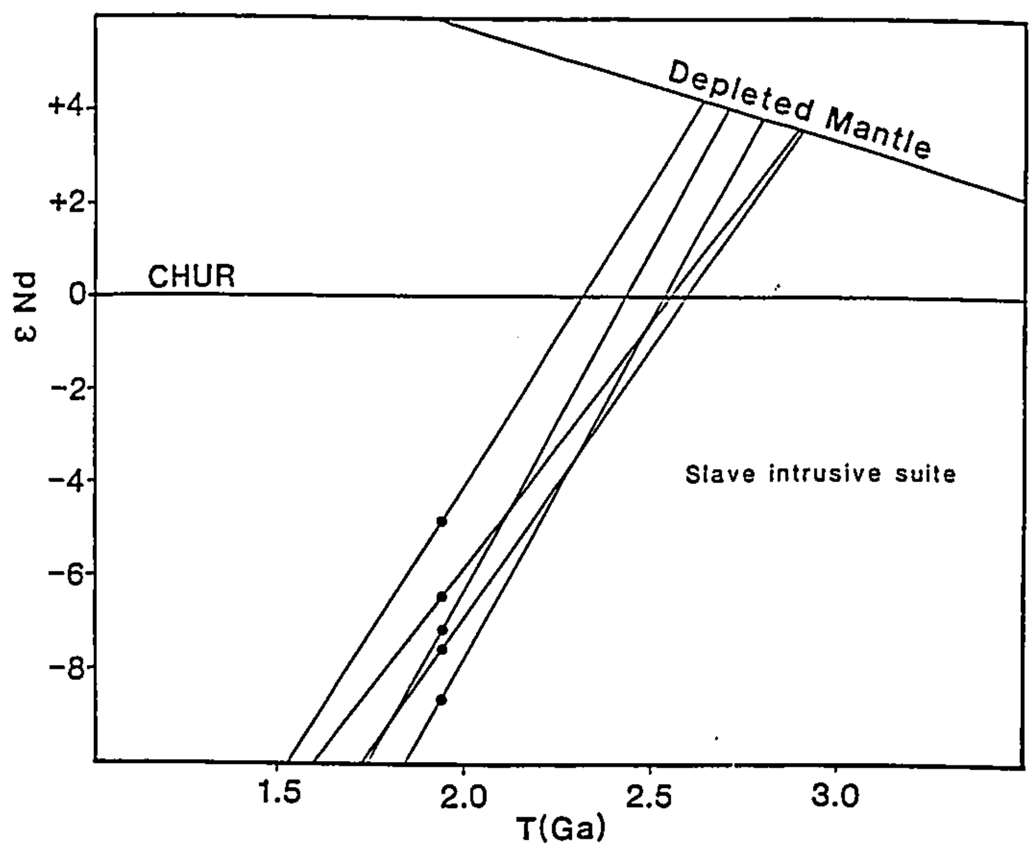


Figure 13: ϵ_{Nd} vs time diagram for Slave intrusive suite.

the Slave suite range from 2.6 to 2.9 Ga and average 2.76 Ga. The average T_{DM} for the Slave suite is older than the model ages (2.6 Ga) for the Deskenatlata rocks. The older model age for the Slave suite support its more negative average ϵ_{Nd} value in that both of these indicate a greater involvement of older crust than in the Deskenatlata intrusive suite.

Plotted on an $^{143}Nd/^{144}Nd$ against $^{147}Sm/^{144}Nd$ diagram (Fig. 14), the data for the Slave suite do not form an isochron but scatter about an errorchron (MSWD = 54.6) defining a poorly constrained age of 2298 +/-1200 Ma (2σ error). Little geological significance can be attributed to this plot other than the scattered data appear to indicate that the Slave suite was derived from isotopically heterogeneous sources. Sample 81-BK-837 has an initial ϵ_{Nd} value of -4.8, falling in the range of the pelitic xenoliths and thus accentuating a potential genetic relationship between certain segments of the Slave suite and pelites, as suggested by field observations, petrography and bulk rock chemistry. Some overlap in ϵ_{Nd} values between Churchill gneisses and Slave suite is observed.

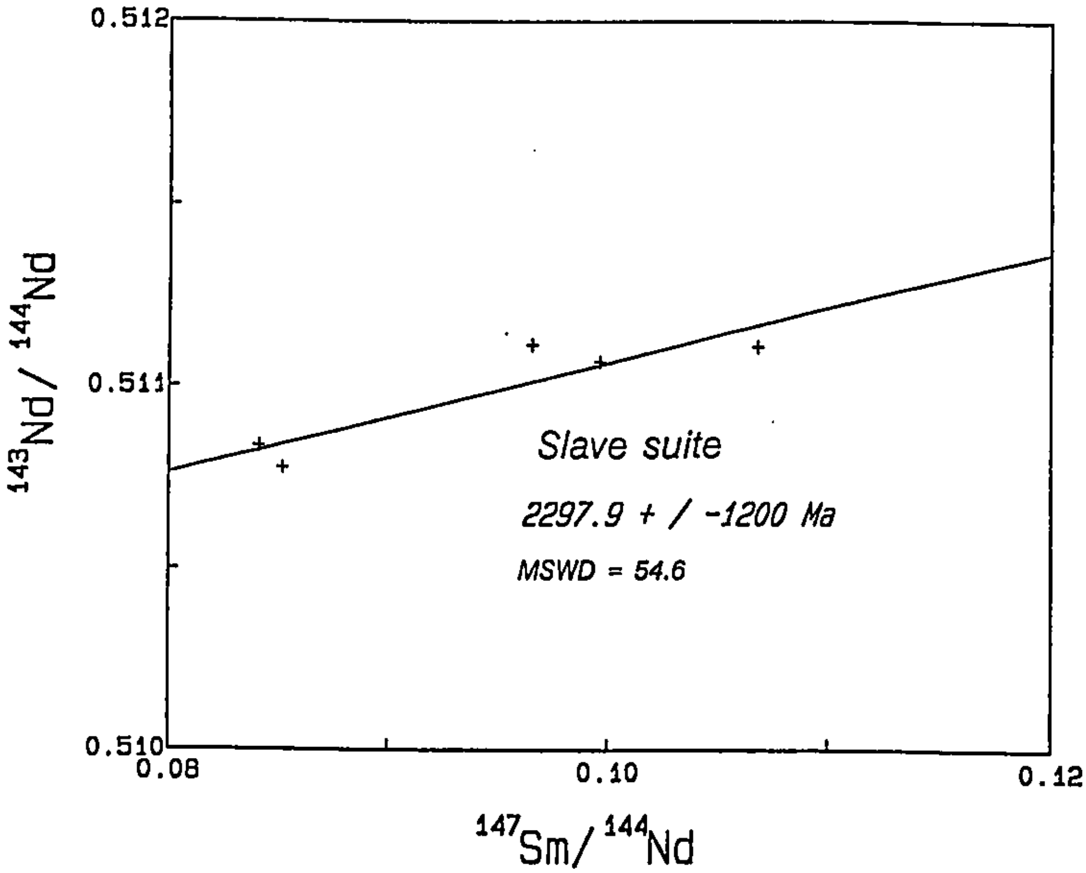


Figure 14: $^{143}Nd/^{144}Nd$ vs $^{147}Sm/^{144}Nd$ diagram for Slave intrusive suite.

4.3.4d Konth intrusive suite

The four samples from the Konth intrusive suite show a clustering of initial ϵ_{Nd} values between -5.0 and -5.6 (Fig. 15) whereas $^{147}Sm/^{144}Nd$ ratios vary from 0.0756 to 0.1066. Similar to the Deskenatlata, the close grouping of ϵ_{Nd} values for the Konth suite suggests an isotopically homogeneous and, potentially, a unique source. Also supporting source homogeneity, the Konth suite data align on an $^{143}Nd/^{144}Nd$ against $^{147}Sm/^{144}Nd$ isochron (MSWD = 0.6) (Fig. 16) defining an age of 1760 +/- 145 Ma (2σ error), an age which does not concord with but whose error overlaps the 1935 Ma U-Pb age. The Konth ϵ_{Nd} values suggest a greater involvement of crustal material in its genesis compared to the Deskenatlata but are somewhat indicative of a source with a more primitive signature than the Slave intrusive suite (except for Slave sample 81-BK-837 which has an initial ϵ_{Nd} of -4.8). The range of ϵ_{Nd} values observed for the Konth suite is completely overlapped by the range of ϵ_{Nd} values for the pelitic xenoliths in the Konth and Slave suites. The T_{DM} ages for the Konth intrusive suite vary from 2.6 to 2.7 Ga.

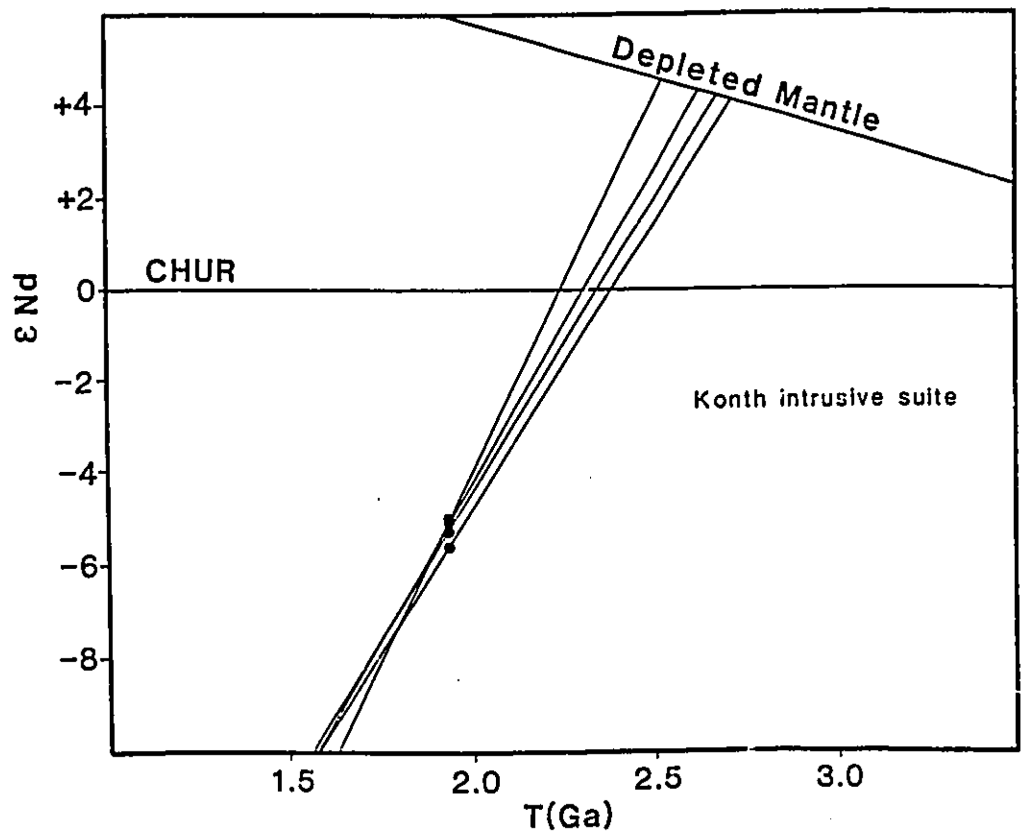


Figure 15: ϵ_{Nd} vs time diagram for Konth intrusive suite.

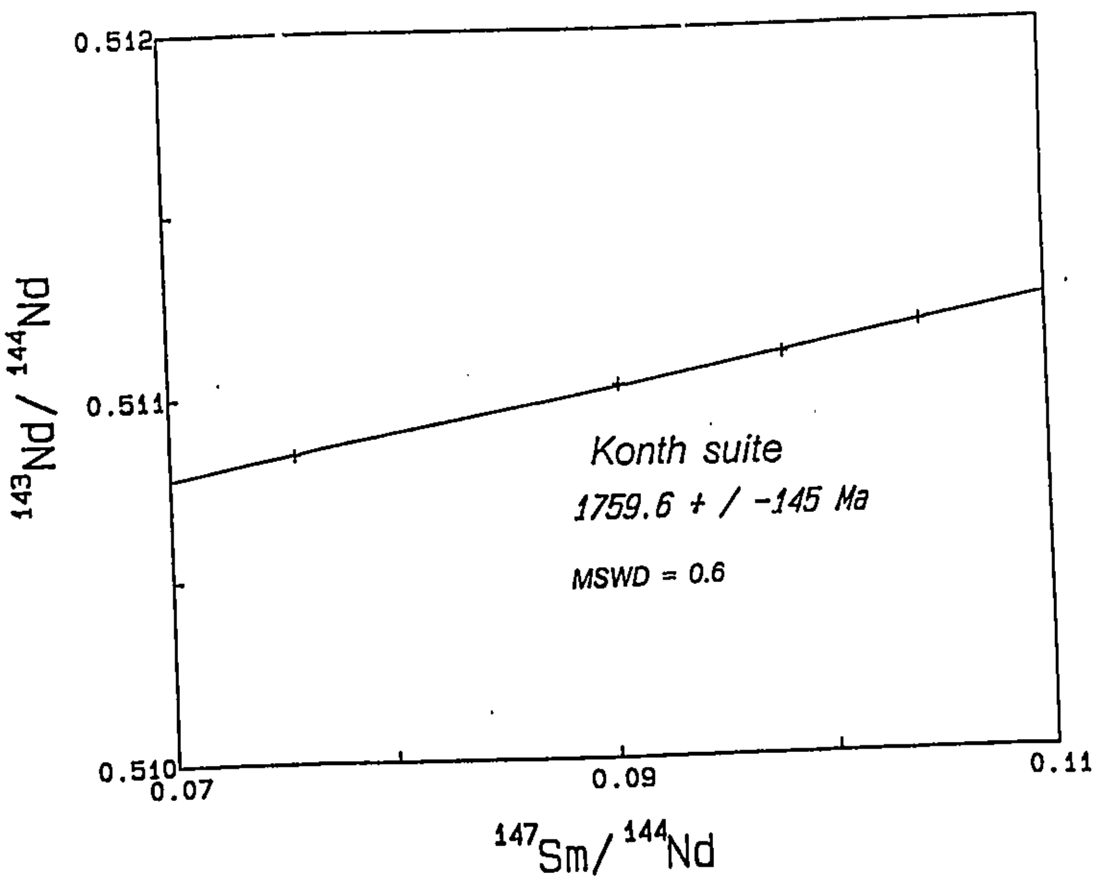
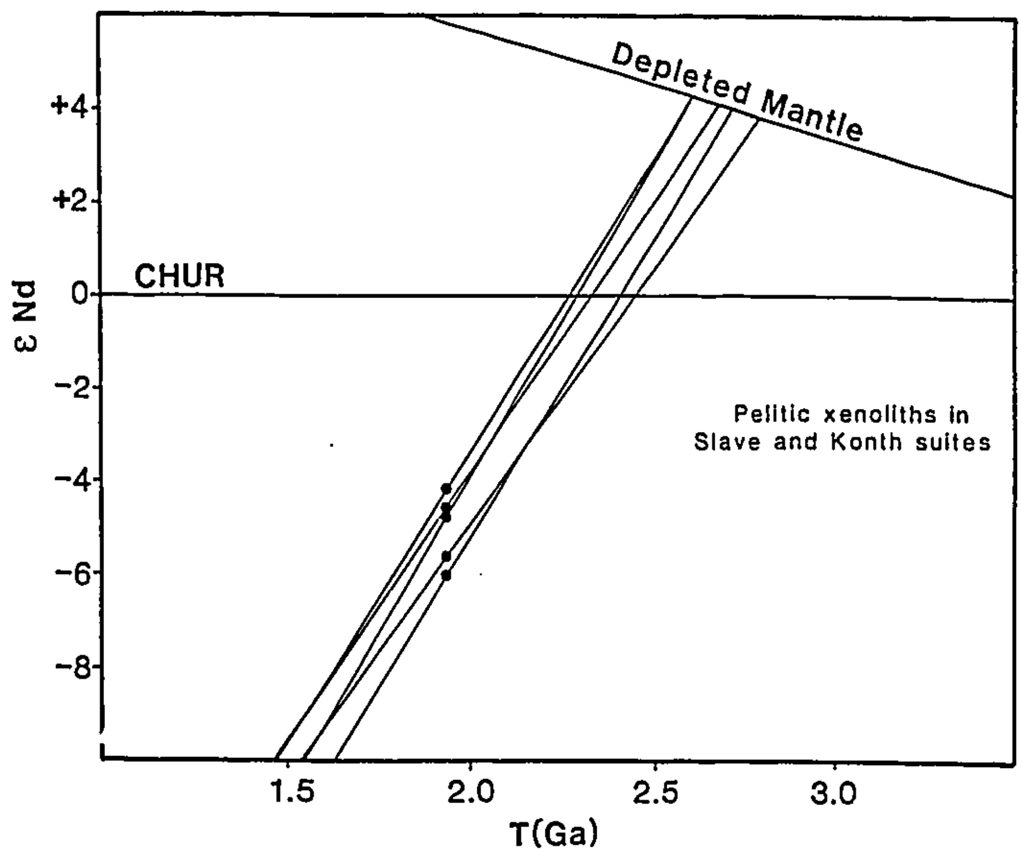


Figure 16: $^{143}Nd/^{144}Nd$ vs $^{147}Sm/^{144}Nd$ diagram for Konth intrusive suite.

4.3.4e Metapelitic xenoliths in Konth and Slave suites

Five samples of dominantly pelitic rocks engulfed by the Konth and Slave suite were analyzed. Their ϵ_{Nd} values, calculated at 1940 Ma, span from -4.1 to -6.0 whereas the model ages vary from 2.6 to 2.8 Ga (Fig. 17). Their $^{147}Sm/^{144}Nd$ show little variability (from 0.0948 to 0.1120) and are typical of continental crust-derived sediments worldwide (Miller et al., 1986). The ϵ_{Nd} values of the pelites cover the range of those of the Konth suite and overlap the Slave suite's less negative ϵ_{Nd} value of -4.8. The T_{DM} ages of the pelites also cover the 2.6 and 2.7 Ga model ages of the Konth suite as well as the 2.6 to 2.8 Ga ages of four of the five Slave suite samples. The similarity in isotopic composition of the pelitic rocks with those of the Konth suite and a sample from the Slave suite (81-BK-837) appears to reinforce the intimate relationship between metasedimentary xenoliths and leucogranites suggested by field observations, petrography and bulk rock chemistry.



<u>Figure 17</u>: ϵ_{Nd} vs time diagram for pelitic paragneiss xenoliths in Konth and Slave suites.

4.3.3f Rocks of the Churchill Province

Eleven of the thirty two samples analyzed for Sm-Nd isotopes are from the Churchill Province proximal to the Taltson magmatic zone. The large number of analyses on rocks of the Churchill Province is justified by the great variety of rock types found immediately east of the Taltson zone, the most common which must be assessed as potential sources to the granitic magmas of the Taltson zone. As described in chapter 1, the rocks comprising the Churchill Province east of the Taltson magmatic zone are subdivided in an eastern granitic gneiss terrane and a western mixed gneiss terrane. Five samples from the granitic gneiss terrane were analyzed. Their ϵ_{Nd} values, calculated at 1940 Ma, and model ages vary from -5.2 to -10.4 and from 2.7 to 2.9 Ga respectively (Fig. 18). It is noteworthy to mention that the more positive ϵ_{Nd} values (-5.2, -6.4 and -6.6) of these rocks are similar to those of the Konth and Slave suites.

The mixed gneiss terrane has an older crustal signature than the other litho-tectonic entities discussed so far. Four samples of these gneisses yielded ϵ_{Nd} values at 1940 Ma ranging from -9.2 to -11.6 and corresponding T_{DM} ages from 2.8 and 2.9 Ga (Fig. 18). The older signature of the western gneisses is in sharp contrast with that of the eastern granitic gneisses and further accentuates the lithological

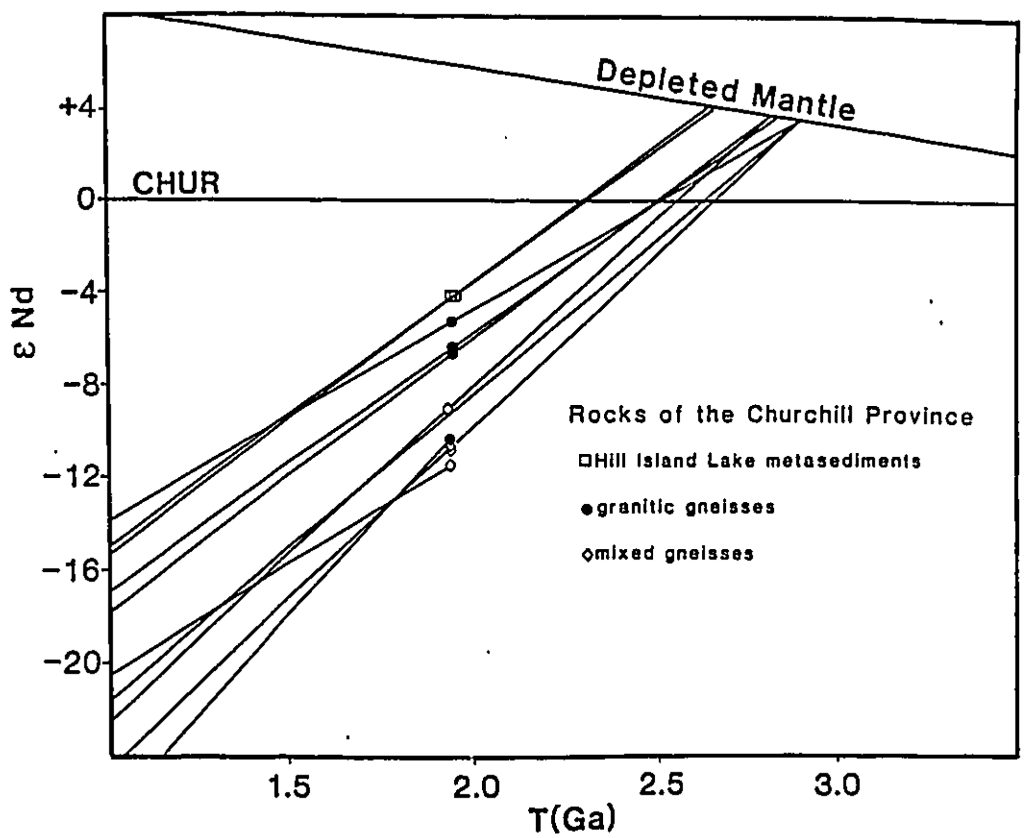


Figure 18: ϵ_{Nd} vs time diagram for mixed gneisses and granitic gneisses of the Churchill Province and for Hill Island Lake metasediments.

differences between the two terranes.

Two samples (RT-88-2 and RT-88-3) of subgreenschist metamorphic grade pelites from Hill Island Lake (c.f. Appendix III) were analyzed. These pelitic rocks are part of a sedimentary assemblage which overlies granitic gneisses of the Churchill Province, in the eastern sector of the study area. Both samples yielded an ϵ_{Nd} of -4.1, a value that makes these rocks indistinguishable, in terms of Nd isotopes, from the pelitic rocks found among the Slave and Konth granites in the Taltson zone.

4.3.5 Discussion

Much like the petrographic and geochemical data, Nd isotope signatures display a certain asymmetry across the Taltson magmatic zone. Less negative initial ϵ_{Nd} values characterize the Deskenatlata intrusive suite whereas more negative initial ϵ_{Nd} values are distinct of the Konth and Slave suites. Furthermore, inferences can be made about the genetic relationships between the various gneiss terranes of the study area and the granitic suites of the Taltson zone.

Two features are dominant in the data from the Deskenatlata intrusive suite. Firstly, ϵ_{Nd} values are clustered in a narrow range and secondly, these values are less negative than those of the other lithologies of the study area (except for the xenoliths in the Deskenatlata suite itself). The narrow range of ϵ_{Nd} values and the isochron plot imply a large, isotopically homogeneous magma source for the Deskenatlata suite. The narrow range of initial ϵ_{Nd} values over such a large area (c.f. Appendix III) is difficult to explain by assimilation of mid and upper crust by melts generated at depth. An unusual amount of heat would be required to thoroughly mix the assimilated heterogeneous continental crust with the intruding magmas on the scale of the Deskenatlata intrusive suite. The uniformity of initial ϵ_{Nd} values of the Deskenatlata may be explained by the mixing of crustally-derived melts with mantle-derived melts prior to emplacement of the plutons. The involvement of some mantle derived material in the genesis of the Deskenatlata is supported by the less negative ϵ_{Nd} values relative to the other intrusive rocks of the Taltson zone as well as I-type petrographic and geochemical features. Mixing of juvenile and crustal components resulting in homogeneous magmas can be achieved by: i) melting at the base of the lithosphere and ii) incorporation of crust-derived sedimentary material overlying a subducting oceanic plate in an arc environment. Emplacement of the Deskenatlata suite magmas at deep crustal levels and slow quenching are suggested by the apparent fractionation of Sm and Nd as reflected by variable $^{147}Sm/^{144}Nd$ ratios as well as variable Sm and Nd abundances observed in this suite.

The broad -4.8 to -8.6 range of initial ϵ_{Nd} values for the Slave suite is suggestive that the source of this suite was isotopically heterogeneous continental crust, thus precluding the dominance of the depleted mantle as a component of the Slave suite magmas. Source heterogeneity is supported by the failure to obtain an isochron from the Slave suite data. The $^{147}Sm/^{144}Nd$ ratios, which approximate the 0.1 value for LREE continental crust (Goldstein et al., 1984; Miller et al., 1986; DePaolo, 1988), are compatible with crustal sources for the Slave suite, one of which may be the pelitic xenoliths found in the Konth and Slave suites. Other sources for the Slave suite appear to be continental crust of Archean age, as indicated by the T_{DM} of 2.7 to 2.9 Ga. Such crust appears to be more prevalent in the western Churchill province (this study; E. Hegner, pers. comm., 1989) than in the Buffalo Head terrane where model ages tend to be in the 2.5 to 2.7 Ga range with few exceeding 2.8 Ga (Thériault and Ross, 1990).

The Konth intrusive suite has more tightly grouped and generally less negative ϵ_{Nd} values than the Slave suite. Moreover, the ϵ_{Nd} range of the metapelitic xenoliths completely overlaps the range of ϵ_{Nd} values of the Konth suite and this suite has a similar average ϵ_{Nd} value (-5.2) to average ϵ_{Nd} value (-5.1) of the xenoliths. The clustering of

ϵ_{Nd} values and the obtention of an isochron from the Konth suite data are compatible with the involvement of a homogeneous sedimentary component. The most simple explanation for the Sm-Nd isotopic features of the Konth is that the latter was mainly generated by melting of the pelitic xenoliths found within this magmatic suite.

Nd isotope systematics indicating crustal melting on the scale of the Slave and especially the Konth suite, have been documented in regions where continent-continent collision has led to tectonic thickening of the continental crust. For example, the well-studied Manaslu leucogranite of the High Himalayan has initial ϵ_{Nd} values of -13 to -16 and mimics isotopic compositions and heterogeneities observed in associated paragneisses of the Tibetan crustal slab (Deniel et al., 1987). France-Lanord and LeFort (1988) invoke crustal melting exclusively as the process responsible for the production of Himalayan leucogranites with initial ϵ_{Nd} values ranging from -11 to -16. Leucogranites in the Hercynian belt of France have Nd isotopic signatures which support derivation by melting of surrounding Cenozoic, Paleozoic and Proterozoic sedimentary gneisses (Peucat et al., 1988).

The Nd isotopic data obtained from the mixed paragneisses in the eastern Deskenatlata suite are enigmatic in that no source terrane, igneous or sedimentary in nature, can be identified in the vicinity of the study area. The presence of juvenile material signaled by the +2.0 ϵ_{Nd} value obtained from an amphibolite may be related to potential basic volcanism associated with Deskenatlata plutonism. Alternately, the amphibolite may represent lower crustal or upper mantle material which was transported to shallower levels or younger gabbro dykes that have been reworked. The more negative initial ϵ_{Nd} values of the Deskenatlata suite may be explained by long term crustal assimilation by the basic magmas at depth. The pelitic gneiss within the Deskenatlata suite may be the result of mixing of juvenile material with an older crustal component, yielding Nd isotopic signatures which are not as strongly crustal as those generally observed in the study area.

The contrasting ϵ_{Nd} values of the granitic and mixed gneiss terranes support the proposition of Bostock and Loveridge (1988) that both gneiss terranes are distinct geologic entities. This is further accentuated by the fact that the mixed gneiss terrane is bounded from the Taltson magmatic zone and the granitic gneiss terrane by structural discontinuities. The range of ϵ_{Nd} values for the granitic gneiss terrane overlaps the more negative values of the pelitic paragneisses within the Konth and Slave suites, suggesting that the latter may be partially derived from the former. The full range of the ϵ_{Nd} values in the pelites may reflect the Nd isotopic composition of rocks which were at the surface of the western Churchill Province at the time of deposition of the pelitic sediments. Other potential source terranes for the pelites is the eastern Slave Province, whose ϵ_{Nd} evolution is identical to that of the pelites (E. Hegner, pers. comm., 1989) and the Buffalo Head terrane which also has Nd crustal ages in the 2.7 Ga range (Thériault and Ross, 1990). However, the similarity of ϵ_{Nd} values of the pelites in the Taltson with those overlying the Churchill gneisses at Hill Island Lake suggests that the pelitic rocks have a common source and may be part of a same sedimentary assemblage which may have overlain the western Churchill Province prior to Taltson plutonism. The isotopic link between the pelites within the Taltson and those at Hill Island Lake is strong evidence in favour of the emplacement of the Taltson granites into Churchill crust.

Chapter 5: Conclusions

The isotopic, chemical and petrographic data presented in previous chapters demonstrate that the Deskenatlata, Slave and Konth intrusive suites have distinct sources and petrogenetic histories. In light of the information presented in this study and present knowledge of western Canadian Shield tectonics presented in chapter 1, the evolution of the Taltson magmatic zone can be placed in a regional tectonic context.

The Deskenatlata intrusive suite displays the most mafic character of the three granitic suites comprising the Taltson zone. The I-type mineralogy is indicative of an igneous source for this suite. Petrographic observations are supported by major and trace element geochemistry. The Deskenatlata exhibits lower SiO_2 (59% to 74%) and greater MgO (up to 2.8%) and FeO + Fe_2O_3 (1.1% to 7.3%) contents than the other two suites and exhibits an affinity for island and continental arc fields on Rb vs (Y + Nb) , Na_2O vs CaO and Rb vs Sr diagrams. Given the geochemistry and petrography of the Deskenatlata suite, anomalously elevated A/CNK values may be explained by thorough assimilation of a pelitic contaminant. Initial ϵ_{Nd} are less negative than those of the Konth and Slave suites and reflect mixing of juvenile and evolved crustal sources. The petrographic, chemical and Nd-isotopic features of this granitic suite are similar to those of arc-derived granodiorites of the Andes and southwest U.S.A..

The Slave and Konth intrusive suites are in sharp contrast with the Deskenatlata; they show evidence for a greater involvement of continental crust than the latter. Potassium feldspar megacrysts and a syenogranite composition typify the Konth suite whereas the Slave suite shows compositional variability from granodiorite to syenogranite. Petrographically, the Konth and Slave suites are difficult to distinguish. Both suites contain restitic and/or primary garnet, spinel, cordierite and sillimanite in abundance. This mineral assemblage closely resembles that of the pelitic xenoliths assimilated by the Konth and Slave suites. The leucocratic nature of these suites is demonstrated by elevated SiO_2 values (66% to 76%), low MgO (0% to 1.5%) and FeO + Fe_2O_3 (0.7% to 4.6%) contents. The Slave suite plots in volcanic arc, continental arc and collisional granite fields on Rb vs (Y + Nb), Na_2O vs CaO and Rb vs Sr diagrams whereas the Konth suite plots in fields suggesting a strictly crustal derivation.

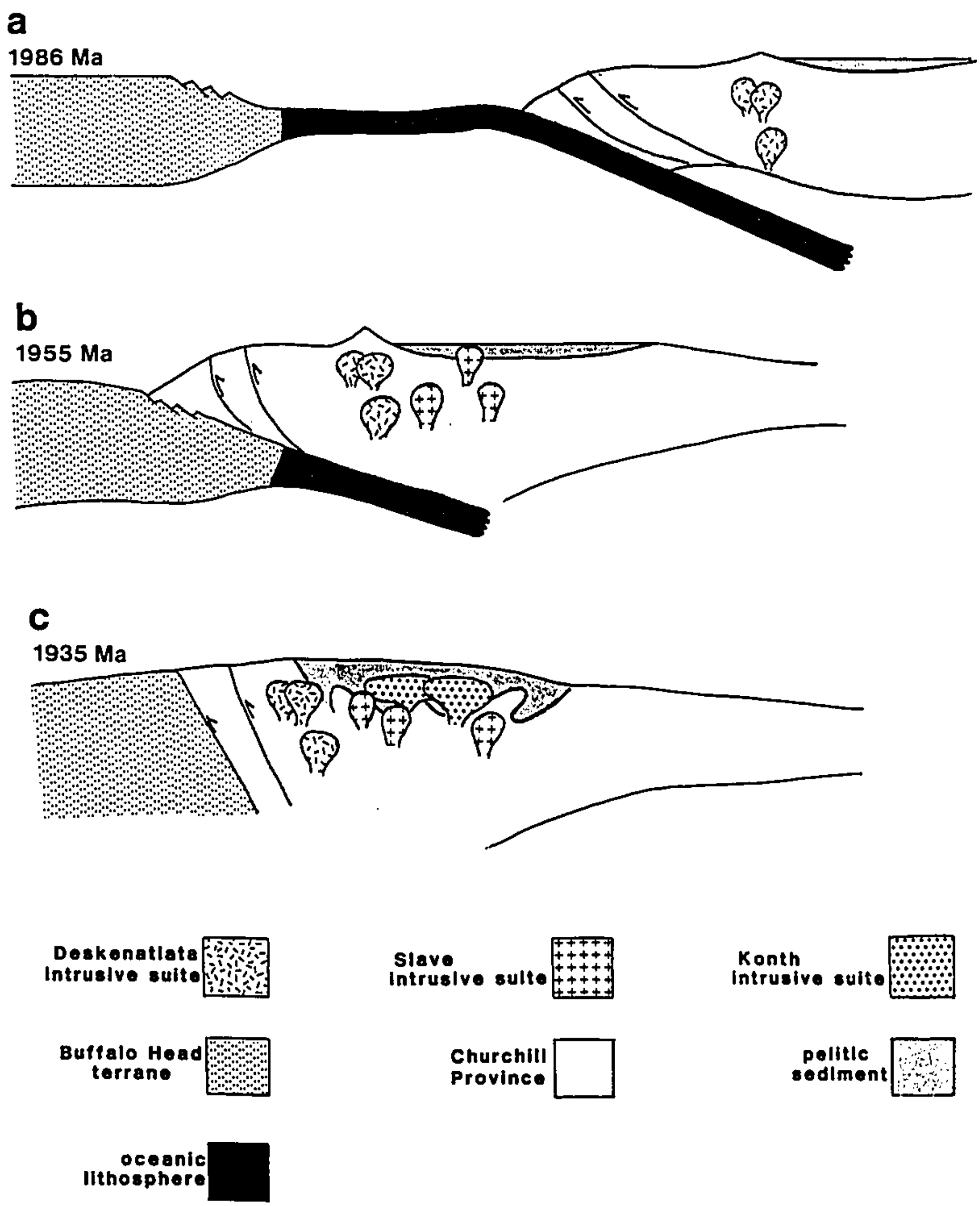
Initial ϵ_{Nd} values ranging from -4.8 to -8.6 and T_{DM} ages from 2.6 to 2.9 Ga for the Slave suite suggest assimilation of various Archean crustal sources, including pelitic paragneiss xenoliths whose ϵ_{Nd} values (at 1.94 Ga) span from

-4.1 to -5.8. Initial ϵ_{Nd} values for the Konth suite range from -4.7 to -5.6 and are completely overlapped by the ϵ_{Nd} values of the pelitic paragneisses engulfed by the Konth and Slave suites. Thus, production of the Konth suite by melting of pelites is suggested by isotopic data and corroborated by petrography and bulk rock chemistry. Commonly a magmatic belt dominated by products of widespread crustal melting, as observed in the Taltson zone, is associated with tectonic thickening and melting of continental crust during continent-continent collision. The Himalayan and the Hercynian belts are appropriate analogs to the Taltson zone.

Partial melting of Archean gneisses of the western Churchill Province, whose ϵ_{Nd} values at 1.94 Ga fall in the -5.2 to -11.6 spectrum can account for the Nd isotopic signatures observed in the Slave suite. Thus, the Slave suite could result from the fusion of various segments of Archean crust varying in isotopic composition and geochemistry. Remobilization of Churchill Province crust is supported by ϵ_{Nd} values of -4.1 at the time of Taltson plutonism for low grade pelitic metasediments overlying Churchill granitic gneisses near Hill Island Lake. On the basis of Nd isotopic signatures, the Hill Island Lake pelites cannot be discriminated from the pelitic rocks engulfed by the leucogranites of the Taltson zone. This implies that metasediments in the Taltson and

Churchill may have belonged to a single sedimentary package overlying the western Churchill Province whose westernmost margin has undergone remobilization during the Taltson event.

As discussed in chapter 1, the Taltson zone is part of an early Proterozoic magmatic belt which includes the Thelon zone and its potential northward extensions. Oblique, eastward subduction of oceanic lithosphere beneath the Churchill Province is believed to be responsible for Thelon plutonism. This was followed by collision and indentation of the Slave Province into the ductile Thelon zone and adjacent Churchill Province at approximately 1967 Ma. Being contemporaneous and continuous with the Thelon zone, the Taltson zone would have evolved by processes compatible with the evolution of the Thelon. Hence, subduction of oceanic lithosphere beneath the Churchill Province and related arc magmatism is represented by the 1986 Ma Deskenatlata intrusive suite (Fig. 19a) which pre-dates the circa 1967 Ma Slave Province-Churchill Province collision. The Deskenatlata event would have been followed by closure of the oceanic basin and collision of the Buffalo Head terrane


a
1986 Ma
b
1955 Ma
c
1935 Ma
Deskenatlata intrusive suite
Slave intrusive suite
Konth intrusive suite
Buffalo Head terrane
Churchill Province
pelitic sediment
oceanic lithosphere

with the Churchill Province. Widespread collision-related melting of Archean crust would have resulted in the production of the Slave and Konth intrusive suites (Figs. 19b and 19c). The 1955 to 1925 Ma crystallization ages for the Slave suite provide time constraints for crustal melting due to the Buffalo Head terrane-Churchill Province collision. Production of Slave suite magmas is essentially due to fusion of Archean Churchill Province crust at various depths due to tectonic thickening along the western margin of the Churchill Province (Fig. 19b). Continued compression and crustal thickening would have resulted in further Slave suite magmatism as well as the generation of the Konth suite by fusion of supracrustal metasediments (Fig. 19c).

References

Anderson. J.L. and Bender, E.E., 1989. Nature and origin of Proterozoic A-type granitic magmatism in the southwestern United States of America. Lithos, v.23, pp.19-52.

Aspler, L.B., 1985. Geology of Nonacho Basin (early Proterozoic) N.W.T.; unpublished Ph.D. thesis, Carleton University, 384 p.

Bateman, P.C., 1983. A summary of critical relations in the Sierra Nevada batholith, California, U.S.A.; in Roddick, J.A. ed., Circum-Pacific plutonic terranes, Geol. Soc. Amer. Memoir 159, pp. 241-254.

Bateman, P.C. and Dodge, F.C.W., 1970. Variations of major element constituents across the Sierra Nevada batholith. Geol Soc. Amer. Bull., v.81, pp.408-420.

Bostock, H.H., 1981. A granitic diapir of batholitic dimensions at the west margin of the Churchill Province; in Current Research, Part B, Geol. Surv. Can., Paper 81-1B, pp. 73-82.

-------------, 1982. Geology of the Fort Smith Map Area, District of Mackenzie, Northwest Territories (NTS 75D). Geol. Surv. Can. Open File 859.

-------------, 1984. Preliminary geological reconnaissance of the Hill Island Lake and Taltson Lake areas, District of Mackenzie; in Current Research, Part A, Geol. Surv. Can., Paper 84-1A, pp.165-170.

-------------, 1986. Reconnaissance geology of Precambrian rocks of the Fort Resolution, Taltson Lake, and Fort Smith areas, District of Mackenzie; in Current Research, Part A, Geol. Surv. Can., Paper 86-1A, pp.35-42.

-------------, 1987. Geology of the south half of the Taltson Lake map area, District of Mackenzie; in Current Research, Part A, Geol. Surv. Can., Paper 87-1A, pp.443-450.

-------------, 1988. Geology of the north half of the Taltson Lake map area, District of Mackenzie; in Current Research, Part C, Geol. Surv. Can., Paper 88-1C, pp.189-198.

Bostock, H.H. and Loveridge, W.D., 1988. Geochronology in the Taltson magmatic zone and eastern cratonic margin, District of Mackenzie; in Radiogenic Age and Isotopic Studies: Report 2, Geol. Surv. Can., Paper 88-2, pp.59-66.

Bostock, H.H., van Breemen, O., and Loveridge, W.D., 1987. Proterozoic geochronology in the Taltson magmatic zone, N.W.T.; in Radiogenic Age and Isotopic Studies: Report 1, Geol. Surv. Can., Paper 87-2, pp.73-80.

Bowring, S.A. and Grotzinger, J.P., 1989. Implication of new U-Pb dating and stratigraphic correlations for current tectonic models for Wopmay orogen and Thelon tectonic zone; in GAC-MAC program with abstracts, v.14, p. A74.

Bowring, S.A., King, J.E., Housh, T.B., Isachsen, C.E. and Podosek, F.A., 1989. Neodymium and lead isotope evidence for enriched early Archean crust in North America. Nature, v.340, pp. 222-225.

Chappell, B.W. and Stephens, W.E., 1988. Origin of infracrustal (I-type) granite magmas. Trans. R. Soc. Edinburgh, v.79, pp.71-86.

Chappell, B.W. and White, A.J.R., 1974. Two contrasting granite types. Pac. Geol., v.8, pp.173-174.

Clarke, D.B., 1981. The mineralogy of peraluminous granites: a review. Can. Mineral., v.19, pp.3-17.

Clemens, J.D. and Wall, V.J., 1981. Origin and crystallization of some peraluminous (S-type) granitic magmas. Can. Mineral., v.19, pp.111-131.

Corretge, J.M., Uqidos, J.M. and Martinez, F., 1977. Les séries granitiques varisques du secteur Centre-Occidental espagnol; in La Chaîne Varisque d'Europe Moyenne et Occidentale, collection interne C.N.R.S. Paris, No.243, pp.453-462.

Culshaw, N.G., 1984. Rutledge Lake, Northwest Territories; a section across a shear belt within the Churchill Province; in Current Research, Part A, Geol. Surv. Can., Paper 84-1A, pp.331-338.

Debon, F. and LeFort, P., 1983. A chemical-mineralogical classification of common plutonic rocks and associations. Trans. R. Soc. Edinburgh, v.73, pp.135-149.

Debon, F., LeFort, P., Sheppard, S.M.F. and Sonet, J., 1986. The four plutonic belts of the Transhimalaya-Himalaya: a chemical, mineralogical, isotopic, and chronological synthesis along a Tibet-Nepal section. J. Petrology, v.27, pp.219-250.

Deniel, C., Vidal, P., Fernandez, A., LeFort, P and Peucat, J.J., 1987. Isotopic study of the Manaslu granite (Himalaya, Nepal): inferences on the age and source of Himalayan leucogranites. Contrib. Mineral Petrology, v.96, pp.78-92.

DePaolo, D.J., 1988. Neodymium isotope geochemistry. Springer-Verlag, Berlin, Heidelberg, New York. 187 p.

Dudas, F.O., 1989. Nd isotopic compositions from the Slave craton: the case of the missing mantle; in GAC-MAC program with abstracts, v.14, p.A24.

Faure, G., 1986. Principles of isotope geology, sec. ed.. J. Wiley and Sons, New York. 589 p.

Foord, E.E., 1977. The Himalaya dike system. Mineral. Record, v.8, pp.461-474.

France-Lanord, C. and LeFort, P., 1988. Crustal melting and granite genesis during the Himalayan collision orogenesis. Trans. R. Soc. Edinburgh, v.79, pp.183-195.

Gibb, R.A., 1978. Slave-Churchill collision tectonics. Nature, v. 271. pp.50-53.

Gibb, R.A., Thomas, M.D., Lapointe, P.L. and Mukhopadhyay, M., 1983. Geophysics of proposed Proterozoic sutures in Canada. Precamb. Res., v.19, pp.349-384.

Godfrey, J.D. and Langenberg, C.W., 1978. Metamorphism in the Canadian Shield of northeastern Alberta; in Metamorphism in the Canadian Shield, Geol. Surv. Can., Paper 78-10, pp.129-138.

Gogte, B.S. and Ramana, Y.V., 1982. Petrological characteristics and elastic properties of granitoids from major tectonic zones of northwestern Himalaya. Himalayan Geology, v.12, pp.132-155.

Goldstein, S.L., O'Nions, R.K. and Hamilton, P.J., 1984. A Sm-Nd study of atmospheric dusts and particulates from major river systems. Earth Planet. Sci. Lett., v.70, pp. 221-236.

Grotzinger, J.P. and McCormick, D.S., 1988. Flexure of the Early Proterozoic lithosphere and evolution of the Kilohigok basin (1.9 Ga), northwest Canadian Shield; in Kleinspehn, K.L. and Paola, C. eds., New perspectives in basin analysis, Springer-Verlag, New York, pp.405-430.

Harris, N.B.W., Pearce, J.A. and Tindle, A.G., 1986. Geochemical characteristics of collision-zone magmatism; in Collision Tectonics, Coward, M.P. and Ries, A.C. eds., Geol. Soc. Spec. Publ. No. 19, pp.67-81.

Henderson, J.B., McGrath, P.H., James, D.T., and Macfie, R.I., 1987. An integrated geological, gravity and magnetic study of the Artillery Lake area and the Thelon Tectonic Zone, District of Mackenzie; in Current Research, Part A, Geol. Surv. Can., Paper 87-1A, pp.803-814.

Henderson, J.B., Thompson, P.H., and James, D.T., 1982. The Healy Lake map area and the Thelon Front problem, District of Mackenzie; in Current Research, Part A, Geol. Surv. Can., Paper 82-1A, pp.191-195.

Hildebrand, R.S. and Bowring, S.A., 1984. Continental intra-arc depressions: a nonextensional model for their origin, with a Proterozoic example from Wopmay orogen. Geology, v.12, pp.73-77.

Hoffman, P.F., 1980. Wopmay orogen: a Wilson cycle of early Proterozoic age in the northwest Canadian Shield; in Strangway, D.W. ed., The continental crust and its mineral resources, Geol Assoc. Can. Special Paper 20, pp. 523-549.

-------------, 1987. Continental transform tectonics: Great Slave Lake shear zone (ca. 1.9 Ga), northwest Canada. Geology, v.15, pp.785-788.

-------------, 1988. United Plates of America, the birth of a craton: Early Proterozoic assembly and growth of Laurentia. Ann. Rev. Earth Planet. Sci., v. 16, pp.543-603.

-------------, 1989. Precambrian geology and tectonic history of North America; in Bally, A.W. and Palmer, A.R. eds., The geology of North America - an overview, v.A, Geol. Soc. Amer., pp.447-511.

Hoffman, P.F. and Bowring, S.A., 1984. Short-lived 1.9 Ga continental margin and its destruction, Wopmay orogen, northwest Canada. Geology, v.12, pp.68-72.

Hoffman, P.F., Culshaw, N.G., Hanmer, S.K., LeCheminant, A.N., McGrath, P.H., Tirrul, R., van Breemen, O., Bowring, S.A. and Grotzinger, J.P.,1986. Is the Thelon front (NWT) a suture?; in GAC-MAC program with abstracts, v.11, p.82.

Jacobsen, S.B. and Wasserburg, G.J., 1980. Sm-Nd evolution of chondrites. Earth Planet. Sci. Lett., v.50, pp.139-155.

Kuskey, T.M., 1989., Accretion of the Archean Slave Province. Geology, v.17, pp.63-67.

Lalonde, A.E., 1989. Hepburn intrusive suite: peraluminous plutonism within a closing back-arc basin, Wopmay orogen, Canada. Geology, v.17, pp.261-264.

LeFort, P., 1975. Himalaya: the collided range. Present knowledge of a continental arc. Amer. J. Sci., v.275A, pp.1-44.

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

Lipman, P.W., 1988. Evolution of silicic magma in the upper crust: the mid Tertiary volcanic field and its cogenetic granitic batholith, northern New Mexico, U.S.A.. Trans. R. Soc. Edinburgh, v.79, pp.265-288.

Lorenzoni, S., Messina, A., Russo, S., Stagno, F. and Zanettin Lorenzoni, E., 1979. The two mica Al_2SiO_5 granites of the Sila (Calabria). Neues Jb. Mineral. Mh., v.27, pp.421-436.

Maniar, P.D. and Piccoli, P.M., 1989. Tectonic discrimination of granitoids. Geol. Soc. Amer. Bull., v.101, pp.635-643.

McGlynn, J.C., Hanson, G.N., Irving, E. and Park, J.K., 1974. Paleomagnetism and age of the Nonacho Group sandstones and associated Sparrow dykes, District of Mackenzie. Can. J. Earth Sci., v.11, pp.30-42.

Miller, R.G., O'Nions, R.K., Hamilton, P.J. and Welin, E., 1986. Crustal residence ages of clastic sediments, orogeny and continental evolution. Chem. Geol., v.57, pp.87-99.

Mortensen, J.K., Thorpe, R.I., Padgham, W.D., King, J.E. and Davis, W.J., 1988. U-Pb zircon ages for felsic volcanism in the Slave Province, N.W.T.; in Radiogenic Age and Isotopic Studies; Report 2, Geol. Surv. Can., Paper 88-2, pp.85-96.

Nelson, B.K. and DePaolo, D.J., 1987. Rapid production of continental crust 1.7 to 1.9 b.y. ago: Nd isotopic evidence from the basement of the North American mid-continent. Geol. Soc. Amer. Bull., v.96, pp.746-754.

Orsini, J.B., 1979. Existence de trois associations magmatiques dans les granitoïdes post Viséen moyen (groupes des granodiorites-monzogranites) de la chaîne vasisque française. C.R. Acad. Sci. Paris, v.289-D, pp.981-984.

Padgham, W.A., ed., 1987. Yellowknife guidebook: a guide to the geology of the Yellowknife volcanic belt and bordering rocks. St. John's, Newfoundland, Geol. Assoc. Can., 209 p.

Patchett, P.J. and Arndt, N.T., 1986. Nd isotopes and tectonics of 1.9-1.7 Ga crustal genesis. Earth Planet. Sci. Lett., v.78, pp.329-338.

Patchett P.J. and Kouvo, O., 1986. Origin of continental crust of 1.9-1.7 Ga age: Nd isotopes and U-Pb zircon ages in the Svecokarelian terrain of south Finland. Contrib. Mineral. Petrology, V.92, pp.1-12.

Patchett, P.J. and Ruiz, J., 1987. Nd isotopic ages of crust formation and metamorphism in the Precambrian of eastern and southern Mexico. Contrib. Mineral. Petrology, v.96, pp.523-526.

Patchett, P.J. and Todt, W., 1987. Origin of the continental crust of 1.9-1.7 Ga age: Nd isotopes in the Svecofennian orogenic terrain of Sweden. Precamb. Res., v.35, pp.145-160.

Pearce, J.A., Harris, N.B.W. and Tindle, A.G., 1984. Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. J. Petrology, v.25, pp.956-983.

Peucat, J.J., Jegouzo, P., Vidal, P. and Bernard-Griffiths, J., 1988. Continental crust formation seen through the Sr and Nd isotope systematics of S-type granites in the Hercynian belt of western France. Earth Planet. Sci. Lett., v.88, pp.60-68.

Pitcher, W.S., 1982. Granite type and tectonic environment; in Mountain Building Processes, Hsü. J. ed., Academic Press, London, pp.19-40.

Richard, P., Shimuzu, N. and Allègre, C.J., 1976. $^{143}Nd/^{146}Nd$, a natural tracer: an application to oceanic basalts. Earth Planet. Sci. Lett., v.31, pp.269-278.

Rogers, G. and Hawkesworth, 1989. A geochemical traverse across the North Chilean Andes: evidence for crust generation from the mantle wedge. Earth Planet. Sci. Lett., v.91, pp.271-285.

Ross, G.A., Parrish, R.R., Villeneuve, M.E. and Bowring, S.A., 1989. Tectonic assembly of the Canadian Shield in the Alberta subsurface. in prep.

Sharpton, V.L., Grieve, R.A.F., Thomas, M.D. and Halpenny, J.F., 1987. Horizontal gravity gradient: an aid to the definition of crustal stucture in North America. Geophys. Res. Lett., v.14, pp.808-811.

Shirey, S.B. and Carlson, R.W., 1988. Pb and Nd isotopic constraints on crustal evolution in the southern Superior province and inferences for a heterogeneous Archean mantle. Geol. Soc. Amer. program with abstracts, v.20, p.A137.

Silver, L.T. and Chappell, B.W., 1988. The Peninsular Ranges Batholith: an insight into the evolution of the Cordilleran batholiths of southwestern North America. Trans. R. Soc. Edinburgh, v.79, pp.105-121.

Smith, A.D. and Ludden, J.N., 1989. Nd isotopic evolution of the Precambrian mantle. Earth Planet. Sci. Lett., v.93, pp.14-22.

Taylor, S.R. and McClennan, S.M., 1985. The continental crust: its composition and evolution. Blackwell Scientific, London, Edinburgh, Boston, Palo Alto, Carlton. 312 p.

Thériault, R.J. and Ross, G.M., 1990. Crustal growth in the crystalline basement of northern Alberta: constraints from Nd isotopes. Geol. Assoc. Can., program with abstracts, v.15, p.A120.

van Breemen, O. and Henderson, J.B., 1988. U-Pb zircon and monazite ages from the eastern Slave Province and Thelon Tectonic Zone, Artillery Lake area, N.W.T.; in Radiogenic Age and Isotopic Studies: Report 2, Geol. Surv. Can., Paper 88-2, pp.73-84.

van Breemen, O., Henderson, J.B., Loveridge, W.D. and Thompson, P.H., 1987a. U-Pb zircon and monazite geochronology and zircon morphology of granulites and granite from the Thelon Tectonic Zone, Healy Lake and Artillery Lake map areas, N.W.T.; in Current Resesarch, Part A, Geol. Surv. Can., Paper 87-1A, pp.783-801.

van Breemen, O., Thompson, P.H., Hunt, P.A., and Culshaw, N., 1987b. U-Pb zircon and monazite geochronology from the northern Thelon Tectonic Zone, District of Mackenzie; in Radiogenic and Isotopic Studies: Report 1, Geol. Surv. Can., Paper 87-2, pp.81-93.

Vidal, P.H., Cocherie, A. and LeFort, P., 1982. Geochemical investigations of the origin of the Manaslu leucogranite (Himalaya, Nepal). Geochim. Cosmochim. Acta, v.46, pp.2279-2292.

Webster, R.K., 1960. Mass spectrometric isotope dilution analysis; in Methods in Geochemistry, Smales and Wagner eds., Interscience, New York, pp.202-246.

White, A.J.R. and Chappell, B.W., 1977. Ultrametamorphism and granitoid genesis. Tectonophys., v.43, pp.7-22.

--------------------------------, 1988. Some supracrustal (S-type) granites of the Lachland Fold Belt. Trans. R. Soc. Edinburgh, v.79, pp.169-181.

White, W.M. and Patchett, J., 1984. Hf-Nd-Sr isotopes and incompatible element abundances in island arcs: implications for magma origins and crust-mantle evolution. Earth Planet. Sci. Lett., v.67, pp.167-185.

Wilson, A.D., 1960. The micro-determination of ferrous iron in silicate minerals by a volumetric and colorimetric method. Analyst, v.85, pp.823-827.

Appendix I
Results of chemical analyses

Deskenatlata intrusive suite

sample #	RT-88-14	RT-88-15	RT-88-16	RT-88-17	RT-88-18
% SiO_2	72.97	64.81	67.80	58.72	68.41
Al_2O_3	13.52	16.45	14.97	17.66	15.75
Fe_2O_3	0.06	0.07	0.15	0.45	1.13
FeO	1.72	3.98	3.77	5.47	2.52
MgO	0.69	1.58	1.61	2.75	1.21
CaO	1.36	3.01	2.36	4.84	2.54
Na_2O	3.99	3.26	3.07	2.88	2.61
K_2O	4.20	3.76	3.24	2.89	4.78
TiO_2	0.26	0.67	0.57	1.45	0.56
P_2O_5	0.06	0.05	0.09	0.38	0.19
MnO	0.03	0.07	0.06	0.08	0.05
S	0.05	0.06	0.05	0.08	0.05
Total	99.31	98.48	98.40	98.56	99.94
ppm Ba	824	1239	1340	417	2531
Cr	16	0	29	41	26
Zr	155	154	196	166	216
Sr	303	472	284	611	312
Rb	111	131	150	65	156
Y	8	42	11	10	17
Nb	0	13	6	14	7
Zn	46	78	126	182	130
V	16	71	63	81	49

sample #	RT-88-19	RT-88-20	85BK-701	85BK-702	85BK-703
% SiO_2	69.29	74.42	67.80	68.70	63.10
Al_2O_3	14.78	12.97	15.50	15.40	14.20
Fe_2O_3	0.71	0.90	0.60	0.50	1.90
FeO	1.87	0.80	3.40	3.40	5.40
MgO	1.99	0.51	0.05	0.08	1.80
CaO	1.59	0.74	3.49	3.21	4.28
Na_2O	2.30	3.43	2.90	3.30	3.20
K_2O	4.95	5.31	3.47	3.18	2.58
TiO_2	0.33	0.21	0.70	0.66	1.25
P_2O_5	0.03	0.06	0.23	0.25	0.41
MnO	0.03	0.04	0.05	0.08	0.14
S	0.05	0.03	0.04	0.02	0.04
Total	98.33	99.60	98.23	98.78	98.38
ppm Ba	910	42	1050	908	908
Cr	23	8	19	19	42
Zr	191	123	240	190	300
Sr	197	95	350	300	350
Rb	138	145	75	79	58
Y	11	12	12	18	32
Nb	0	0	12	13	22
Zn	126	117	53	54	110
V	14	2	60	50	99

Sample #	85BK-704	85BK-706	80BK-977
%SiO_2	71.20	71.20	73.60
Al_2O_3	14.20	14.50	14.60
Fe_2O_3	0.80	0.60	0.40
FeO	1.90	1.20	0.70
MgO	0.04	0.02	0.02
CaO	2.05	1.77	1.76
Na_2O	2.60	2.80	3.10
K_2O	5.70	5.34	4.59
TiO_2	0.53	0.31	0.20
P_2O_5	0.13	0.09	0.06
MnO	0.04	0.02	0.02
S	0.02	0.00	0.03
Total	99.21	98.85	99.08
ppm Ba	1480	1226	992
Cr	9	9	7
Zr	250	140	86
Sr	290	330	347
Rb	120	120	107
Y	28	2	0
Nb	15	7	5
Zn	38	31	21
V	26	23	5

Slave intrusive suite

Sample #	RT-88-23	86BK-43X	86BKL-60	87BKN-64	86BKM-82
%SiO_2	72.23	67.65	74.80	70.39	72.55
Al_2O_3	14.62	17.44	13.46	13.62	14.39
Fe_2O_3	0.60	0.80	0.31	1.35	0.34
FeO	0.72	2.94	1.32	2.11	1.56
MgO	0.41	1.51	0.42	1.19	0.61
CaO	1.09	2.77	1.12	1.79	0.92
Na_2O	2.91	4.43	3.02	2.85	2.61
K_2O	5.98	1.59	4.55	4.57	6.07
TiO_2	0.17	0.44	0.13	0.49	0.27
P_2O_5	0.10	0.05	0.06	0.12	0.12
MnO	0.01	0.08	0.08	0.02	0.01
S	0.05	0.06	0.05	0.07	0.05
Total	99.10	99.12	99.57	99.06	99.82
ppm Ba	596	216	616	1116	515
Cr	5	51	10	34	11
Zr	115	119	91	401	125
Sr	117	249	105	187	110
Rb	221	59	82	176	328
Y	11	39	22	9	10
Nb	0	8	0	4	6
Zn	70	105	59	104	87
V	0	53	4	61	15

Sample #	86BKM-144	87BKN-151	87BKN-171	86BKL-253	86BK-360
% SiO_2	75.93	72.47	75.79	73.72	73.47
Al_2O_3	13.85	14.42	13.61	14.35	14.77
Fe_2O_3	0.05	0.09	0.62	0.29	0.13
FeO	1.22	1.32	1.46	1.04	0.82
MgO	0.42	0.46	0.42	0.44	0.27
CaO	2.37	0.81	1.00	1.06	0.86
Na_2O	4.05	2.75	3.36	2.97	3.14
K_2O	1.83	5.63	4.41	5.62	5.68
TiO_2	0.04	0.18	0.13	0.22	0.13
P_2O_5	0.05	0.17	0.04	0.12	0.13
MnO	0.03	0.02	0.06	0.02	0.01
S	0.04	0.04	0.04	0.05	0.05
Total	100.09	98.63	101.31	100.15	99.65
ppm Ba	179	323	1327	482	316
Cr	19	14	9	6	22
Zr	51	82	161	141	63
Sr	142	73	135	101	100
Rb	23	325	111	306	283
Y	17	13	36	19	14
Nb	0	1	3	5	4
Zn	49	169	23	91	120
V	3	0	0	11	0

Sample #	86BK-361	87BK-378	80BK-100	80BK-978	81BK-835
SiO_2	72.31	74.28	74.90	74.80	71.40
Al_2O_3	14.72	13.55	14.00	14.80	14.00
Fe_2O_3	0.49	0.48	0.90	0.80	0.40
FeO	1.06	0.78	0.70	0.90	2.40
MgO	0.57	0.52	0.06	0.01	0.06
CaO	1.72	0.71	0.93	1.80	1.45
Na_2O	3.99	2.71	3.40	4.00	3.48
K_2O	4.54	5.93	4.82	3.48	4.98
TiO_2	0.20	0.15	0.04	0.23	0.42
P_2O_5	0.07	0.05	0.05	0.05	0.19
MnO	0.02	0.03	0.03	0.05	0.00
S	0.04	0.05	0.06	0.01	0.06
Total	100.12	98.52	99.89	100.93	98.84
ppm Ba	1741	1035	1125	1290	882
Cr	18	135	4	5	12
Zr	150	157	44	105	297
Sr	266	69	255	416	180
Rb	171	204	122	68	186
Y	5	22	29	1	27
Nb	0	13	3	4	13
Zn	53	141	14	42	59
V	13	152	0	7	22

Sample #	81BK-836	81BK-837
% SiO_2	73.70	75.30
Al_2O_3	14.60	15.10
Fe_2O_3	0.90	0.20
FeO	0.00	1.00
MgO	0.00	0.01
CaO	1.33	0.83
Na_2O	2.87	2.90
K_2O	5.76	5.49
TiO_2	0.16	0.19
P_2O_5	0.07	0.13
MnO	0.00	0.01
S	0.00	0.00
Total	99.39	101.16
ppm Ba	797	419
Cr	12	13
Zr	84	103
Sr	219	126
Rb	122	295
Y	3	0
Nb	5	8
Zn	30	41
V	7	9

Konth intrusive suite

Sample #	RT-88-13	RT-88-22	86BK-5C	86BKM-82	86BKM-92
% SiO_2	74.63	71.75	72.02	72.55	75.28
Al_2O_3	13.98	14.55	14.76	14.39	13.85
Fe_2O_3	0.00	0.79	0.90	0.34	0.06
FeO	1.80	0.91	0.61	1.56	0.65
MgO	0.37	0.54	0.59	0.61	0.32
CaO	0.74	0.89	1.10	0.92	0.74
Na_2O	3.13	2.69	2.89	2.61	3.35
K_2O	5.27	6.07	5.61	6.07	4.93
TiO_2	0.16	0.33	0.26	0.27	0.10
P_2O_5	0.18	0.13	0.12	0.12	0.16
MnO	0.02	0.03	0.02	0.01	0.01
S	0.05	0.04	0.02	0.05	0.05
Total	99.78	98.97	99.12	99.82	99.64
ppm Ba	312	544	585	515	179
Cr	12	0	8	11	18
Zr	86	215	157	125	30
Sr	62	103	110	110	44
Rb	403	276	342	328	244
Y	19	23	17	10	13
Nb	3	9	0	6	0
Zn	89	83	156	87	60
V	17	11	14	15	3

Sample #	86BKM-122	86BK-168	87BKL-212	86BKM-269	87BKN-285
%SiO_2	73.88	71.65	72.26	72.08	72.19
Al_2O_3	14.91	14.49	14.62	14.49	14.49
Fe_2O_3	0.00	0.99	0.25	0.33	0.76
FeO	1.21	0.72	1.38	1.49	1.05
MgO	0.58	0.61	0.58	0.53	0.53
CaO	1.01	1.18	1.04	0.90	1.07
Na_2O	3.02	3.60	2.76	2.76	2.79
K_2O	5.95	4.95	5.88	6.00	5.87
TiO_2	0.28	0.23	0.26	0.27	0.27
P_2O_5	0.11	0.08	0.09	0.17	0.10
MnO	0.01	0.02	0.02	0.02	0.02
S	0.05	0.05	0.05	0.05	0.03
Total	101.21	98.80	99.48	100.15	99.43
ppm Ba	647	1161	676	502	689
Cr	5	8	9	5	17
Zr	154	175	169	141	143
Sr	110	191	110	95	115
Rb	219	206	198	337	228
Y	13	16	18	18	21
Nb	5	3	7	5	4
Zn	89	113	30	122	78
V	14	6	4	11	7

Sample #	86BKL-340	87BKN-343	87BK-374	81BK-838	80BK-469
%SiO_2	71.97	72.24	69.08	73.40	68.70
Al_2O_3	14.34	15.25	14.25	14.70	15.60
Fe_2O_3	0.19	0.59	0.90	0.20	0.90
FeO	1.68	0.77	2.48	0.80	2.50
MgO	0.67	0.77	0.89	0.01	0.04
CaO	0.91	1.10	1.36	0.96	1.39
Na_2O	2.59	4.29	2.18	2.98	3.00
K_2O	6.20	4.20	6.07	5.51	5.29
TiO_2	0.42	0.22	0.71	0.18	1.04
P_2O_5	0.16	0.03	0.34	0.12	0.14
MnO	0.03	0.02	0.03	0.01	0.04
S	0.04	0.05	0.05	0.00	0.04
Total	99.57	99.88	98.86	98.87	98.68
ppm Ba	609	1527	888	389	876
Cr	0	28	0	13	17
Zr	275	141	447	94	463
Sr	120	390	112	125	154
Rb	328	91	294	287	192
Y	23	5	32	0	32
Nb	11	0	24	7	42
Zn	159	31	131	78	52
V	9	28	36	8	36

Sample #	81BK-839	81BK-840	80BK-154	81BK-841	81BK-842
% SiO_2	72.70	69.60	73.20	74.20	72.70
Al_2O_3	14.30	15.20	14.70	14.20	15.10
Fe_2O_3	0.30	0.40	0.20	0.40	0.00
FeO	1.10	2.60	1.30	1.00	0.80
MgO	0.01	0.02	0.02	0.02	0.01
CaO	0.73	1.22	0.88	0.78	0.61
Na_2O	2.44	2.71	2.80	2.87	2.62
K_2O	6.97	6.28	5.64	5.99	7.04
TiO_2	0.45	0.55	0.21	0.34	0.25
P_2O_5	0.19	0.20	0.14	0.14	0.14
MnO	0.01	0.02	0.03	0.02	0.01
S	0.00	0.00	0.01	0.00	0.00
Total	99.20	98.80	99.13	99.96	99.28
ppm Ba	661	737	382	422	437
Cr	13	30	16	8	10
Zr	231	302	107	200	115
Sr	135	111	112	112	123
Rb	321	338	309	316	268
Y	6	19	6	1	0
Nb	18	23	10	12	8
Zn	110	41	73	91	57
V	18	26	12	11	5

Sample #	80BK-574
% SiO_2	73.60
Al_2O_3	14.80
Fe_2O_3	0.00
FeO	1.10
MgO	0.01
CaO	0.83
Na_2O	3.00
K_2O	5.82
TiO_2	0.26
P_2O_5	0.15
MnO	0.01
S	0.03
Total	99.61
ppm Ba	375
Cr	9
Zr	132
Sr	106
Rb	309
Y	0
Nb	12
Zn	93
V	10

Appendix II
CIPW norms

Deskenatlata granodiorite

sample #	Q	or	ab	an	c	hy	mt	il	ap
RT-88-14	28.68	24.82	33.76	6.36	0.08	4.43	0.13	0.49	0.14
RT-88-15	19.93	22.22	27.59	14.61	1.66	10.21	0.10	1.27	0.12
RT-88-16	27.62	19.15	25.98	11.12	2.34	9.98	0.22	1.08	0.21
RT-88-17	14.04	17.08	24.37	21.53	1.90	14.46	0.65	2.75	0.88
RT-88-18	26.92	28.25	22.09	11.36	1.59	5.88	1.64	1.06	0.44
RT-88-19	29.60	29.25	19.46	7.69	2.82	7.31	1.03	0.63	0.07
RT-88-20	31.77	31.38	29.02	3.28	0.38	1.70	1.30	0.40	0.14
85BK-701	28.61	20.51	24.54	15.81	1.18	4.81	0.87	1.33	0.53
85BK-702	28.81	18.79	27.92	14.29	1.29	5.09	0.72	1.25	0.58
85BK-703	21.59	15.25	27.08	16.76	0.00	10.80	2.75	2.37	0.95
85BK-704	29.25	33.69	22.00	9.32	0.34	2.13	1.16	1.01	0.30
85BK-706	30.34	31.56	23.69	8.19	1.11	1.28	0.87	0.59	0.21
80BK-977	34.07	27.13	26.23	8.34	1.48	0.70	0.58	0.40	0.14

Slave monzogranite

sample #	Q	or	ab	an	c	hy	mt	il	ap
RT-88-23	29.49	35.34	24.62	4.75	1.62	1.59	0.87	0.32	0.23
86BK-43X	25.86	9.40	37.49	13.42	3.52	7.92	1.16	0.84	0.12
86BKL-60	36.00	26.89	25.55	5.16	1.67	3.15	0.45	0.25	0.14
87BKN-64	30.14	27.01	24.12	8.10	1.02	4.95	1.96	0.93	0.28
86BKM-144	39.80	10.81	34.27	11.43	1.02	1.05	0.00	0.00	0.12
87BKN-151	32.03	33.27	23.27	2.91	2.74	3.24	0.13	0.34	0.39
87BKN-171	35.77	26.06	28.43	4.70	1.59	3.11	0.90	0.25	0.09
86BKL-253	31.73	33.21	25.13	4.47	1.74	2.44	0.42	0.42	0.28
86BK-360	31.03	33.57	26.57	3.42	2.20	1.89	0.16	0.25	0.30
86BK-361	26.81	26.83	33.76	8.08	0.28	2.69	0.67	0.38	0.16
87BK-378	33.28	35.04	22.93	3.20	1.50	2.14	0.70	0.28	0.12
80BK-100	34.74	28.49	28.77	3.66	1.85	0.74	1.30	0.08	0.12
80BK-978	34.47	20.57	33.85	7.97	1.53	0.66	1.16	0.44	0.12
81BK-835	27.84	29.43	29.45	5.95	0.70	3.64	0.58	0.80	0.44
81BK-836	32.56	27.36	30.21	6.14	1.47	0.00	0.00	0.00	0.16
81BK-837	32.51	34.04	24.29	3.27	2.95	1.40	0.29	0.36	0.30

Konth syenogranite

sample #	Q	or	ab	an	c	hy	mt	il	ap
RT-88-13	33.22	31.14	26.49	2.50	2.21	4.00	0.00	0.30	0.42
86BK-5C	30.84	33.15	24.45	4.67	2.22	1.47	1.28	0.49	0.28
86BKM-82	30.61	35.87	22.09	3.78	2.14	3.68	0.49	0.51	0.28
86BKM-92	34.86	29.14	28.35	2.63	2.04	1.79	0.09	0.19	0.37
86BKM-122	30.01	35.16	25.55	4.29	1.93	3.22	0.00	0.53	0.25
86BKM-168	28.48	29.25	30.46	5.33	1.26	1.68	1.44	0.44	0.19
87BKL-212	29.98	34.75	23.35	4.57	2.04	3.38	0.36	0.49	0.21
86BKM-269	29.89	35.46	23.35	3.35	2.23	3.37	0.48	0.51	0.39
87BKN-285	30.29	34.69	23.61	4.66	1.84	2.21	1.10	0.51	0.23
86BKL-340	29.63	36.64	21.92	3.47	2.10	3.96	0.28	0.80	0.37
87BKN-343	27.52	24.82	36.30	5.26	1.72	2.52	0.86	0.42	0.07
87BK-374	28.66	35.87	18.45	4.53	2.44	4.91	1.30	1.35	0.79
81BK-838	32.78	32.56	25.22	3.98	2.38	1.05	0.29	0.34	0.28
80BK-469	27.90	31.26	25.39	4.72	3.21	2.30	1.30	1.98	0.32
81BK-839	30.31	41.19	20.25	2.38	1.87	1.07	0.43	0.85	0.44
81BK-840	26.09	37.11	22.93	4.75	2.21	3.62	0.58	1.04	0.46
81BK-343	22.44	33.04	22.17	8.30	2.40	4.88	0.58	2.66	0.65
80BK-154	33.20	33.33	23.69	2.82	2.96	1.98	0.29	0.40	0.32
81BK-841	32.83	35.40	24.29	2.96	1.91	1.03	0.58	0.65	0.32
81BK-842	29.10	41.60	22.17	2.11	2.40	1.10	0.00	0.47	0.32
80BK-574	31.77	34.39	25.39	3.14	2.42	1.63	0.00	0.49	0.35

<u>Legend</u>

Mln: Mylonite

Ngp: Nonacho Group: unmetamorphosed clastic sediments

Ksy: Konth intrusive suite: dominantly foliated megacrystic syenogranite

Smz: Slave intrusive suite: dominantly foliated coarse-grained monzogranite

Dgd: Deskenatlata intrusive suite: dominantly massive medium-grained granodiorite

D-Prg: Deskenatlata intruding abundant xenoliths of mainly granulite grade pelitic, quartzo-feldspathic and calcareous paragneiss and amphibolite

Prg: Paragneiss: granulite and amphibolite grade pelitic and subordinate quartzo-feldspathic paragneiss and minor volcanics

Hms: Hill Island Lake metasediments: mainly lower to sub-greenschist pelites and greywackes

Ggd: Gagnon Lake granodiorite

Cp: Granitic plutons intruding Churchill Province gneisses

Cgg: Churchill Province granitic gneisses

Cmg: Churchill Province mixed gneisses

- - - - - Asummed or defined geological contact

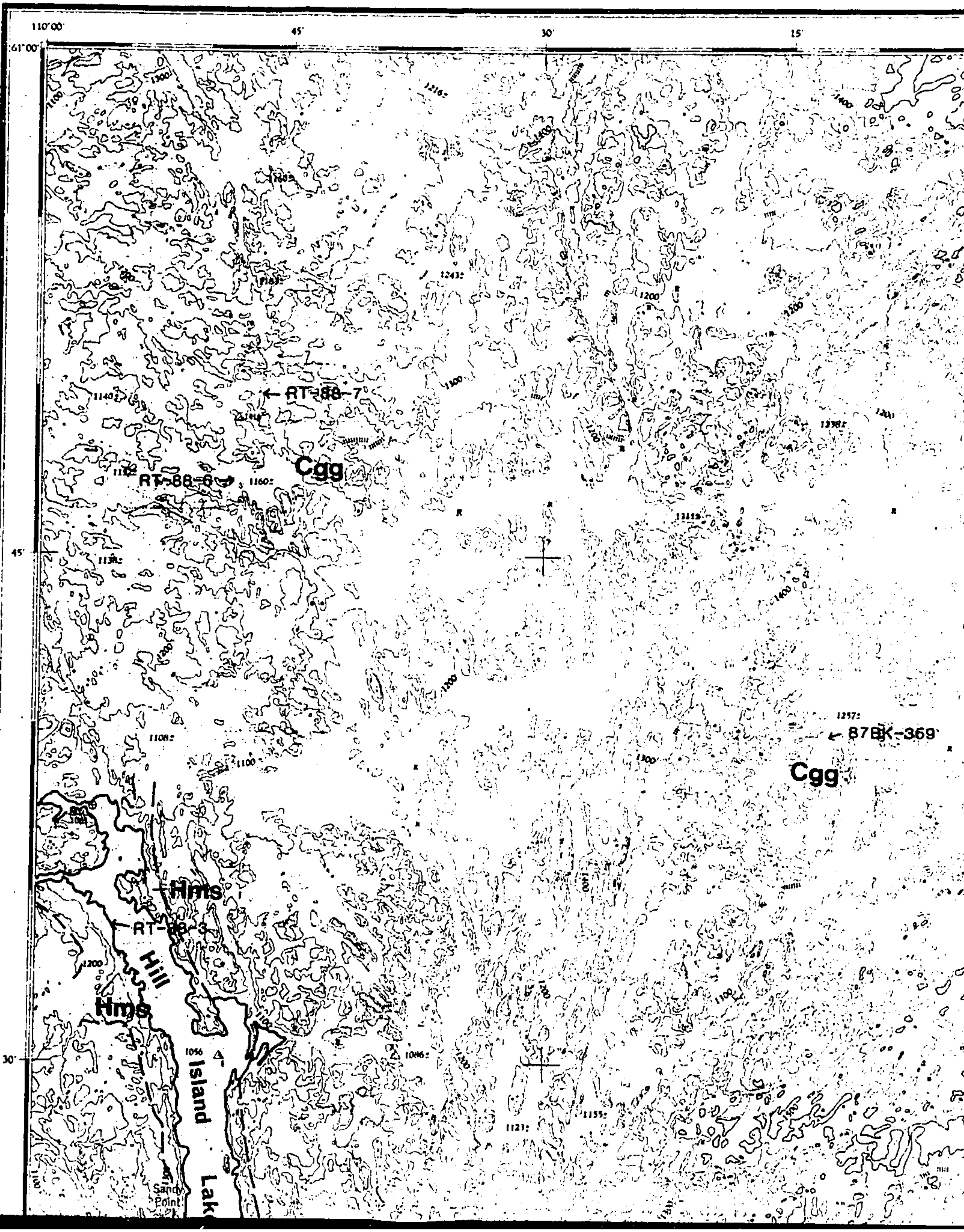
—·—·— Limit of exposed Precambrian rocks

.... Limit of unmapped Precambrian rocks

RT-88-1 Sample location

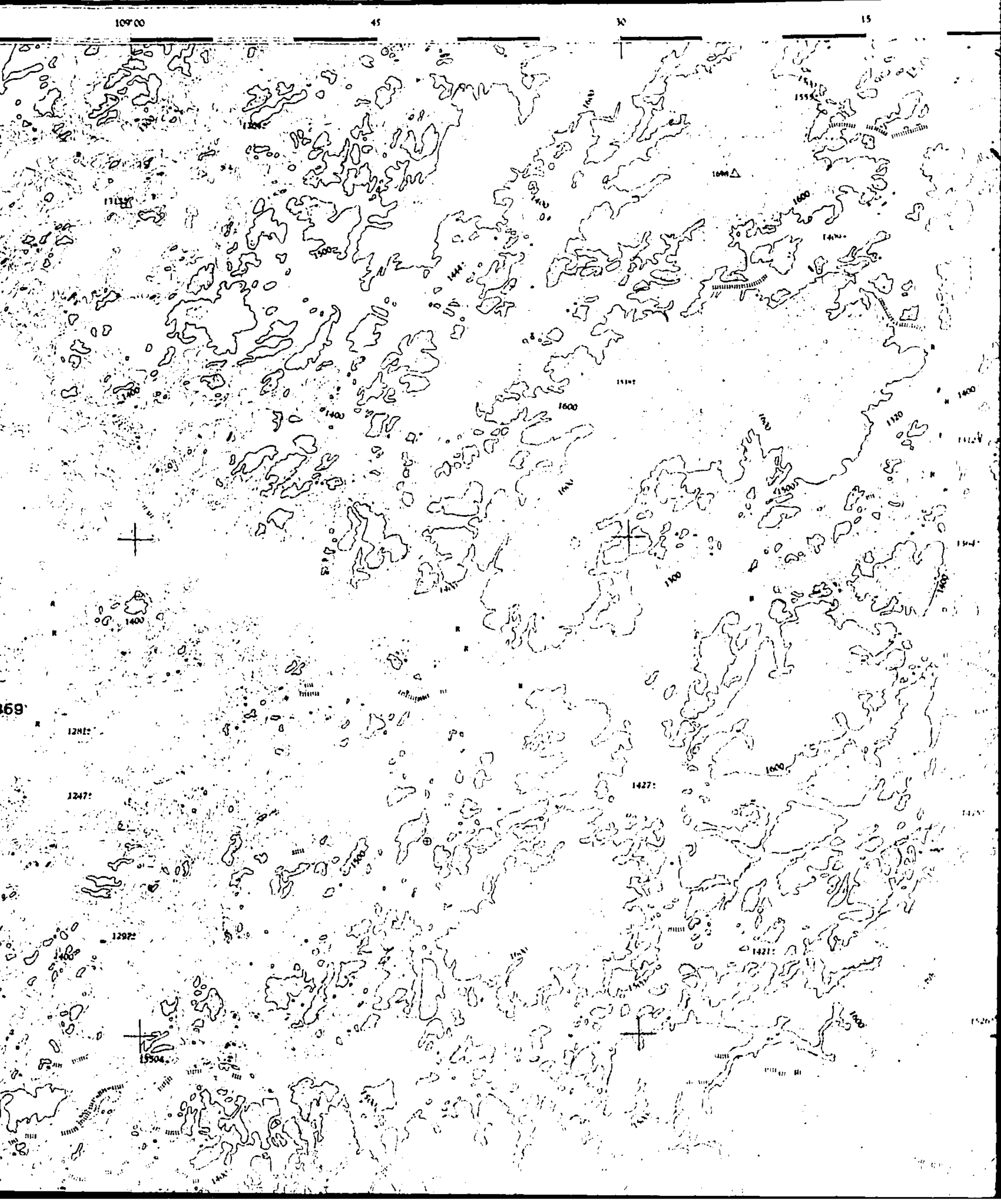
75 C

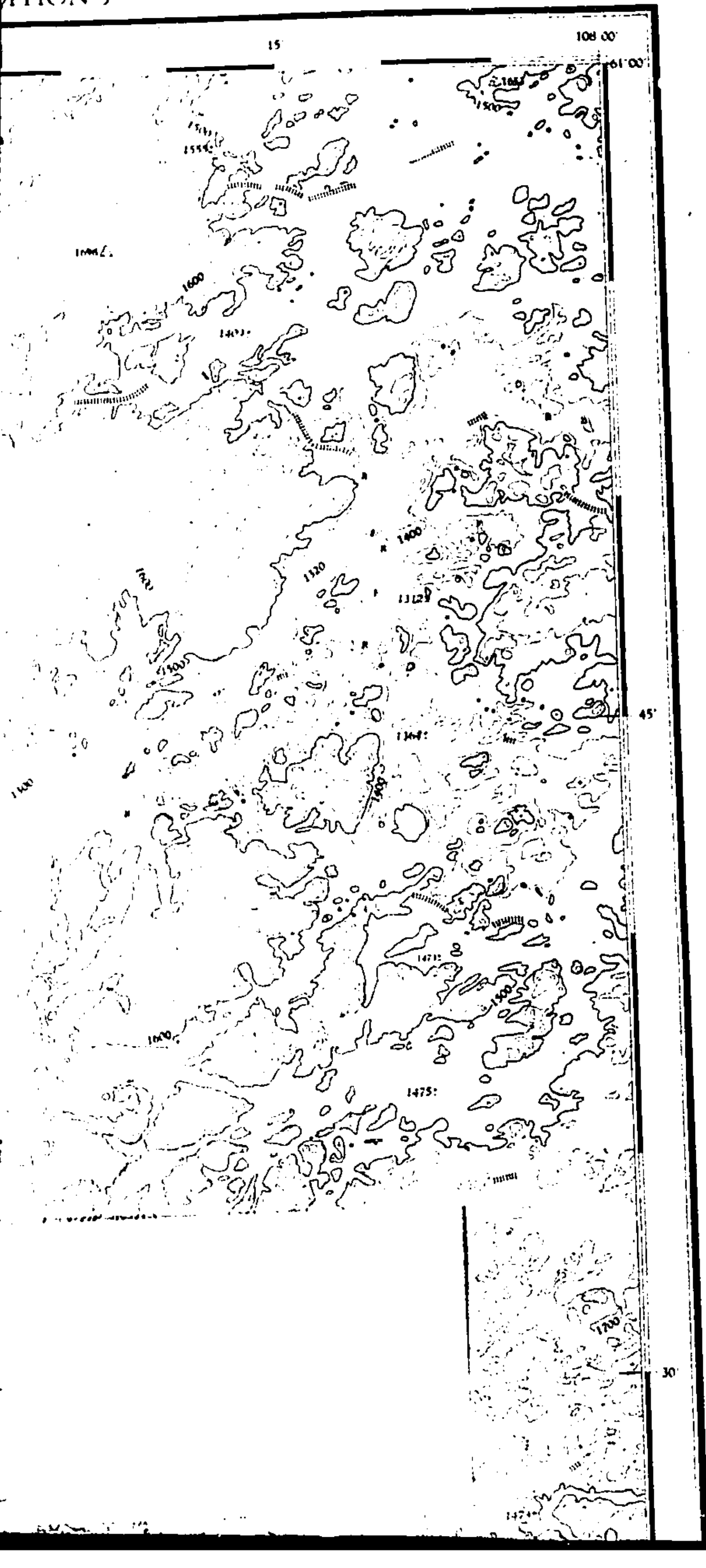
1:250,000

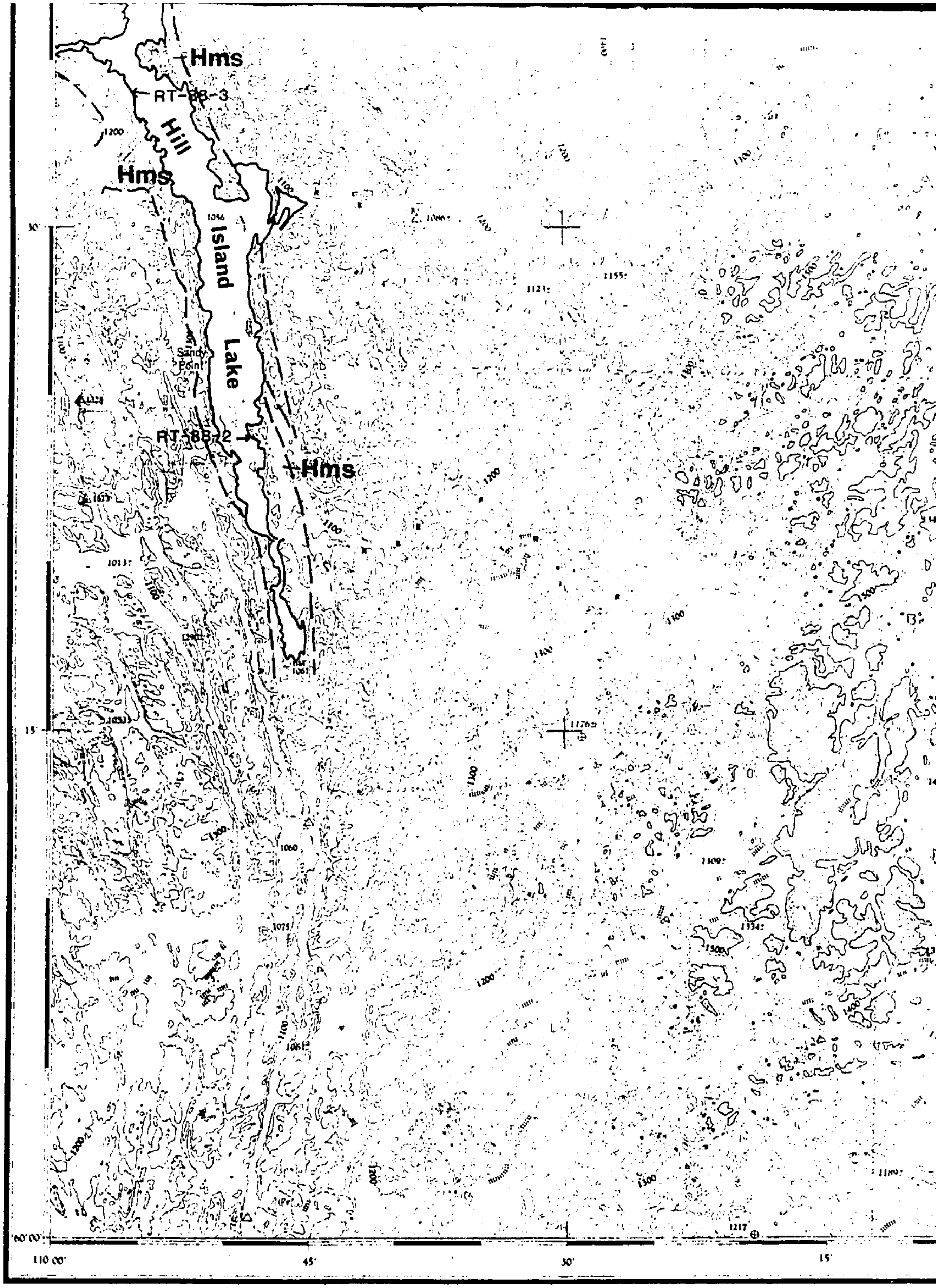

110°00'
45'
30'
15'
61°00'
RT-88-7
RT-88-6
Cgg
45'
87BK-369
Cgg
Hms
RT-88-3
Hill
Hms
30'
Island
Sandy Point

CANADA

EDITION 3




15'
108°00'
61°00'
1500
1600
1400
1320
1300
45'
1475
1700
30'

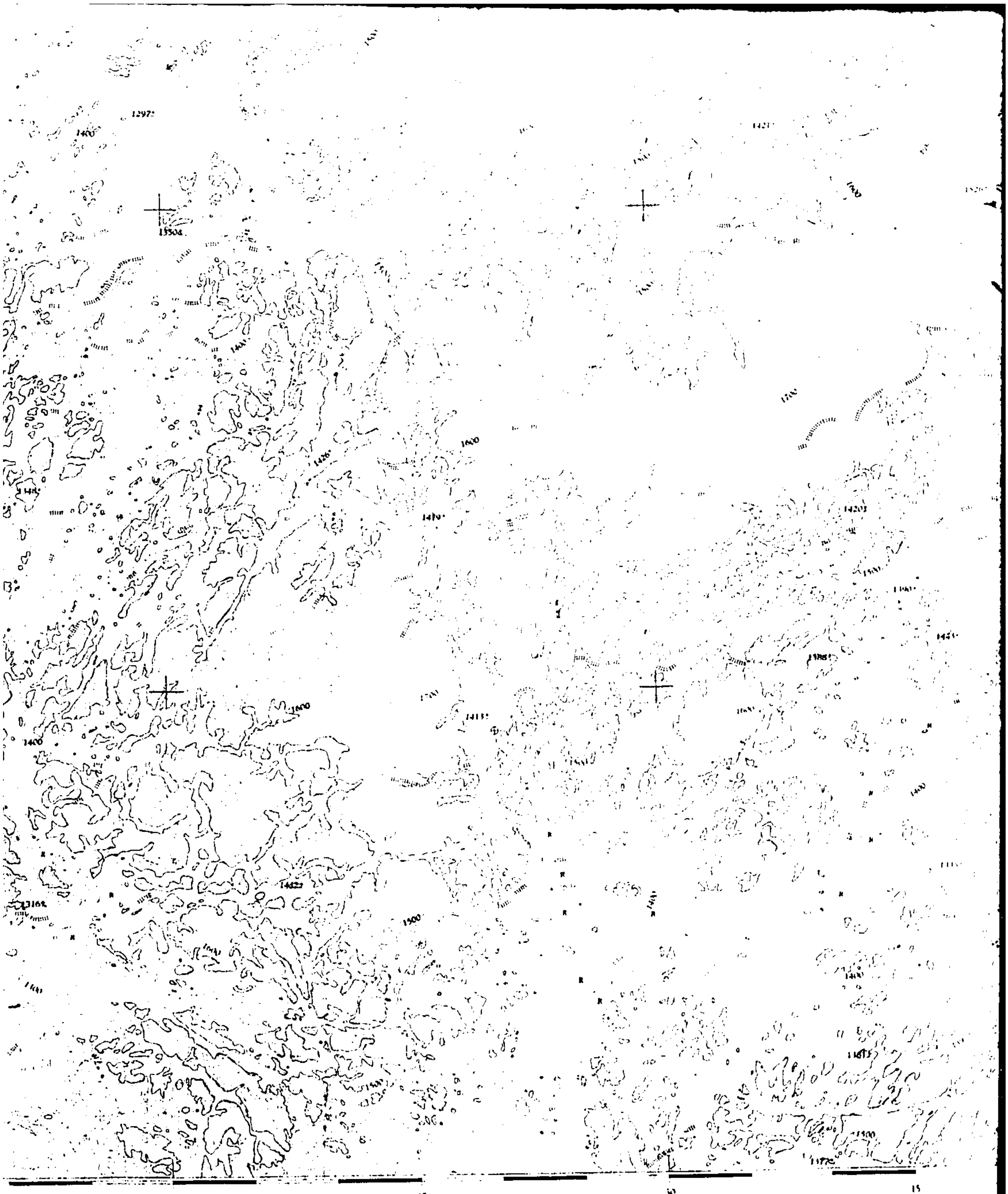


THE DECLINATION OF THE COMPASS NEEDLE 1962
DECLINAISON MAGNETIQUE EN 1962

Compiled 1959-60 by the ARMY SURVEY ESTABLISHMENT, R.C.E.
from air photographs taken in 1954-55
Printed 1963

Copies may be obtained from the Map Distribution Office

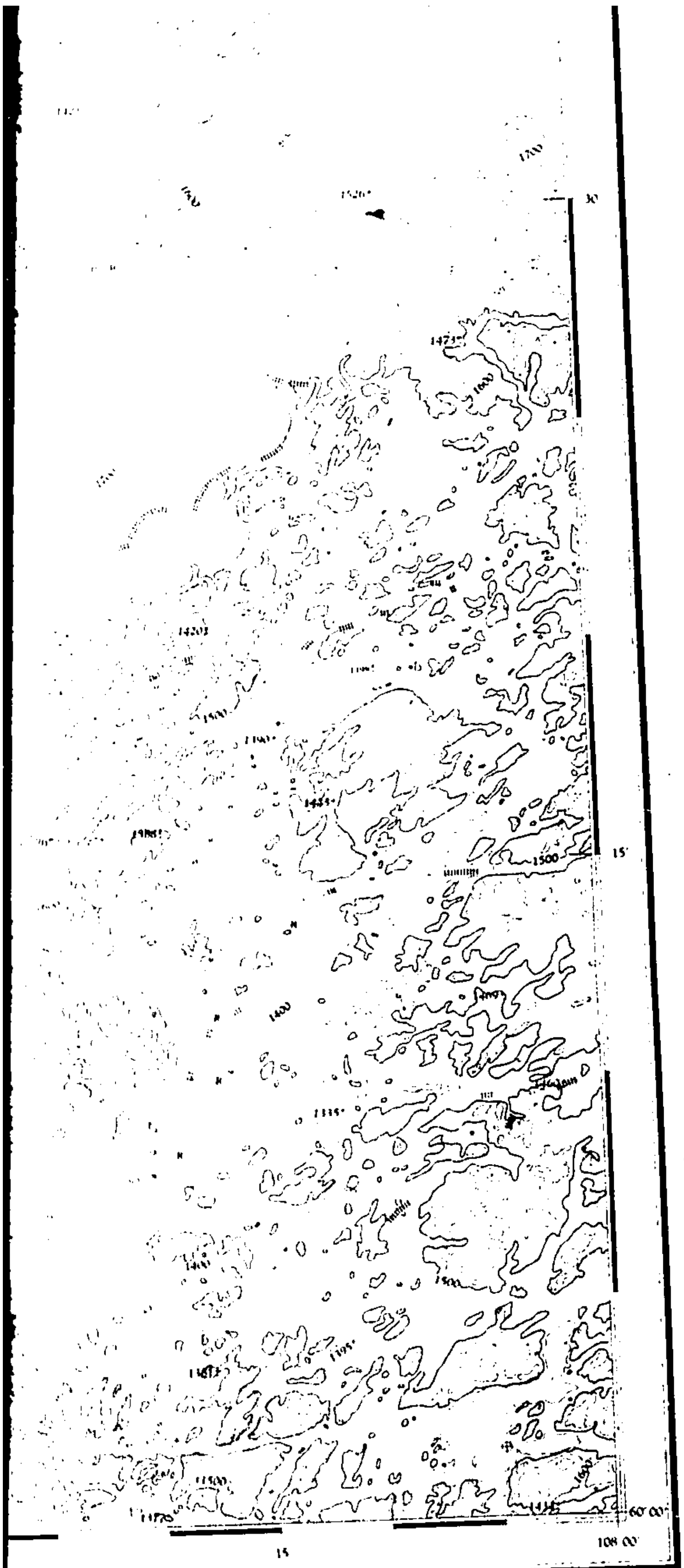
HIL



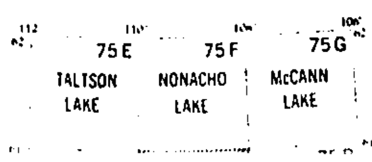
LL ISLAND LAKE

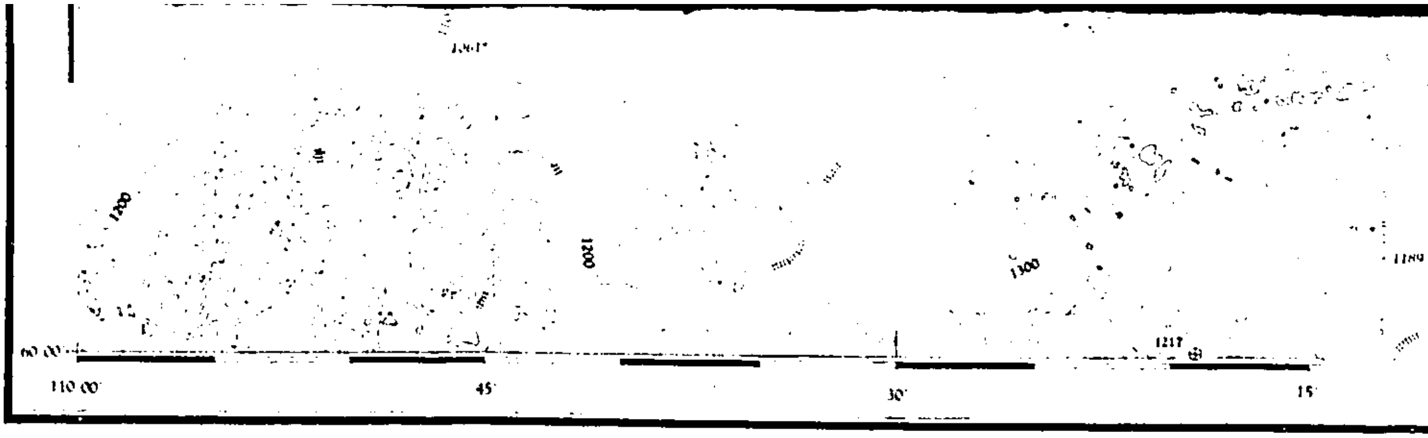
[illegible] SERVICE TOPOGRAPHIQUE DE L'ARMEE, (G.R.C.) [illegible]
[illegible] 1963

[illegible]

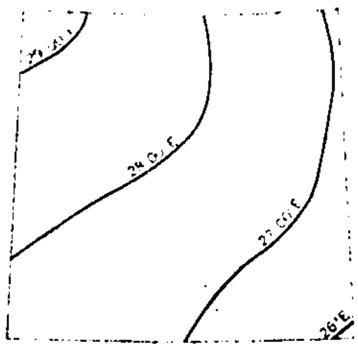


SERVICE TOPOGRAPHIQUE DE L'ARMÉE,





THE DECLINATION OF THE COMPASS NEEDLE 1962
DECLINAISON MAGNÉTIQUE EN 1962



The declination of the compass needle is decreasing 5 minutes annually
La déclinaison magnétique décroît de 5 minutes annuellement

Compiled 1959 ... the ARMY SURVEY ESTABLISHMENT, R.C.E.
from air photographs taken ...
Printed 1963

Copies may be obtained from the Map Distribution Office,
Department of Mines and Technical Surveys, Ottawa.

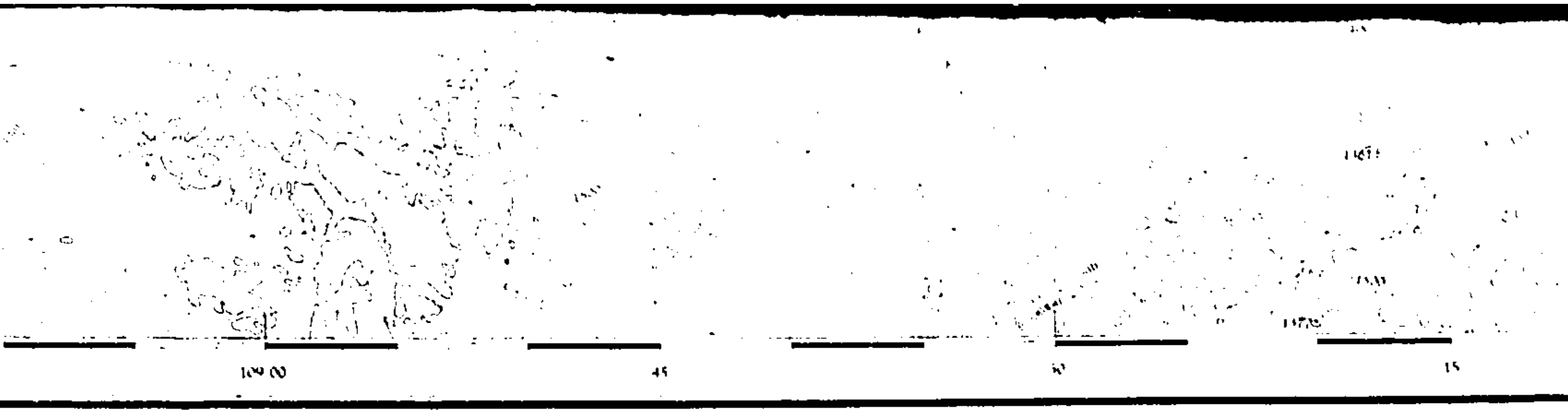
HI

Roads	Routes	
loose surface, all weather	de gravier, toute saison	less than 2 lanes / moins de 2 voies; dry weather / période sèche
cart track, trail	de terre, sentier	
Spot elevation, precise, approximate	Point coté, précis, approximatif	950 · 950±
Boundary monument	Borne frontière	
Pingo	Buttes de terre	
Depression contours	Courbes de cuvette	
Cliff or low relief	Falaise ou relief peu accentué	
Esker	Esker	

Miles 5 0

Kilometres 5 0

Transverse Merc...
North American ...
Contour Interv...
Elevations in feet abo...



LL ISLAND LAKE

DISTRICT OF MACKENZIE

NORTHWEST TERRITORIES

Scale 1:250,000 Échelle

5 10 15 20 **Milles**

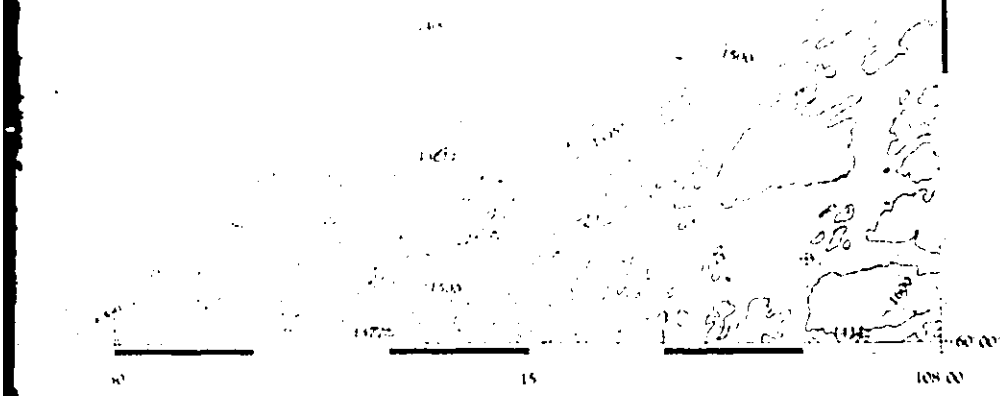
5 10 15 20 25 30 **Kilomètres**

...r Projection	Projection transverse de Mercator
...atum 1927	Réseau géodésique nord-américain unifié 1927
... 100 feet	Équidistance des courbes 100 pieds
...e Mean Sea Level	Élévations en pieds au dessus du niveau moyen de la mer

[illegible] **SERVICE TOPOGRAPHIQUE DE L'ARMEE, (G.R.C.)** [illegible] 1963

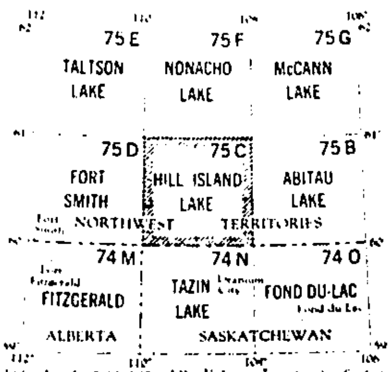
[illegible]

Building	Bâtiment	Intermittent stream	[illegible]
Post Office	Bureau de poste	Intermittent lake	[illegible]
Church	Église	Rapids; falls	Rapides; chute
School	École	Marsh or swamp	Marais ou marécage
Astronomical monument	Repère astronomique	String bogs	[illegible]
R.C.M.P. Detachment	Poste de la G.R.C.	Icefield or Glacier	Champ de glace [illegible]
Horizontal control point	Point géodésique	Tundra Polygons	Sols polygonaux
Landing ground	Piste d'atterrissage	Tundra Ponds	Étangs de toundra



SERVICE TOPOGRAPHIQUE DE L'ARMEE,

Bureau de poste	Intermittent stream	Cours d'eau intermittent
	Intermittent lake	Lac intermittent
	Rapids, falls	Rapides, chute
	Marsh or swamp	Marais ou marécage
Repère astronomique	String bogs	Marais en chapelet
Piste de la G.R.C.	Icefield or Glacier	Champ de glace ou glacier
Point géodésique	Tundra Polygons	Sols polygonaux
Piste d'atterrissage	Tundra Ponds	Étangs de toundra



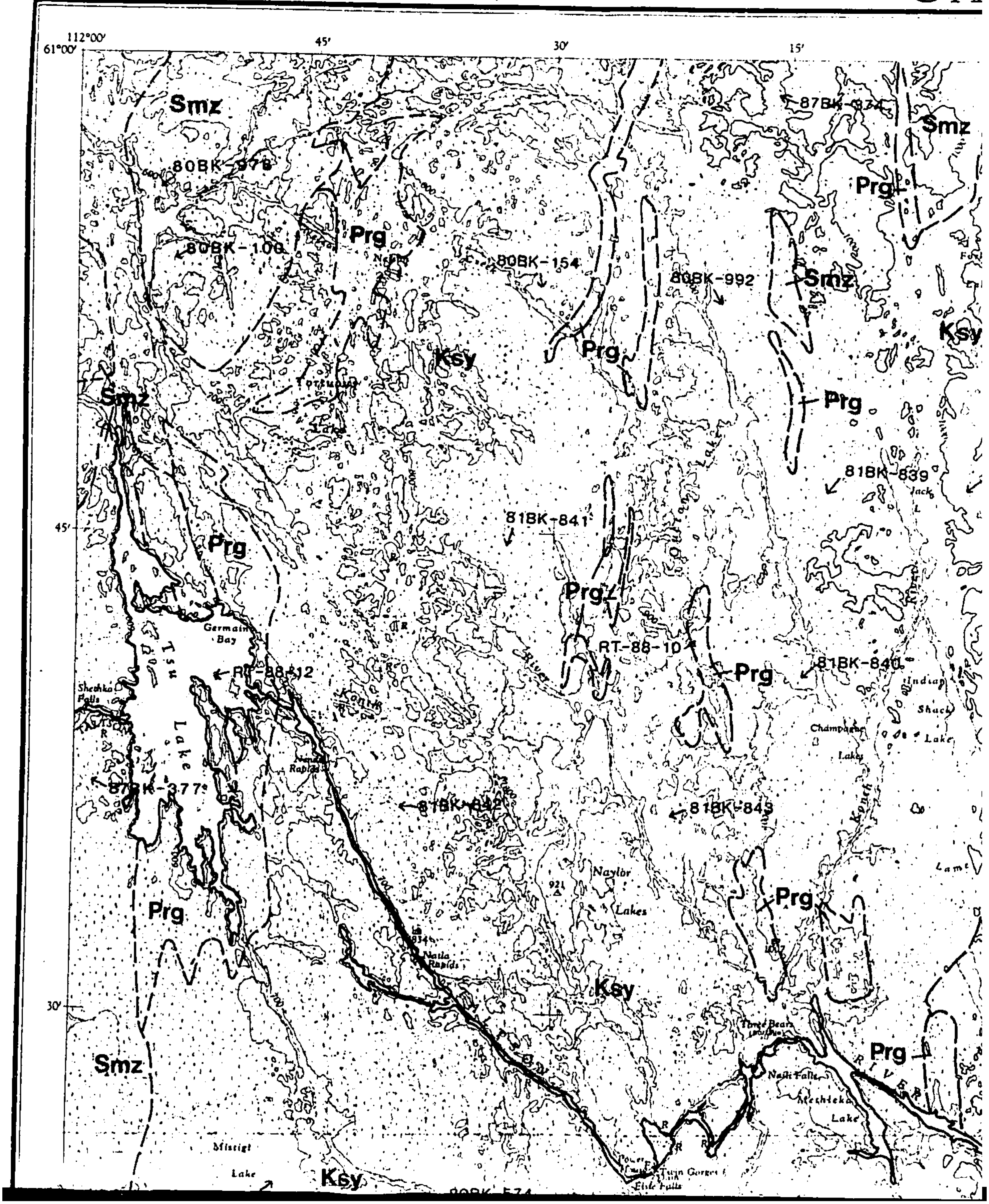
Index to adjoining maps of the National Topographic System
Tableau d'assemblage du Système National de Référence Cartographique

HILL ISLAND LAKE
75 C
EDITION 3

75 D

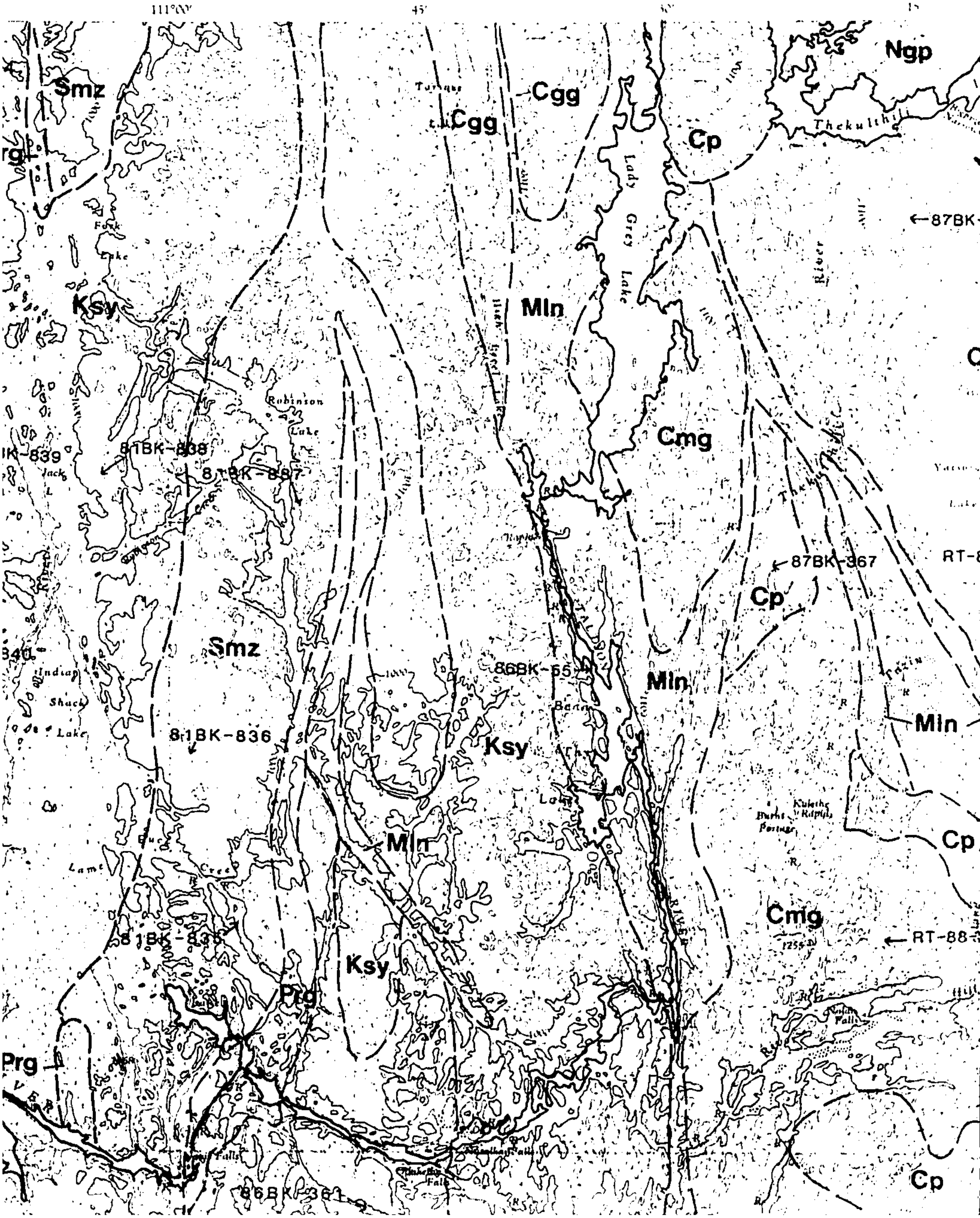
1:250,000

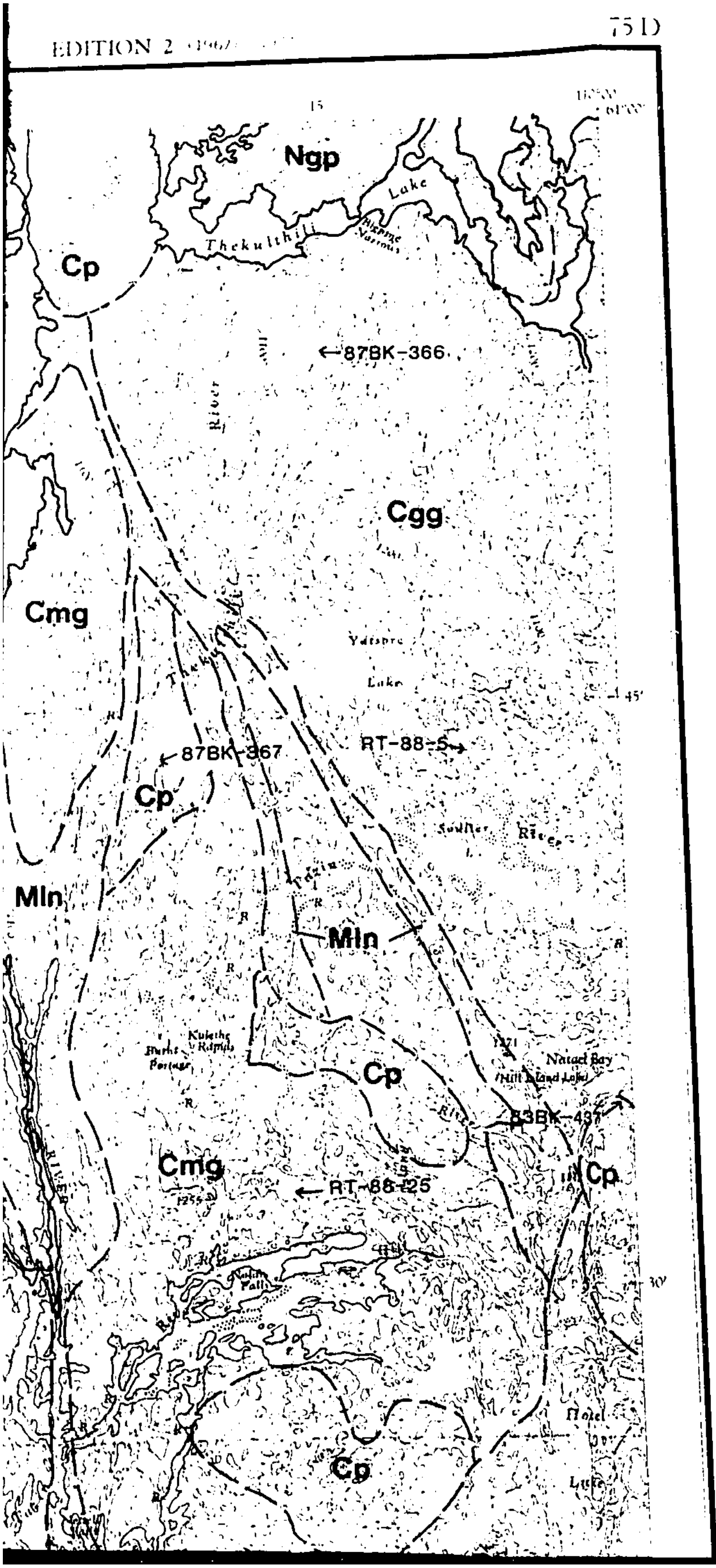
CA



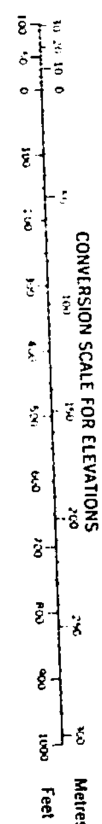
CANADA

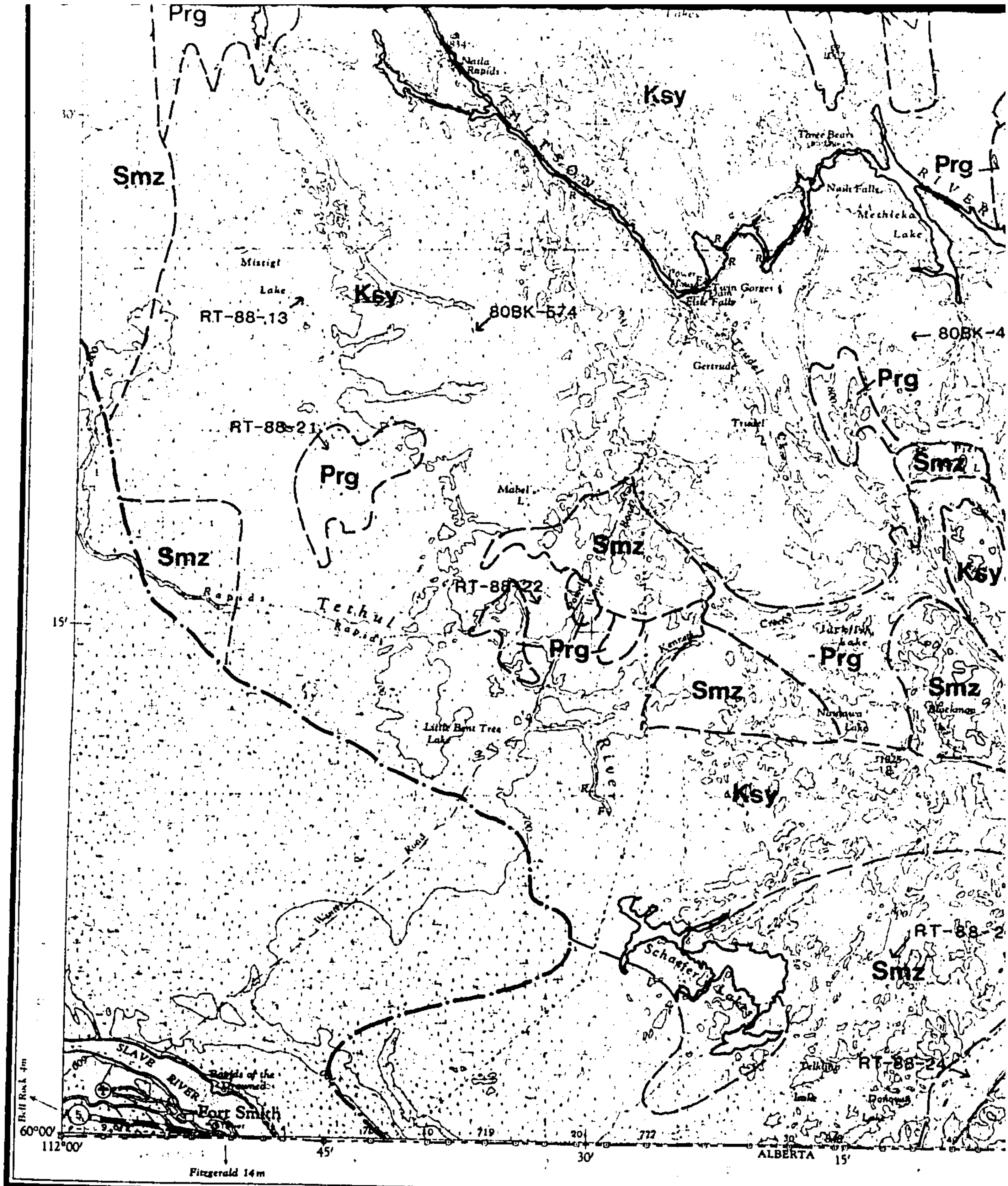
EDITION 2 (1967)





Refer to this map as 75 D EDITION 2 MCE SERIES A 502 (1967)





Compiled, 1960-61, by the SURVEYS AND MAPPING BRANCH, DEPARTMENT OF MINES AND TECHNICAL SURVEYS, from air photographs taken in 1955. Field surveys 1957. Printed 1962.

Copies may be obtained from the Map Distribution Office, Department of Mines and Technical Surveys, Ottawa.

Road, loose or stabilized surface, all weather . . . . Route, gravier aggloméré, toute saison . . 2 lanes or more

Power transmission line . . . . Ligne de transport d'énergie . . . . 2 voies ou plus

Transverse Mercator Projection
North American Datum 1927 (1956)
Contour Interval 100 feet
Elevations in feet above Mean Sea Level
Magnetic declination 28°36' East at centre of map 1962
Annual change (decreasing) 5.6'

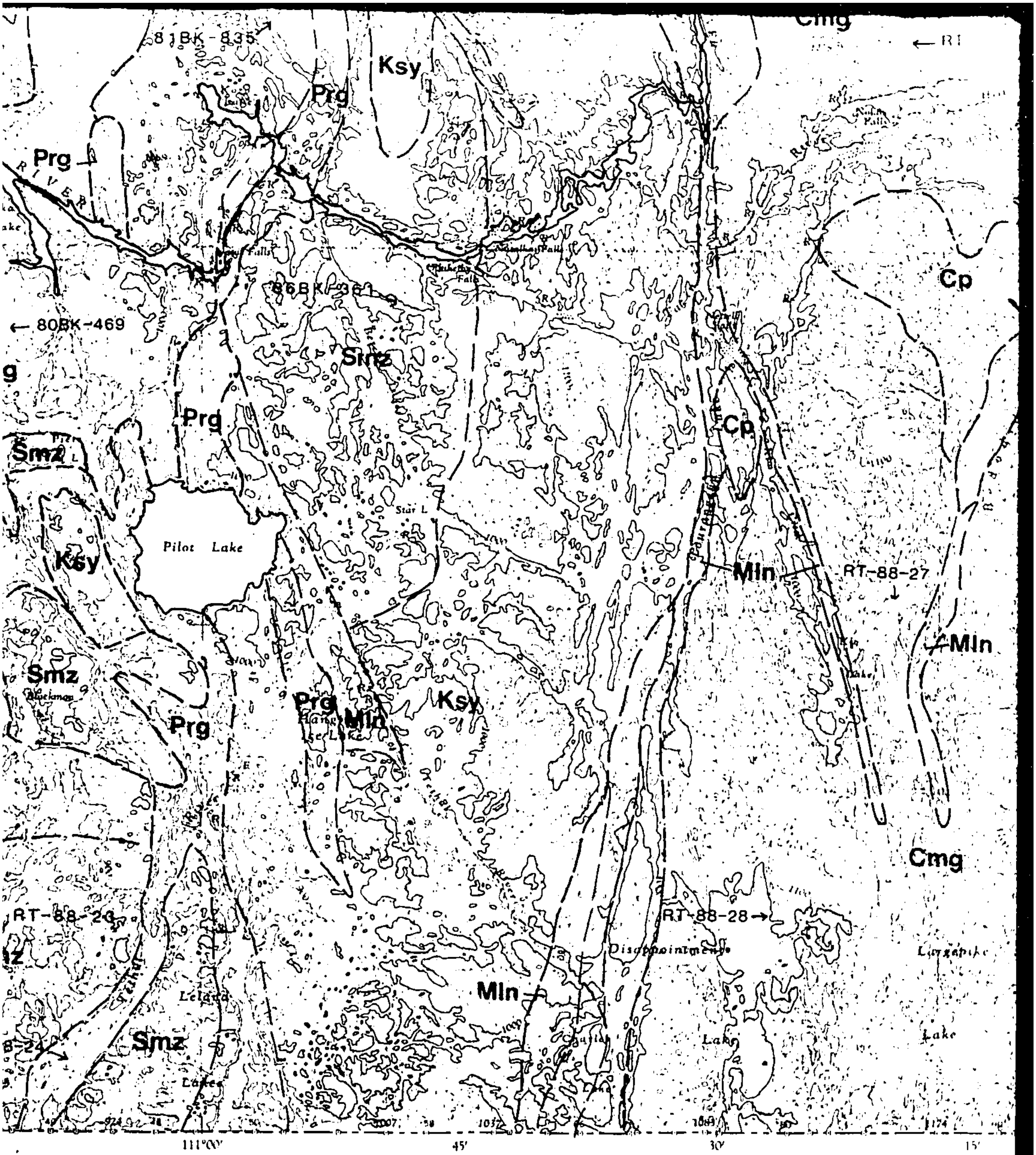
Interim corrections 1967.

Interim corrections 1977

FO

NOR

DI



FORT SMITH

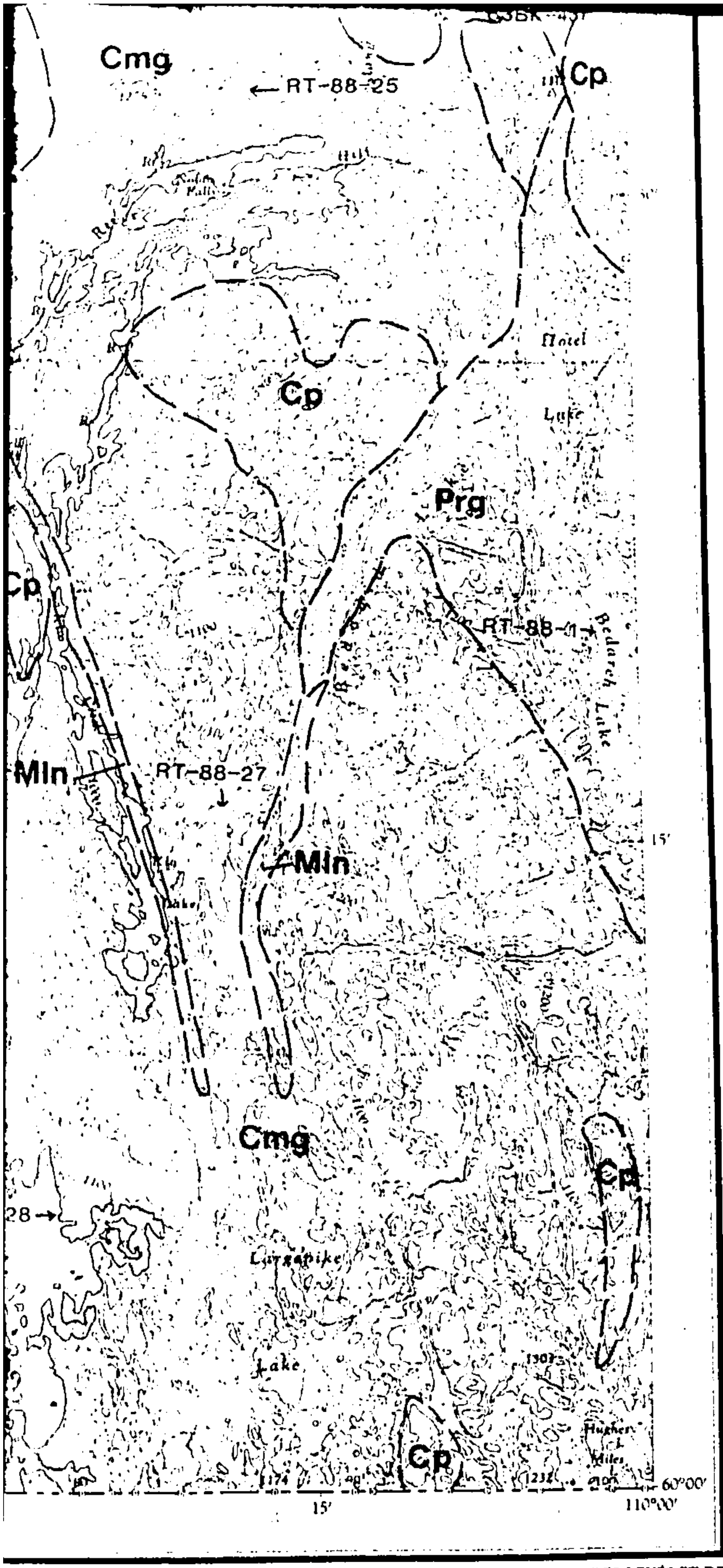
NORTHWEST TERRITORIES

DISTRICT OF MACKENZIE

Scale 1:250,000 Échelle

Corrections provisoires 1967.

Corrections Provisoires, 1977



STREAM JUNCTION

VC

VC 9715

12VVC9715

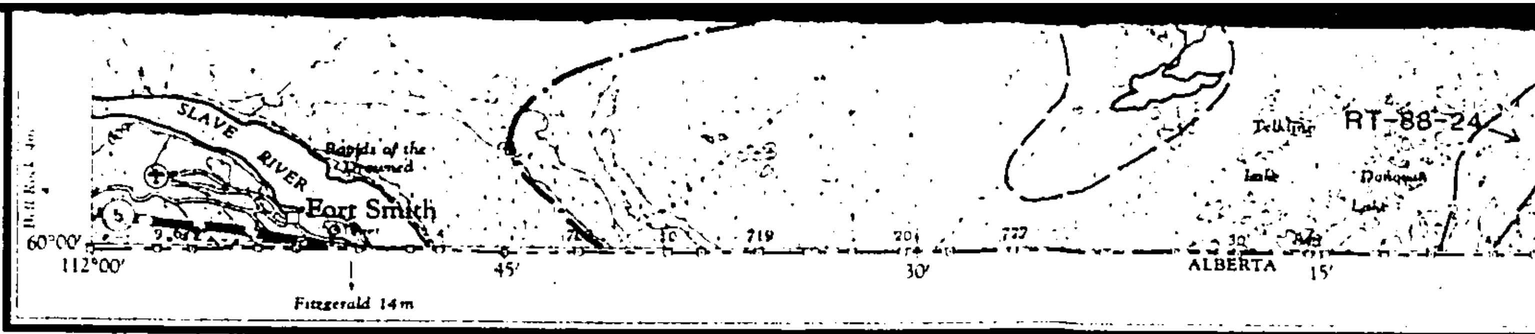
TEN THOUSAND METRE
UNIVERSAL TRANSVERSE MERCATOR GRID
ZONE 12

Rédigée en 1960-61, par la DIRECTION DES LEVÉS ET DE LA CARTOGRAPHIE, MINISTÈRE DES MINES ET DES RELEVÉS TECHNIQUES, d'après les photographies ... en 1959. Travaux exécutés sur le terrain en 19... Imprimée en 1967.

67.

Ces cartes sont en vente au Bureau ... cartes, ministère des Mines et des Relevés techniques, Ottawa.

177



Compiled, 1960-61, by the SURVEYS AND MAPPING BRANCH, DEPARTMENT OF MINES AND TECHNICAL SURVEYS, from air photographs taken in 1955. Field surveys 1957. Printed 1962.

Copies may be obtained from the Map Distribution Office, Department of Mines and Technical Surveys, Ottawa.

Transverse Mercator Projection
North American Datum 1927 (1956)
Contour Interval 100 feet
Elevations in feet above Mean Sea Level
Magnetic declination 28°36' East at centre of map 1967
Annual change (decreasing) 5.6'

Interim corrections 1967.

Interim corrections 1977

Road, loose or stabilized surface, all weather ....Route, gravier aggloméré, toute saison .. 2 lanes or more / 2 voies ou plus

Power transmission line.......... Ligne de transport d'énergie ....

[illegible]	Chemin, toute saison	
[illegible]	Chemin de terre ou d'hiver	
[illegible]	Sentier ou portage	
Town	Ville	□
[illegible]	Village ou hameau	o
Post office	Bureau de poste	P
Building	Bâtiment	•

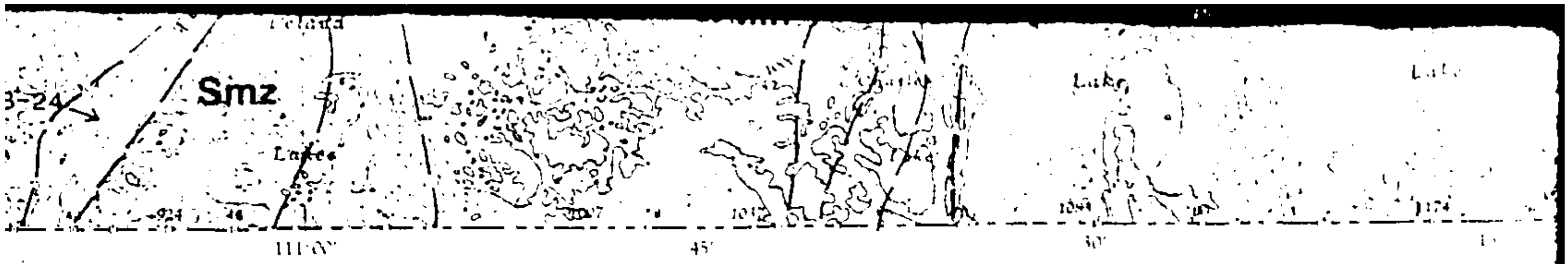
Miles 5

Kilometres 5

N

PROVISIONAL MA

Some names on this map are not yet official. Corrections or additions are invited by the Surveys and Mapping Branch.



FORT SMITH

NORTHWEST TERRITORIES

DISTRICT OF MACKENZIE

Scale 1:250,000 Échelle

Corrections provisoires 1967.

Corrections Provisoires 1977

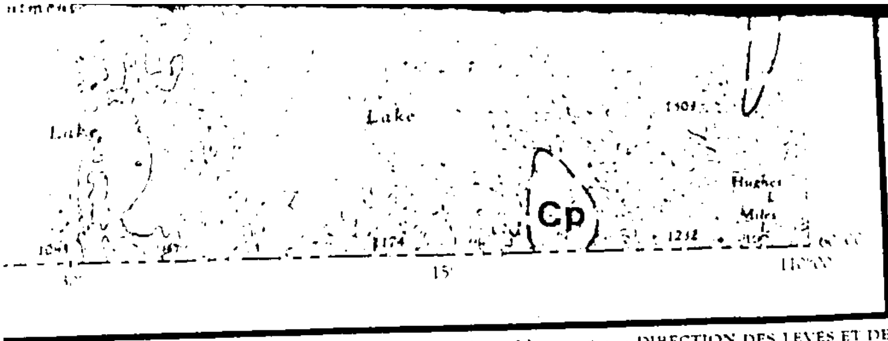
Boundary monument — Borne frontière

Marsh or swamp

Surveyed line — Ligne arpentée

AL MAP

CARTE PROVISOIRE



TEN THOUSAND METRE

ZONE 12

... DIRECTION DES LEVÉS ET DE LA CARTOGRAPHIE, MINISTÈRE DES MINES ET DES RELEVÉS TECHNIQUES.

...soires 1967.

...soires 1977

		△
Boundary monument	Borne frontière	○
	Repère de nivellement en pieds	2550
	Rapides, chutes	
... swamp	Marais ou marécage	
	Courbes de cuvette	
Surveyed line	Ligne arpentée	

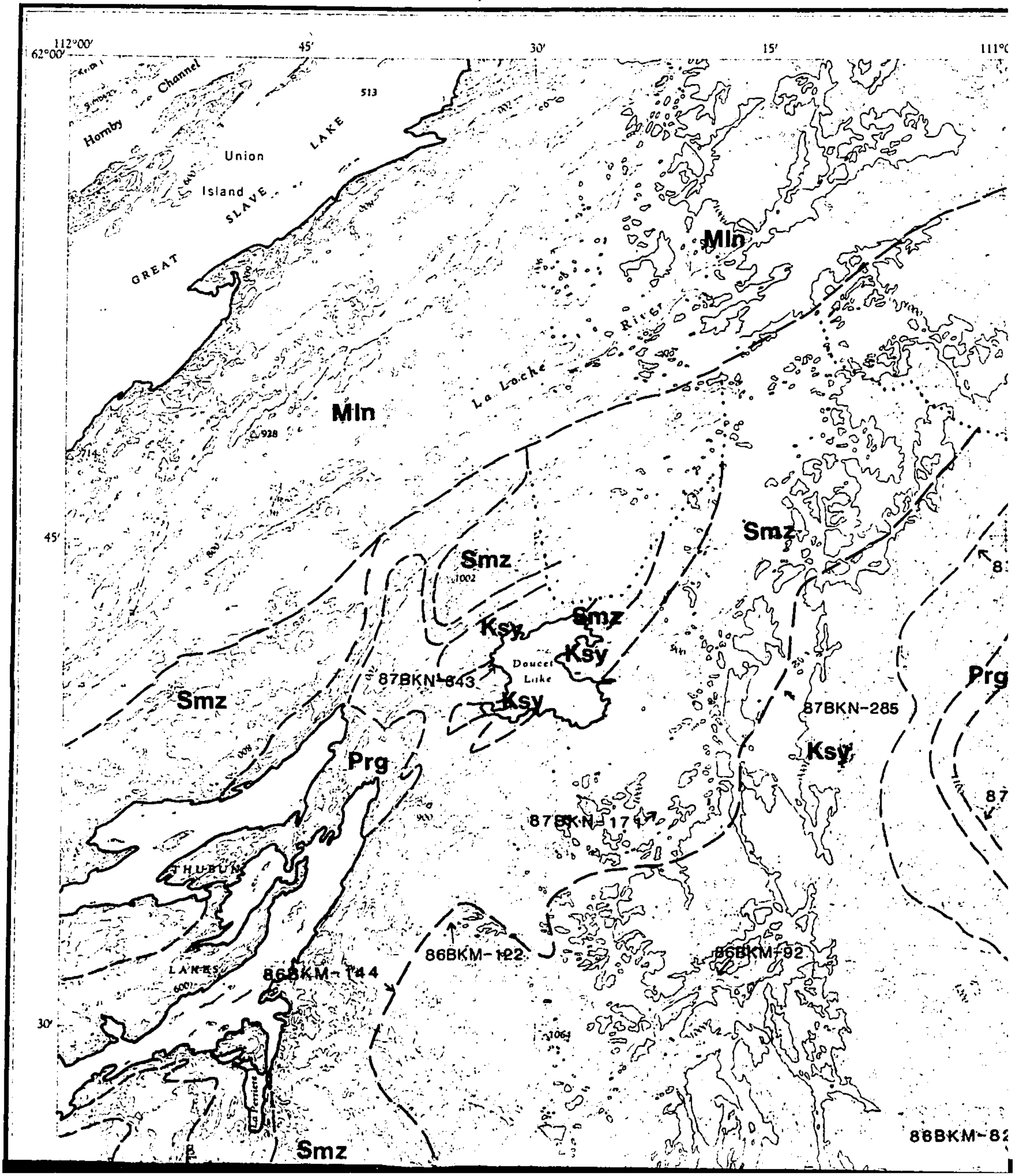
FORT SMITH
75 D
EDITION 2 (1967)

(1977

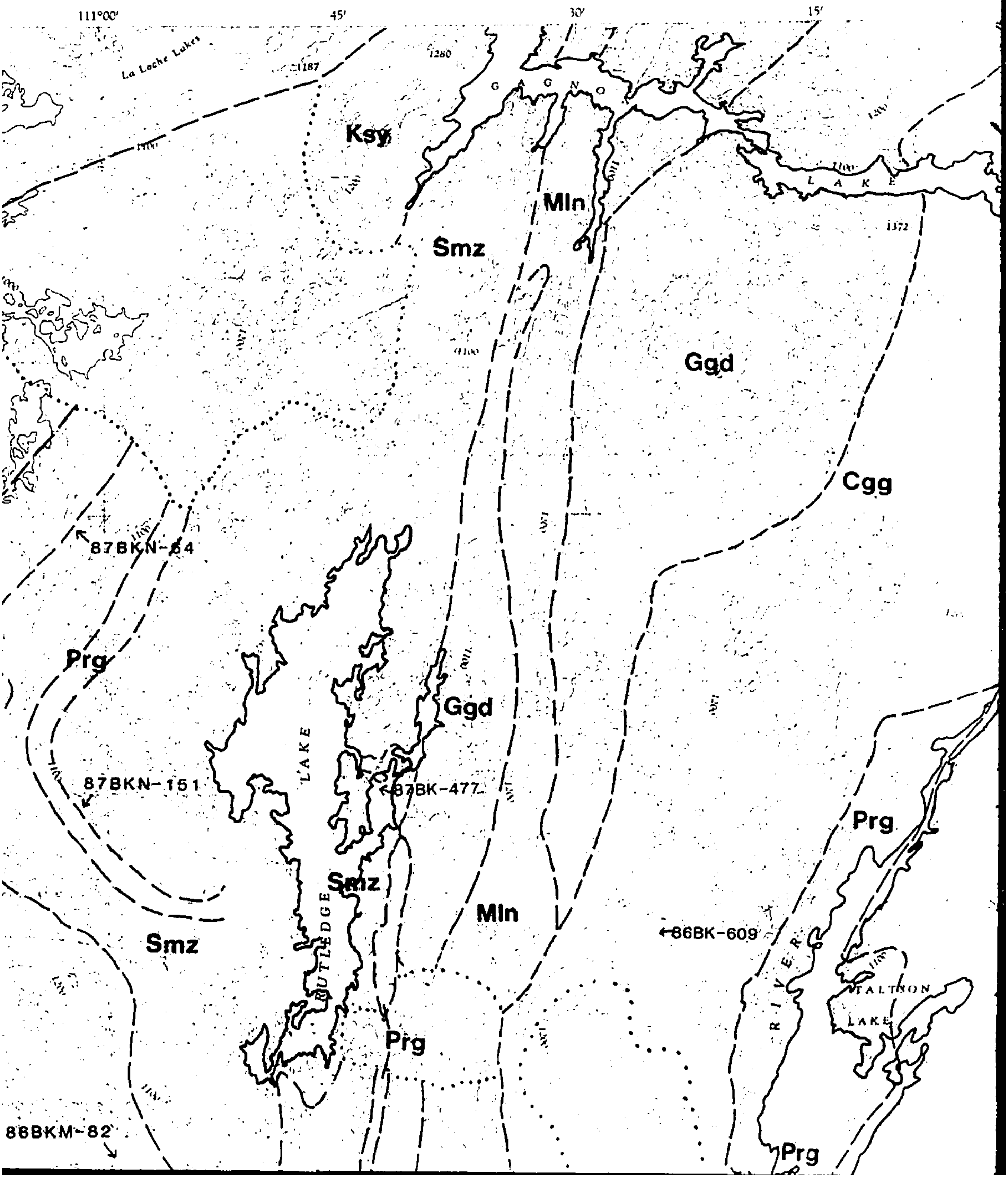
75 E

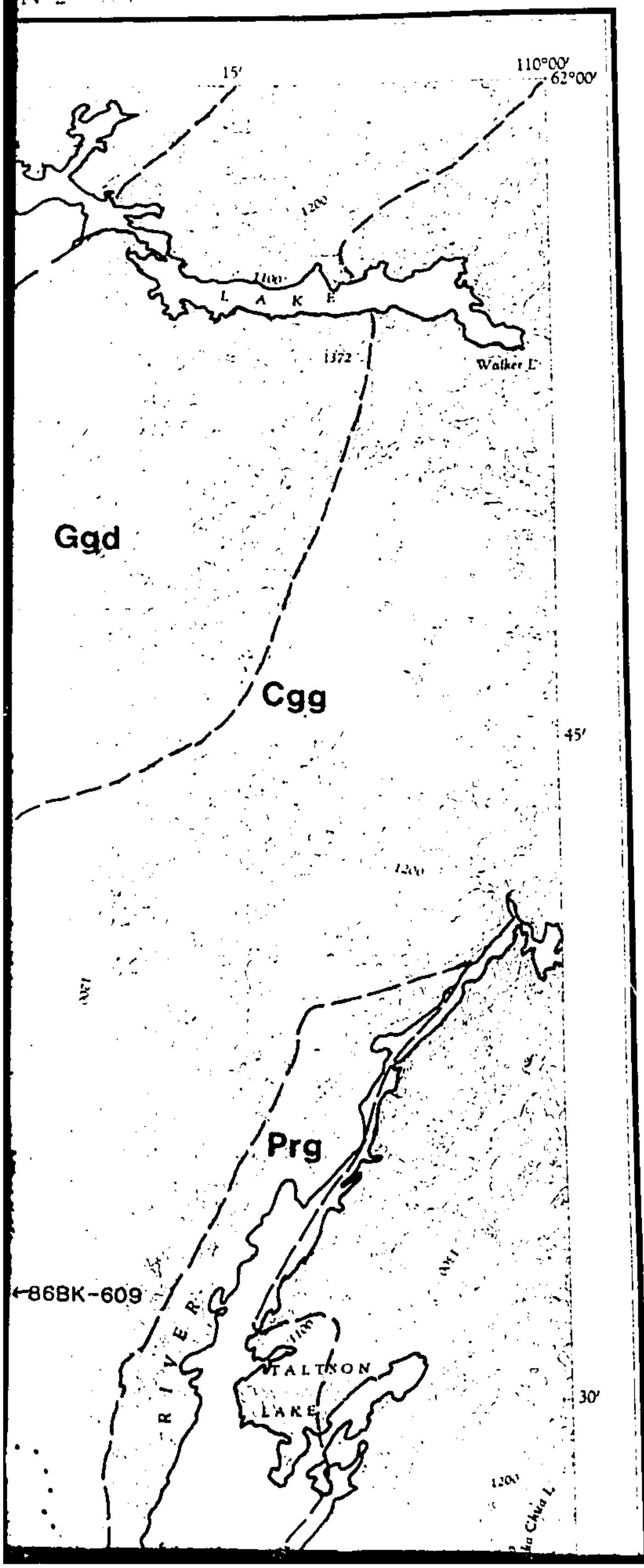
1:250,000

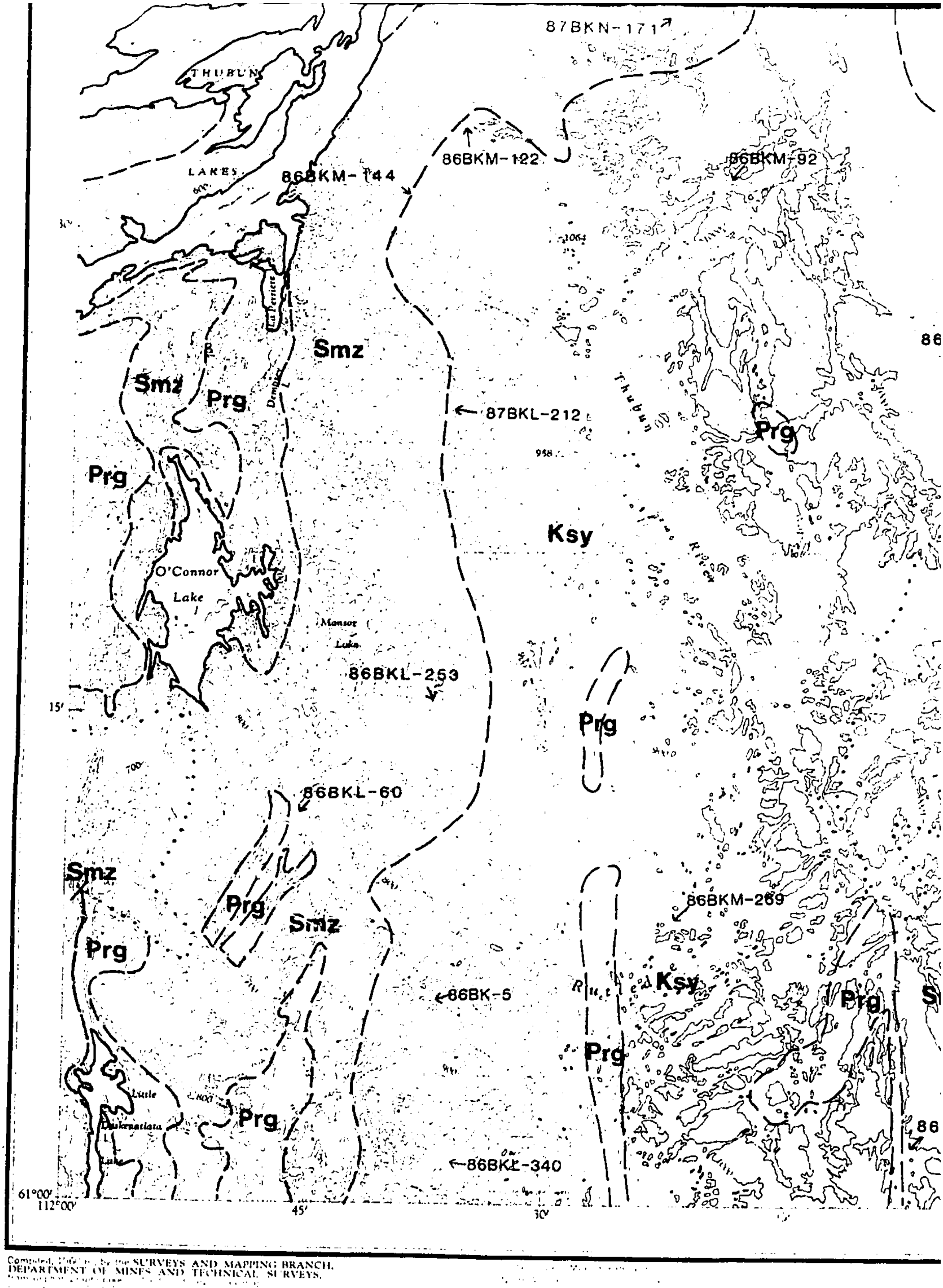
CAN



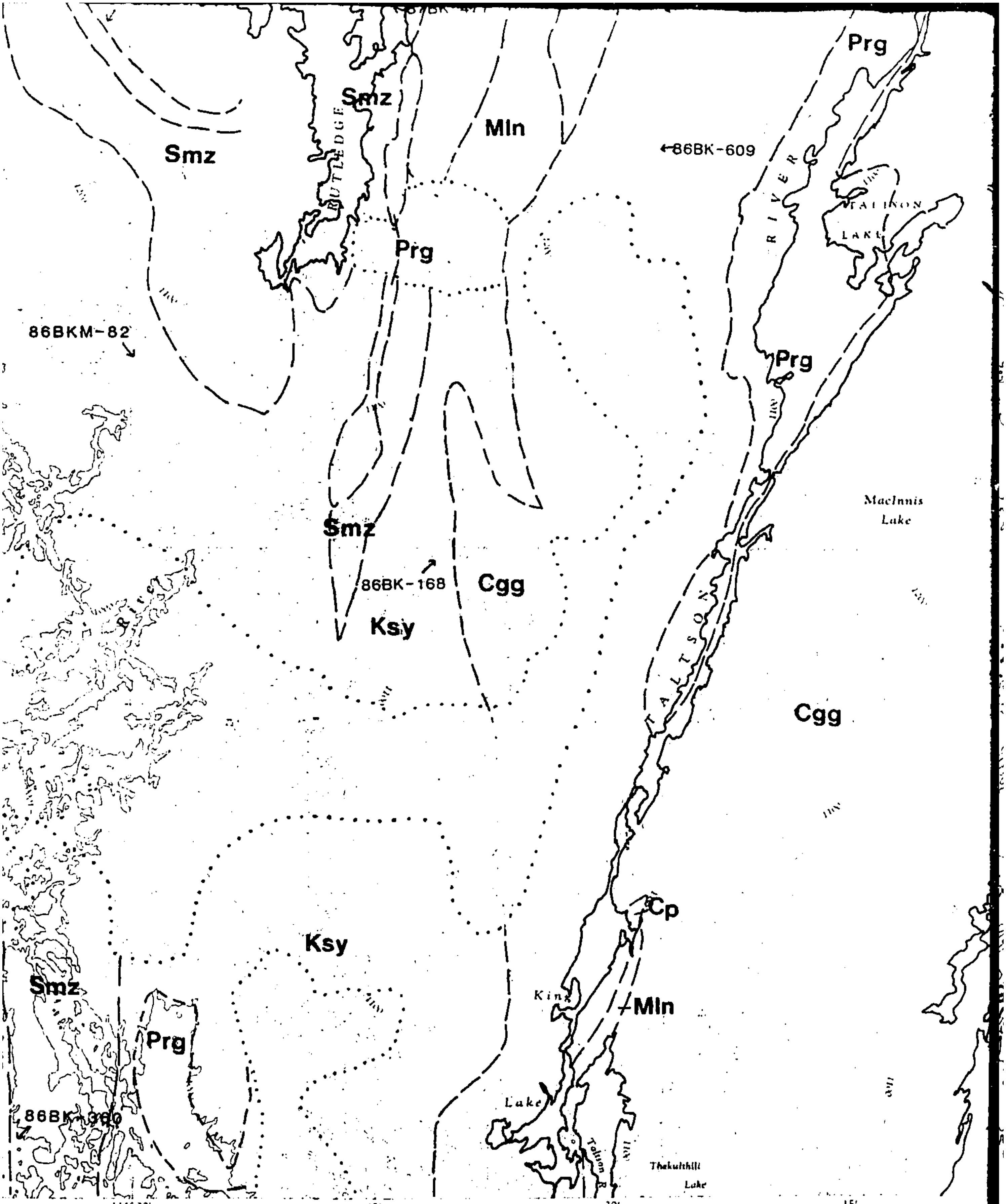
CANADA EDITION 2



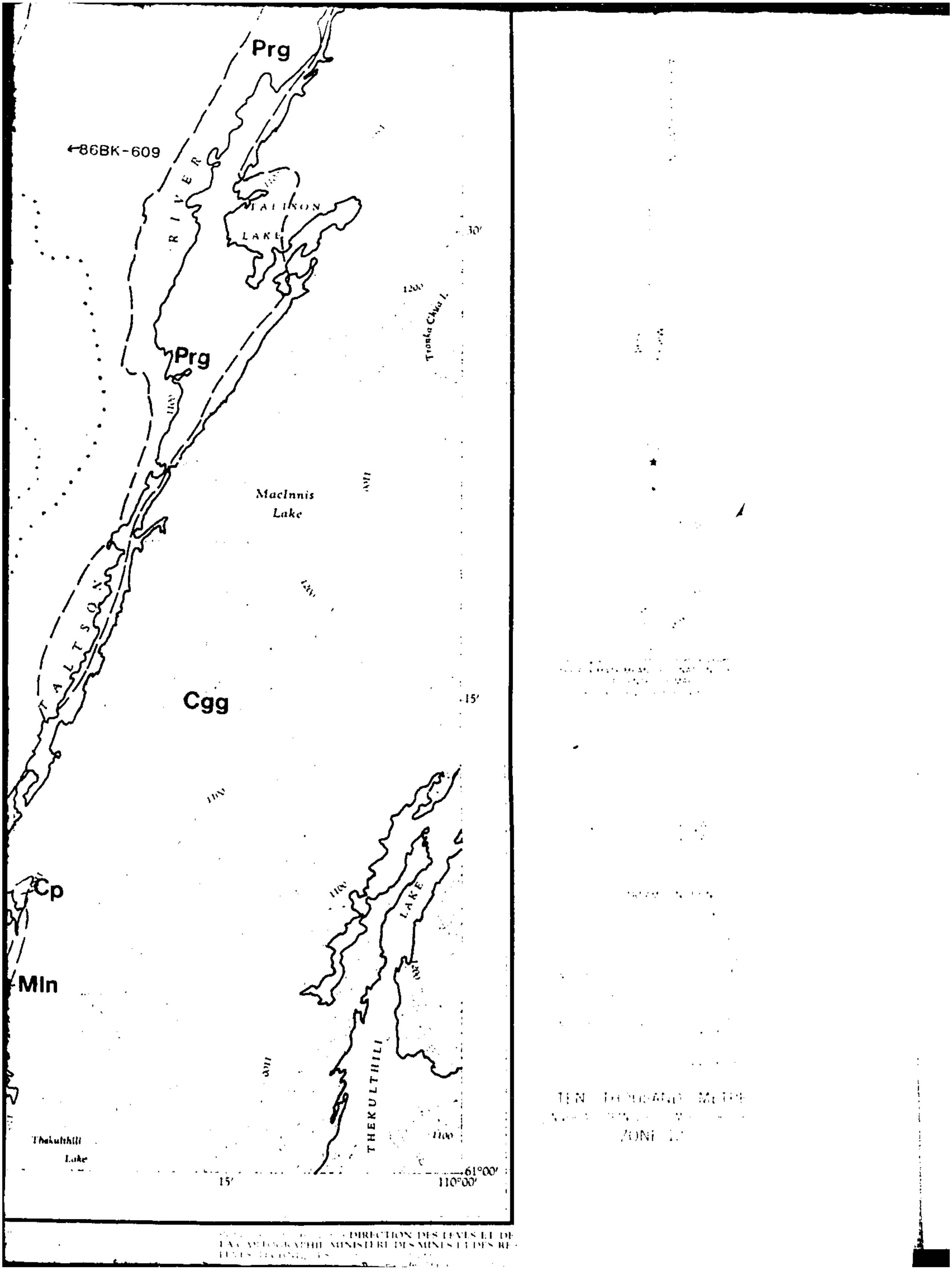

15'
110°00'
62°00'
1200
1100
L A K E
1372
Walker L.
Ggd
Cgg
45'
1200
Prg
←86BK-609
R I V E R
TALTSON
LAKE
30'
1200

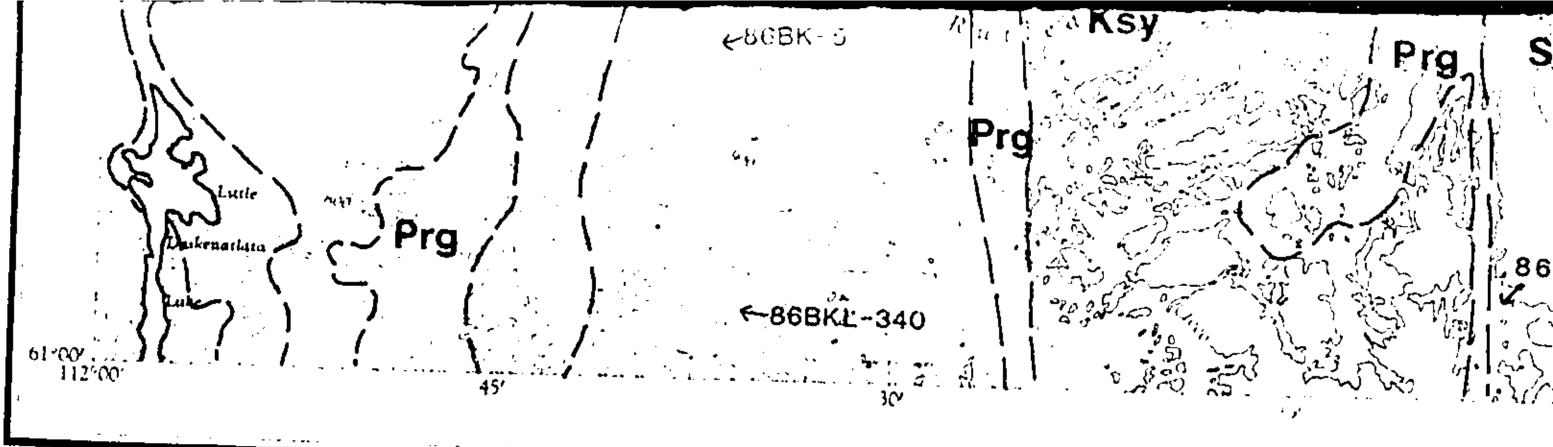


Compiled ... by the SURVEYS AND MAPPING BRANCH,
DEPARTMENT OF MINES AND TECHNICAL SURVEYS.


Prg
Smz
RUTLEDGE
Mln
86BK-609
Smz
RIVER
TALTSON
LAKE
Prg
86BKM-82
Prg
Smz
86BK-168
Cgg
Ksy
MacInnis
Lake
TALTSON
Cgg
Cp
Ksy
Smz
King
Mln
Prg
86BK-360
Lake
Taltson R.
Thekulthili
Lake
111°00'
45'
30'
15'

ALTSON LAKE


Prg
86BK-609
RIVER
LAKE
Prg
MacInnis Lake
TALTSON
Cgg
Cp
Mln
LAKE
THEKULTHILI
Thekulthili Lake
30'
15'
61°00'
15'
110°00'



Compiled ... by the SURVEYS AND MAPPING BRANCH,
DEPARTMENT OF MINES AND TECHNICAL SURVEYS,

Copies may be obtained from the Map Distribution Office,
Department of Mines and Technical Surveys, Ottawa

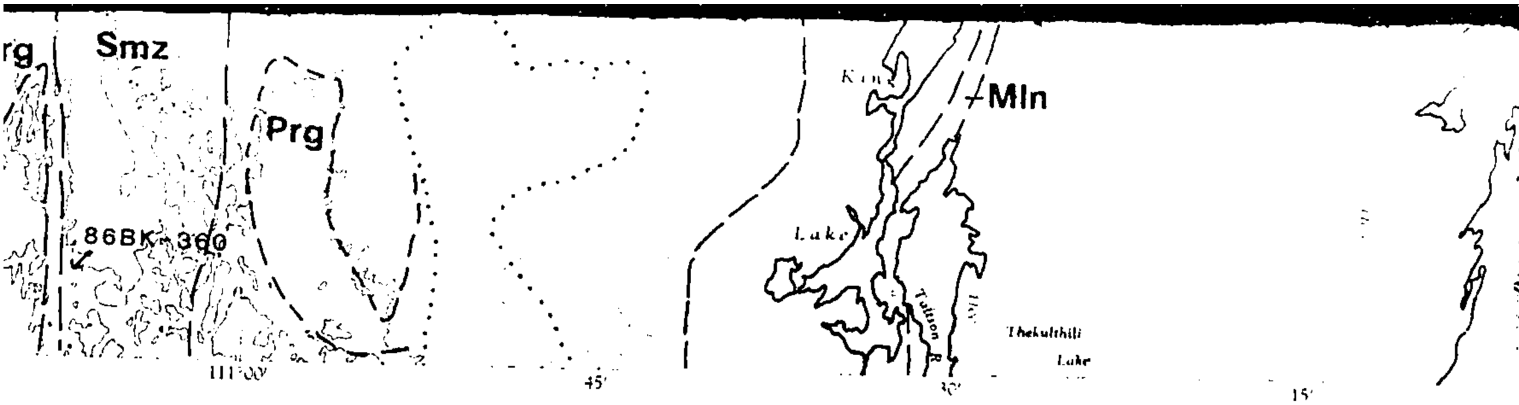
TAL

NORT

DIST

PROVISIONAL M

Some names on this map are not yet ...
Corrections or additions are invited by ...
veys and Mapping Branch



TALTSON LAKE

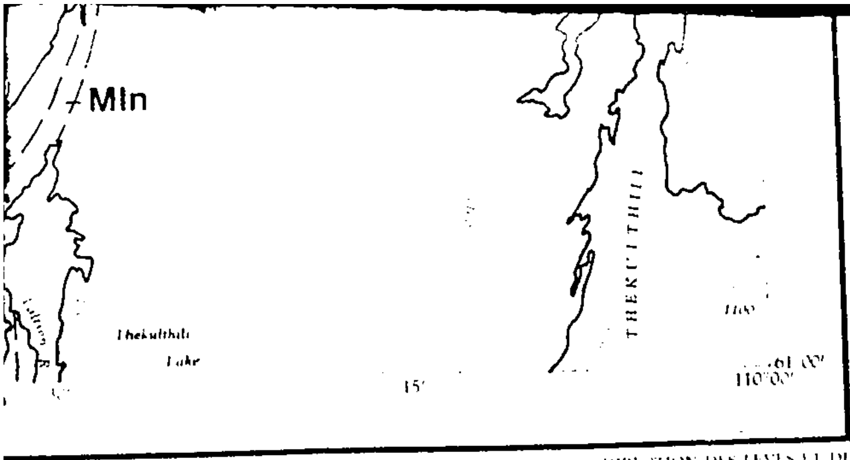
NORTHWEST TERRITORIES

DISTRICT (F MACKENZIE

Scale 1:250,000 Echelle

NAL MAP

CARTE PROVISOIRE



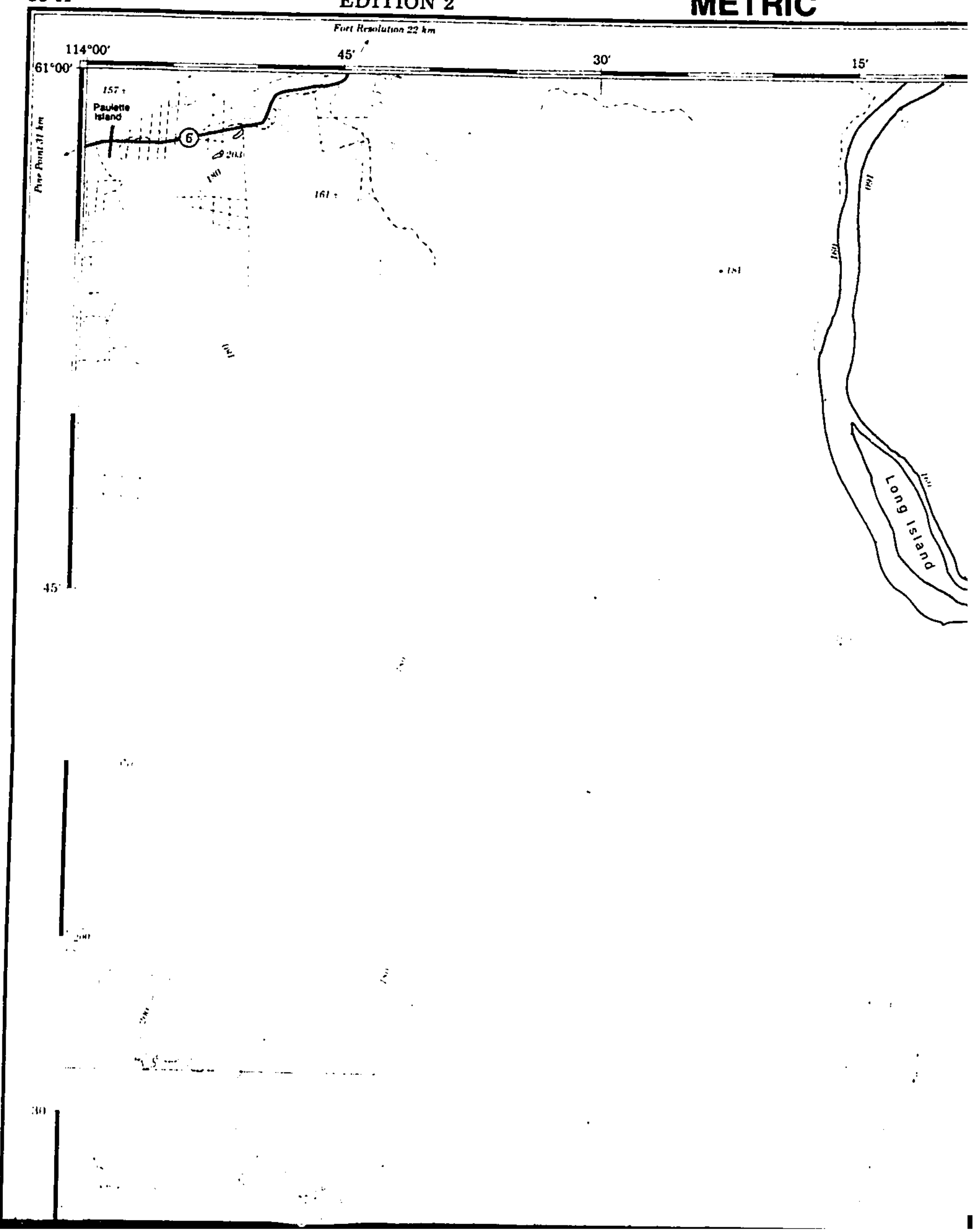
DIRECTION DES LEVES ET DE
LA CARTOGRAPHIE, MINISTERE DES MINES ET DES RE
LEVES TECHNIQUES

75E

85 A

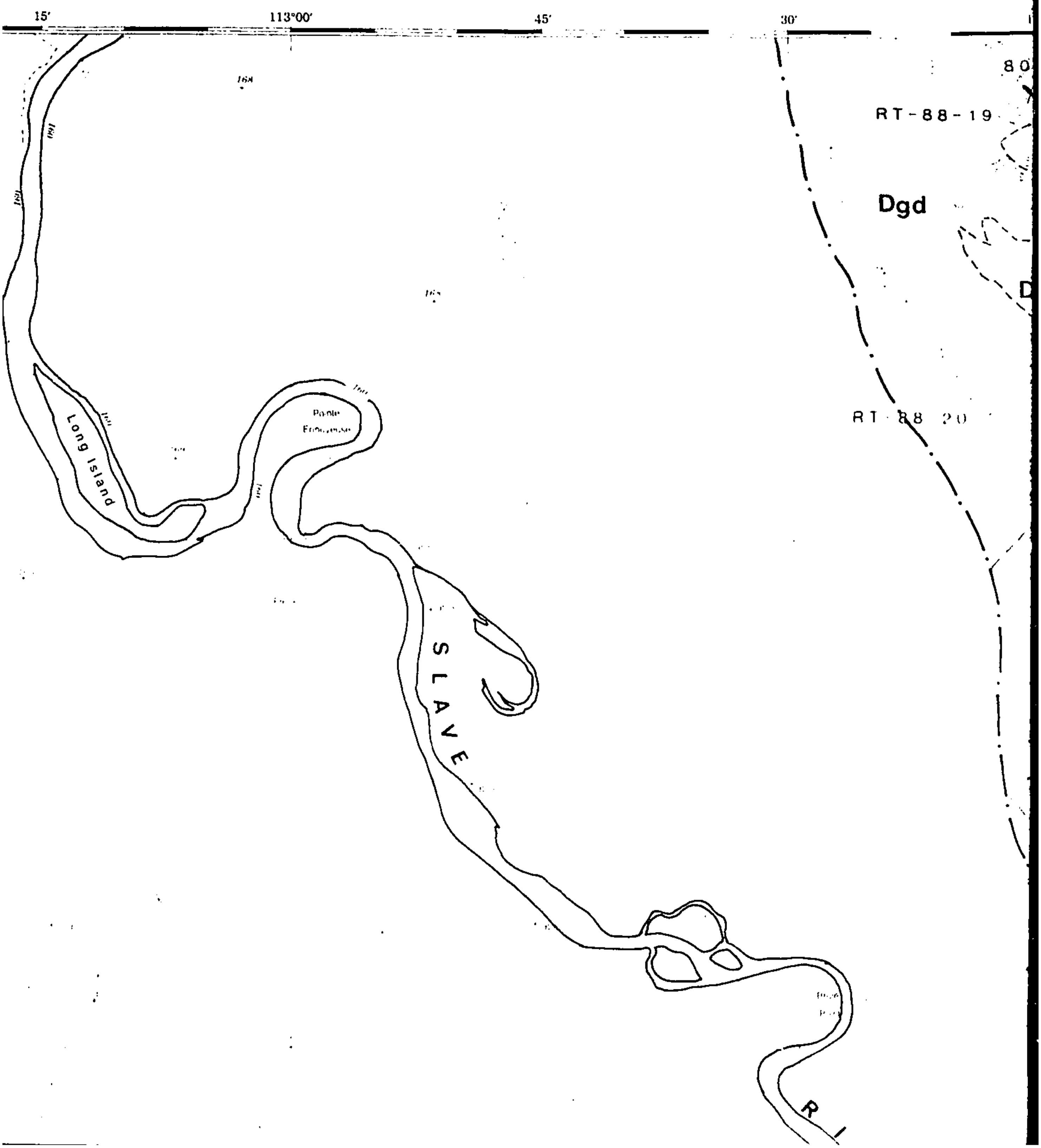
EDITION 2

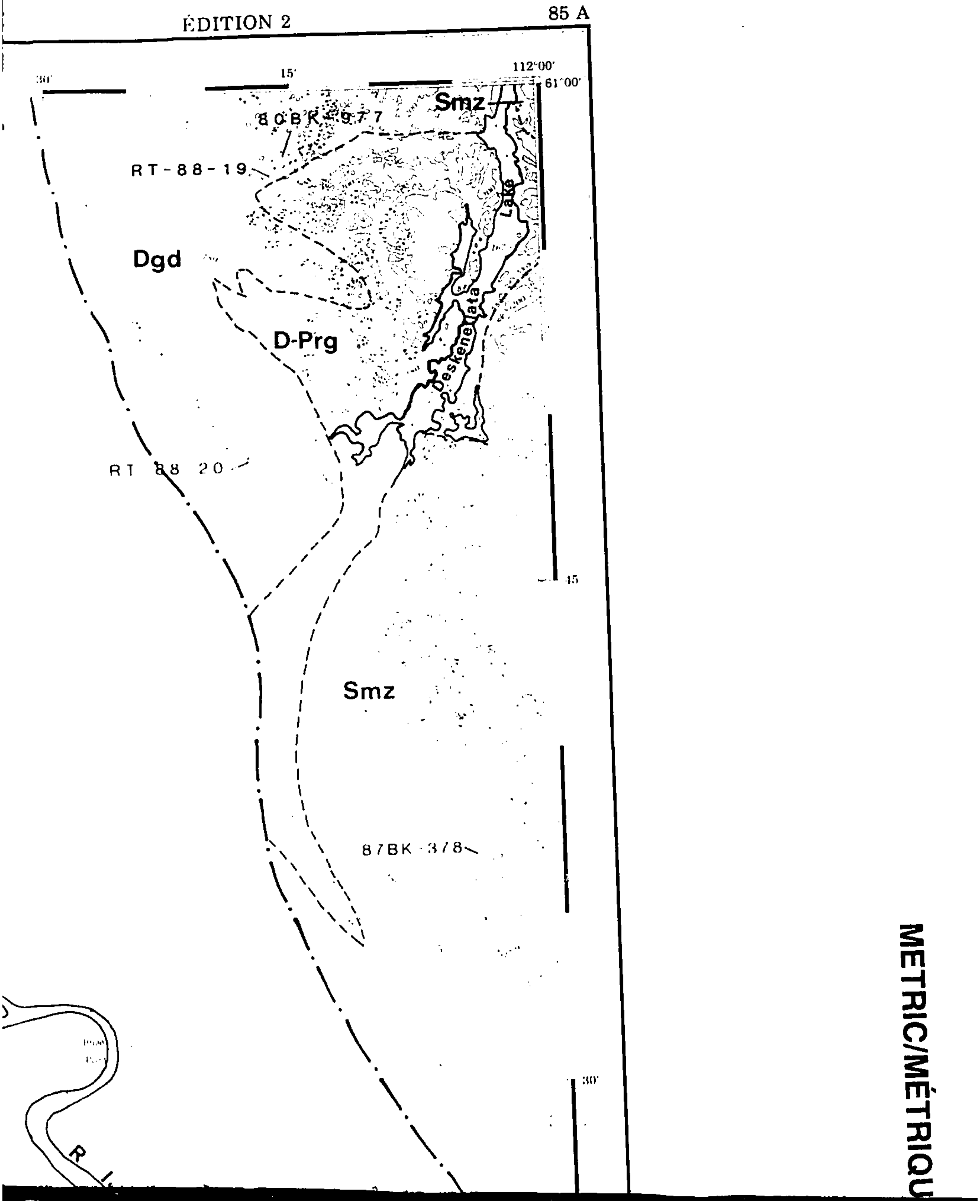
METRIC



TRIC/MÉTRIQUE

Canada **MÉTRIQUE** ÉDITION





METRIC/MÉTRIQU

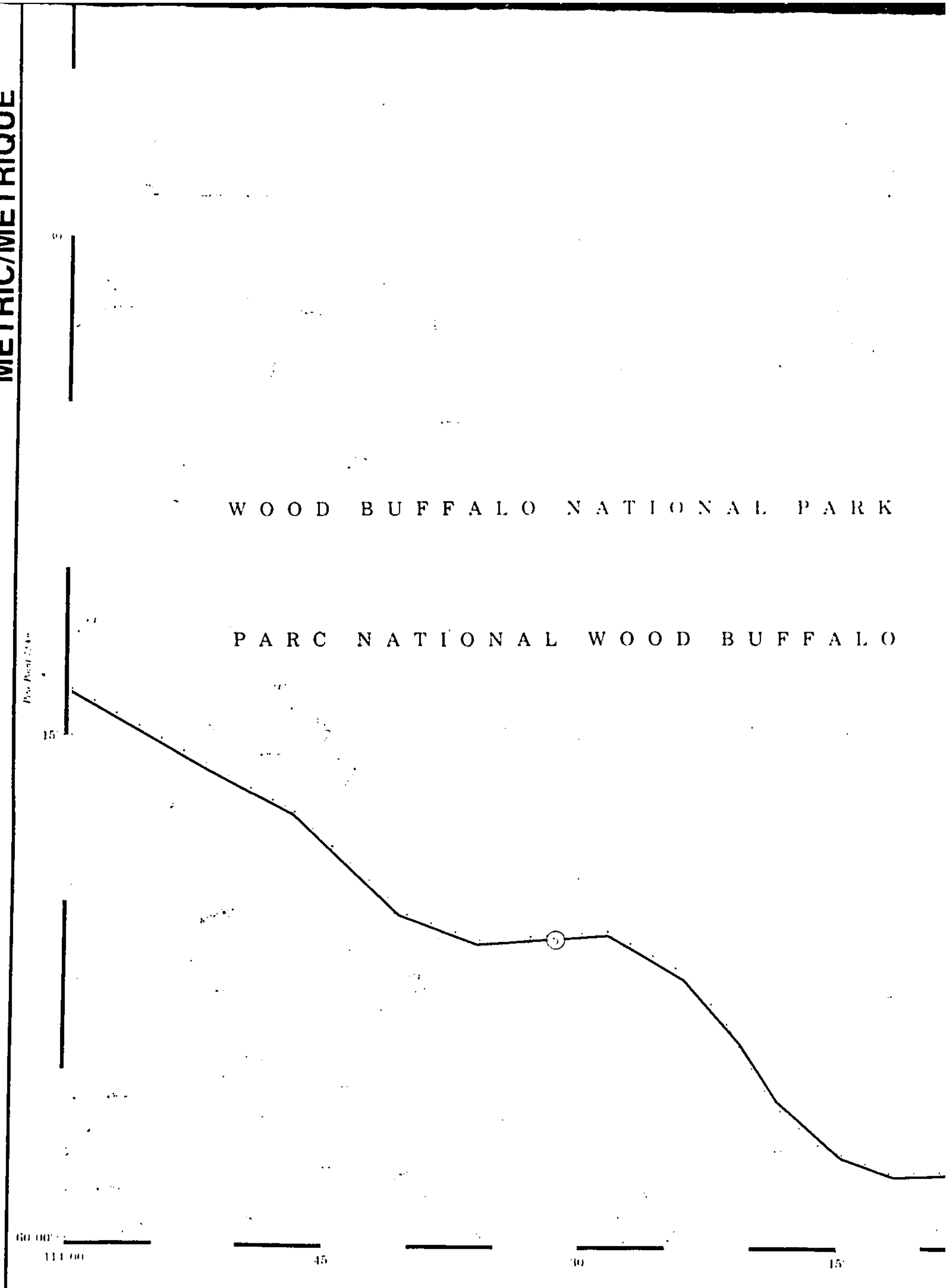
KLEWI RIVER

85 A

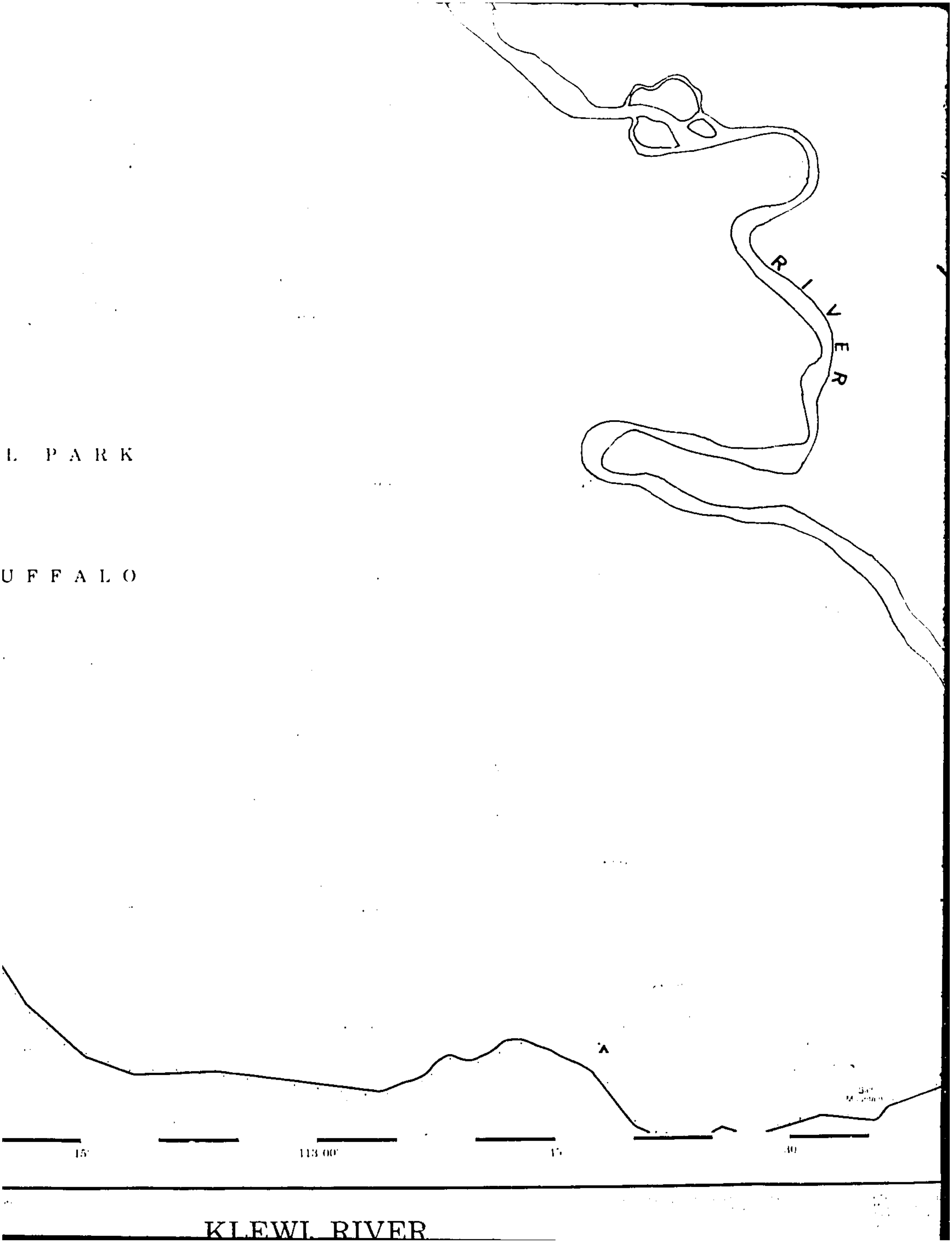
EDITION 2 EDITION

METRIC/MÉTRIQU

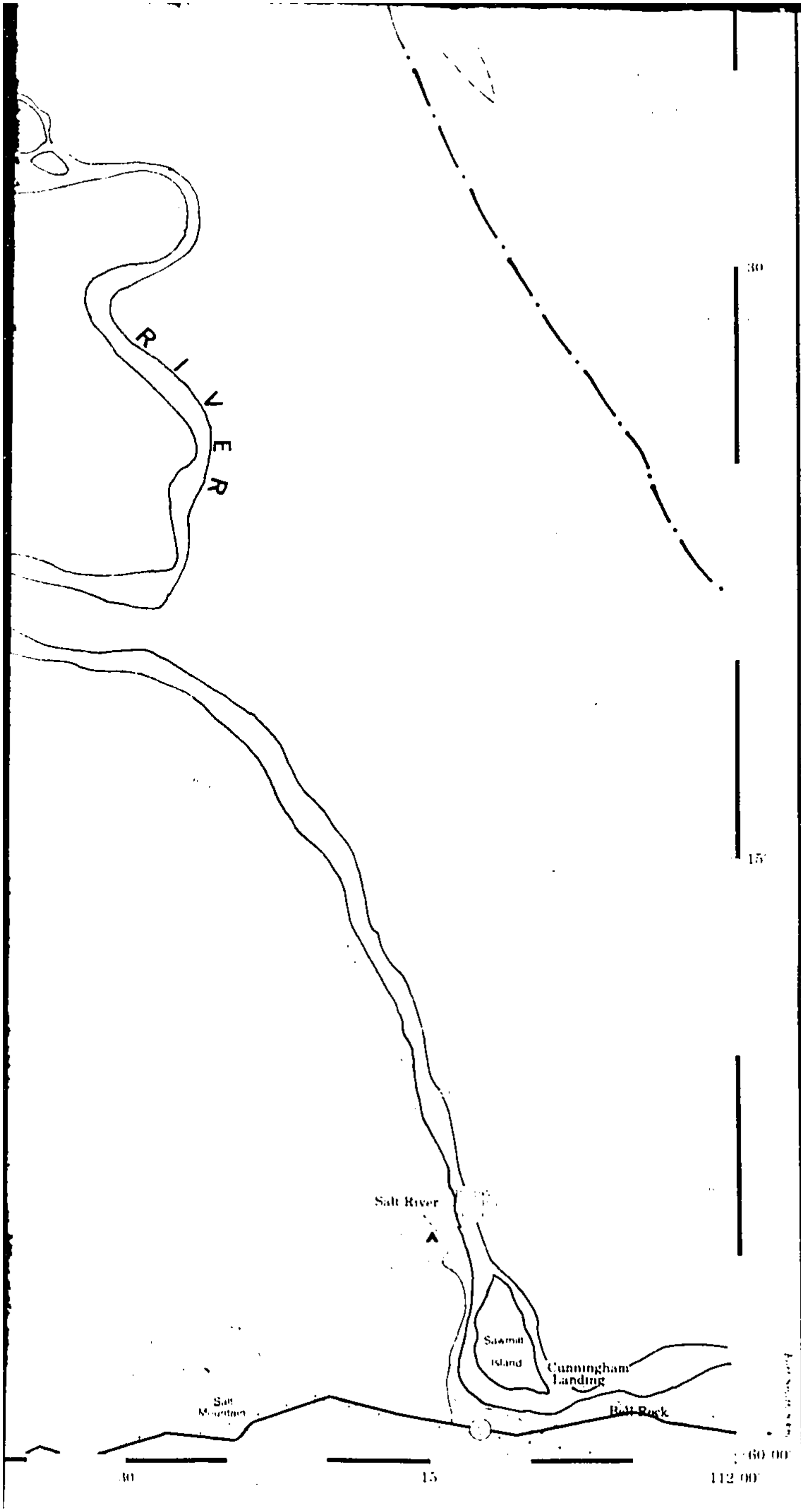
METRIC/MÉTRIQUE

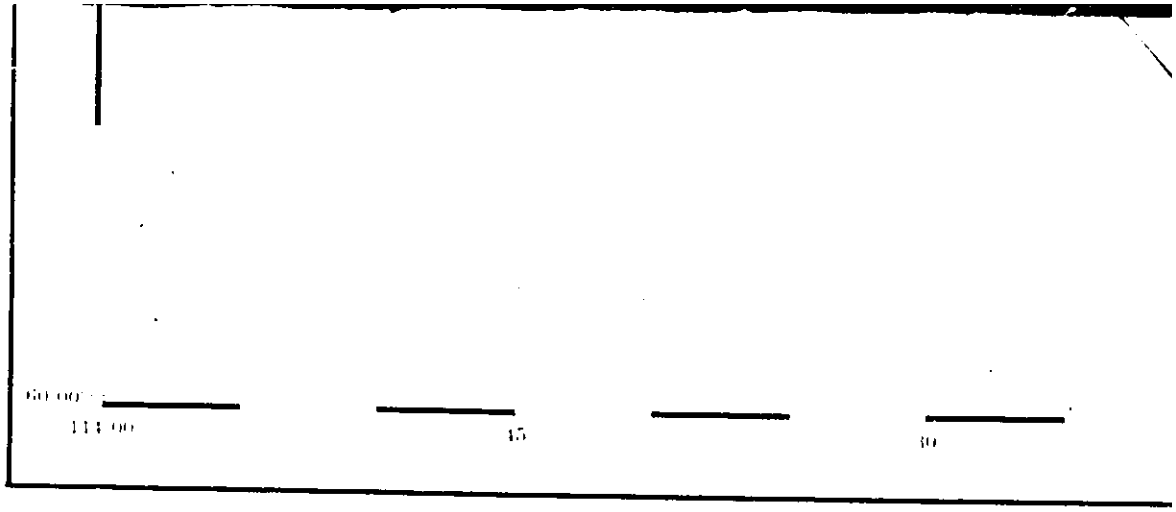


PRODUCED BY THE CANADA CENTRE FOR MAPPING (OTTAWA)
DEPARTMENT OF ENERGY, MINES AND RESOURCES
DERIVED FROM 1:50 000 MAPS [illegible]
[illegible] IN DIAGRAM. PUBLISHED IN [illegible]


L PARK
UFFALO
RIVER
15'
113 00'
15'
30'
KLEWI RIVER

METRIC/MÉTRIQUE





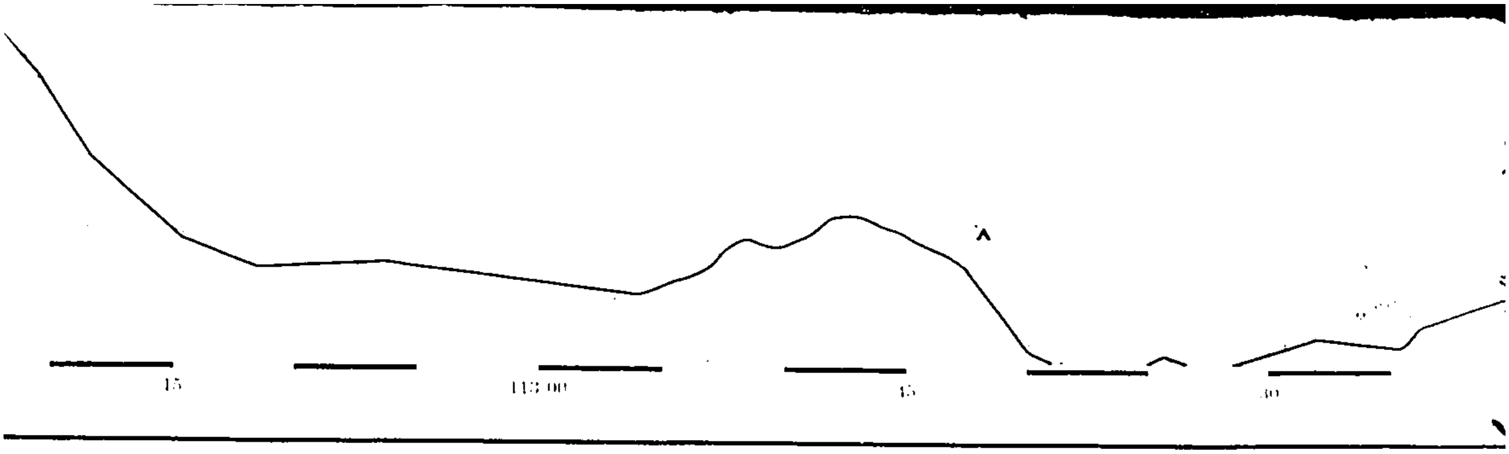
PRODUCED BY THE CANADA CENTRE FOR MAPPING, OTTAWA
DEPARTMENT OF ENERGY, MINES AND RESOURCES
DERIVED FROM 1:50 000 MAPS. INFORMATION CURRENT AS SHOWN IN DIAGRAM. PUBLISHED IN 1988

COPIES MAY BE OBTAINED FROM THE CANADA MAP OFFICE
DEPARTMENT OF ENERGY, MINES AND RESOURCES, OTTAWA
OR YOUR NEAREST MAP DEALER

1980

Miles 5

Kilo



KLEWI RIVER

DISTRICT OF MACKENZIE DISTRICT DE MACKENZIE

NORTHWEST TERRITORIES TERRITOIRES DU NORD-OUEST

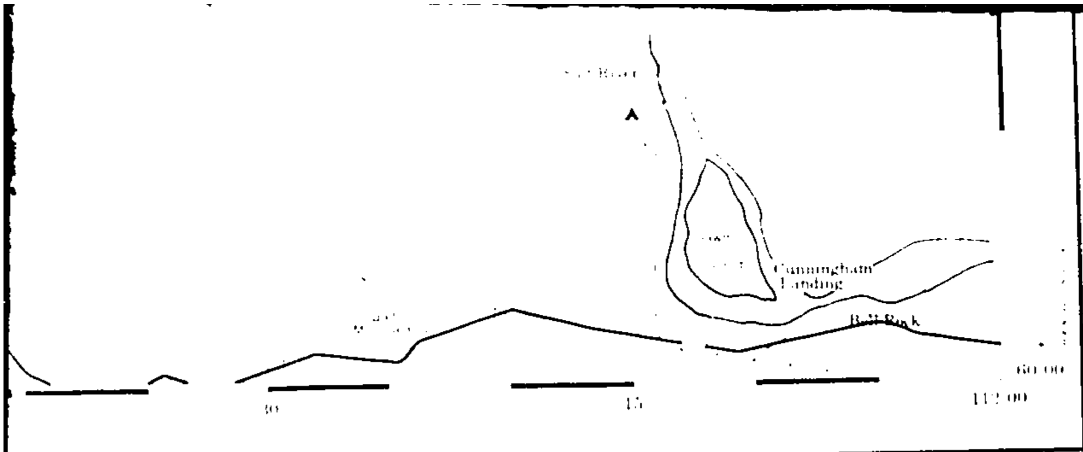
Scale 1:250 000 Échelle

5 0 5 10 15 20 Milles

Kilometres 5 0 5 10 15 20 25 30 Kilometres

CONTOUR INTERVAL 20 MET

Elevations in Metres above Mean



CONVERSION SCALE FOR ELEVATIONS — ÉCHELLE DE CONVERSION DES ALTITUDES

20 Miles

Kilometres

CONTOUR INTERVAL 20 METRES
Elevations in Metres above Mean Sea Level
North American Datum 1927
Transverse Mercator Projection

EQUIDISTANCE DES COURBES 20 METRES
Altitudes en mètres
Système de référence géodésique nord-américain 1927
Projection transverse de Mercator

Index to adjoining Maps of the National Topographic System
Tableau d'assemblage du Système national de référence cartographique

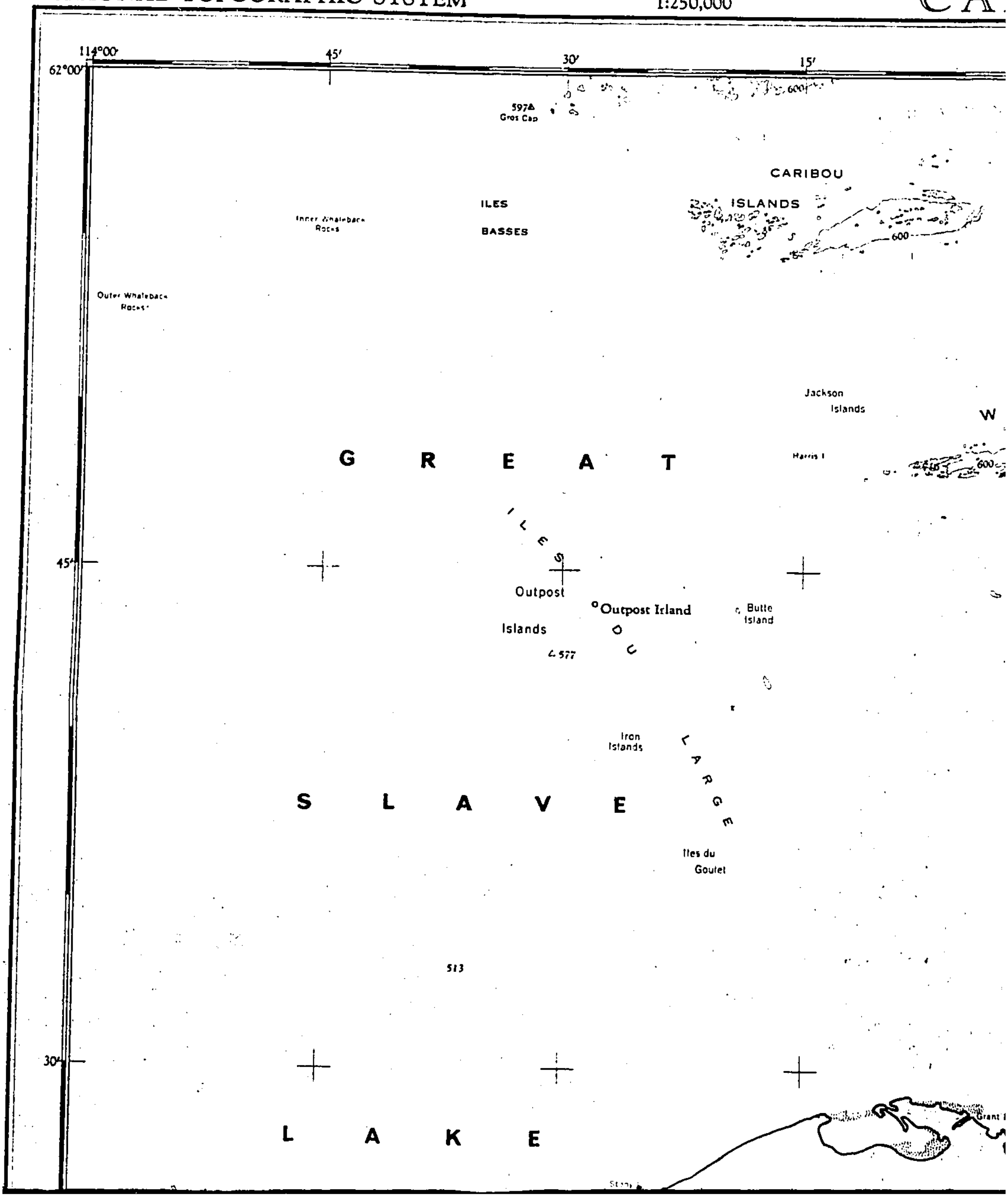
KLEWI RIVER

85 A

EDITION 2 EDITION

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

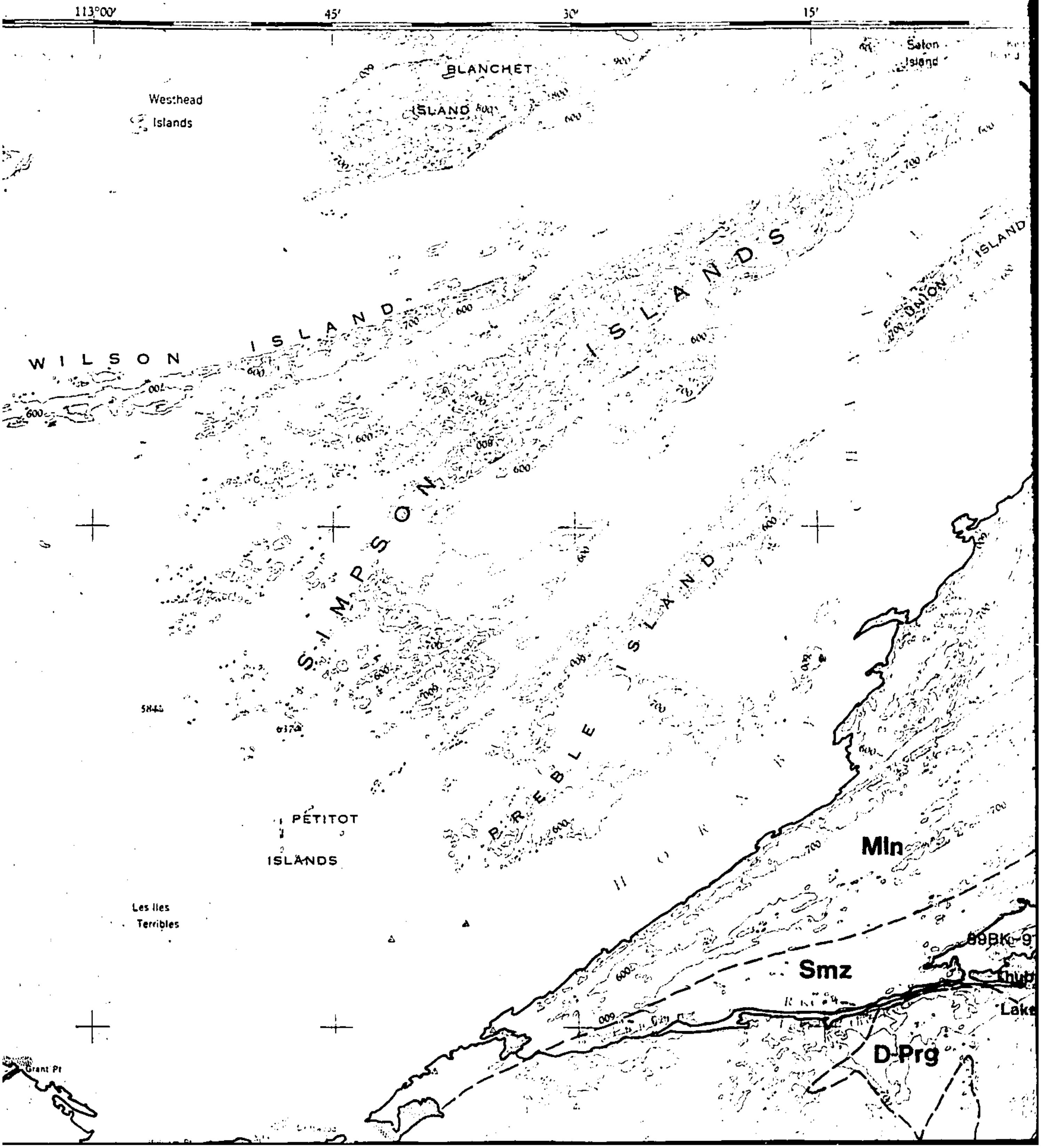
NATIONAL TOPOGRAPHIC SYSTEM 1:250,000 CA



ANADA

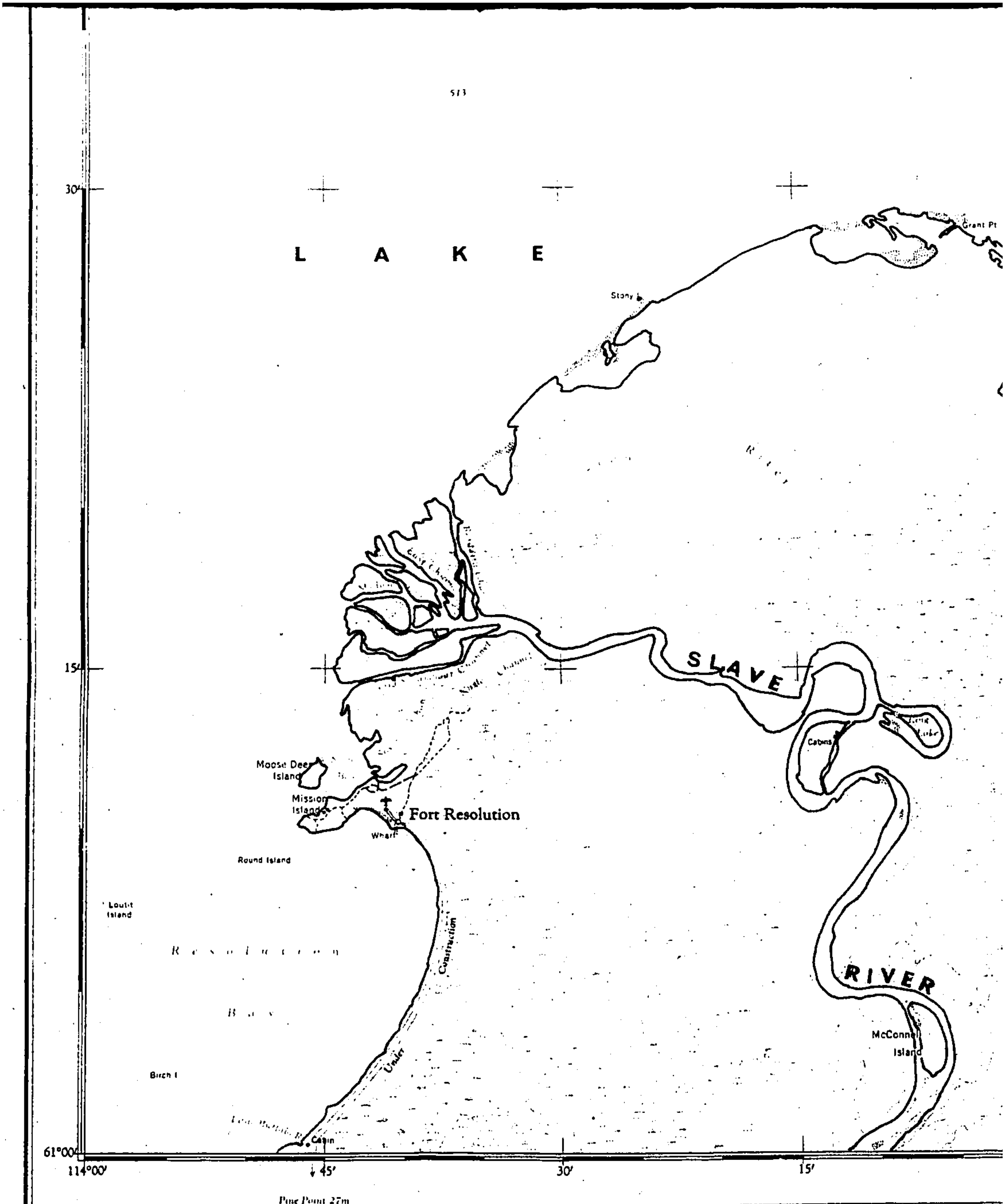
THIRD EDITION

SHEE

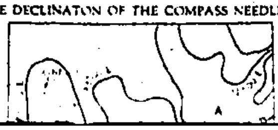


SHEET 85 H

Refer to this map as (1967)



THE DECLINATON OF THE COMPASS NEEDLE 1955

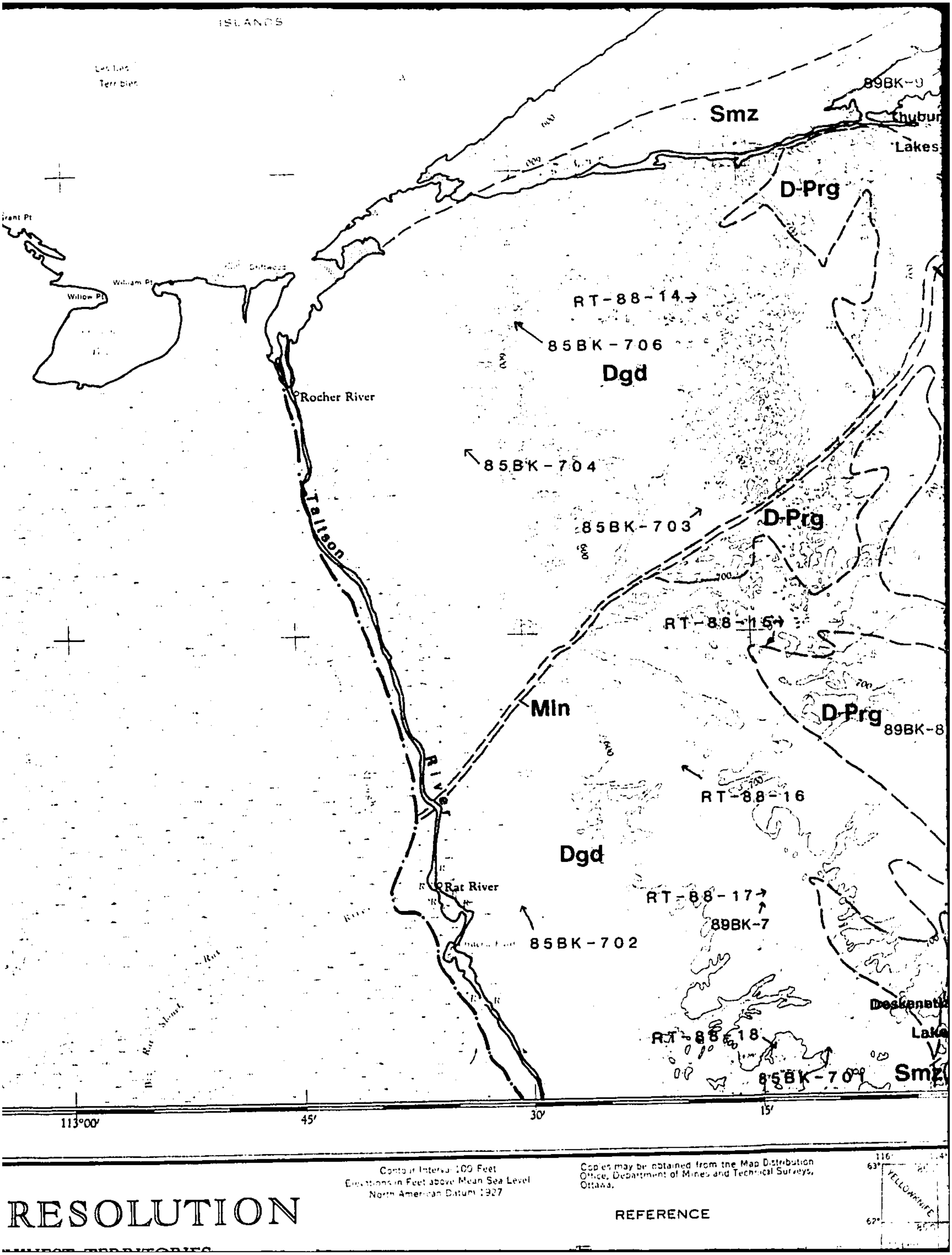


Produced and printed by the SURVEYS AND MAPPING BRANCH, DEPARTMENT OF MINES AND TECHNICAL SURVEYS, 1959, from air photographs taken in 1953 and 1954.
Interim corrections 1967.

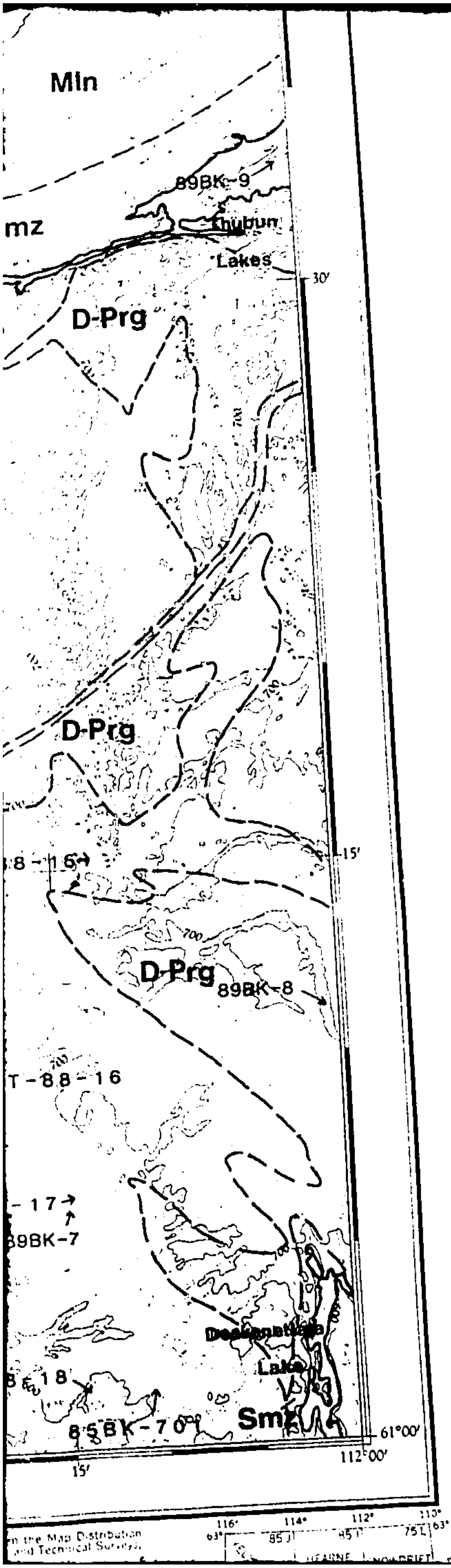
Transverse Mercator Projection

REFERENCE

FORT R



ISLANDS
89BK-9
Smz
Lakes
D-Prg
Grant Pt
William Pt
Willow Pt
Driftwood
RT-88-14
85BK-706
Dgd
Rocher River
85BK-704
Taltson
85BK-703
D-Prg
RT-88-15
Mln
D-Prg
89BK-8
River
RT-88-16
Dgd
Rat River
RT-88-17
89BK-7
85BK-702
RT-88-18
85BK-701
Smz
113°00′
45′
30′
15′
Contour Interval 100 Feet
Elevations in Feet above Mean Sea Level
North American Datum 1927
Copies may be obtained from the Map Distribution Office, Department of Mines and Technical Surveys, Ottawa.
RESOLUTION
REFERENCE
YELLOWKNIFE



100 000 M SQUARE IDENTIFICATION

GRID ZONE DESIGNATION

12 V

UD VD 680
UC VC
40

TO GIVE A REFERENCE TO NEAREST 1000 METRES

EXAMPLE ISLAND

SQUARE Read letters of 100 000 m square UD

EASTING Read number on grid line immediately to left of point 7
Estimate tenths of a square from this line eastward to point 1
71

NORTHING Read number on grid line immediately below point 1
Estimate tenths of a square from this line northward to point 4
14

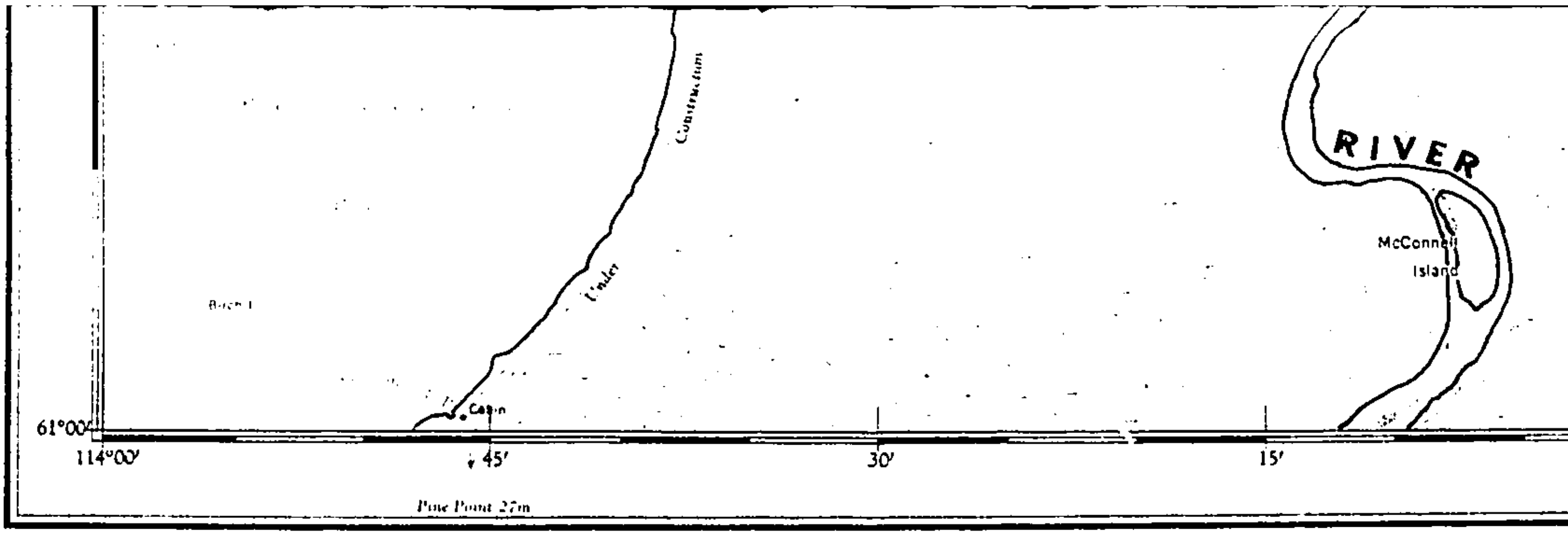
MILITARY GRID REFERENCE to nearest 1 000 metres UD7114

12VUD7114

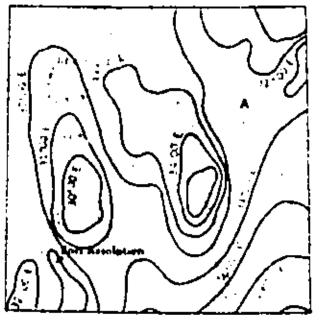
TEN THOUSAND METRE

UNIVERSAL TRANSVERSE MERCATOR GRID

ZONE 12



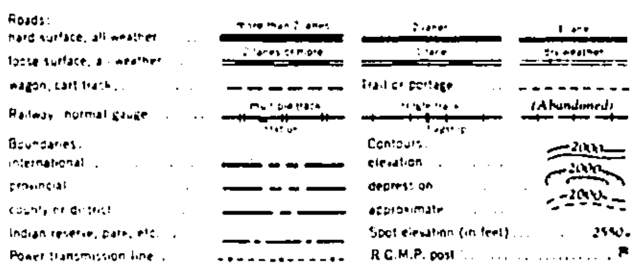
THE DECLINATON OF THE COMPASS NEEDLE 1959



The declination of the compass needle at any place along a red line is the declination given on that red line. At other places the declination is between those given on the neighbouring red lines, thus at the place marked A the declination is between 31 00'E and 32 00'E. The declination of the compass needle is decreasing 8 minutes annually.

Produced and printed by the SURVEYS AND MAPPING BRANCH, DEPARTMENT OF MINES AND TECHNICAL SURVEYS, 1959, from air photographs taken in 1953 and 1954.
Interim corrections 1967.

REFERENCE



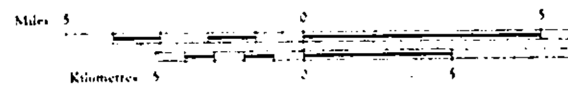
Transverse Mercator Projection

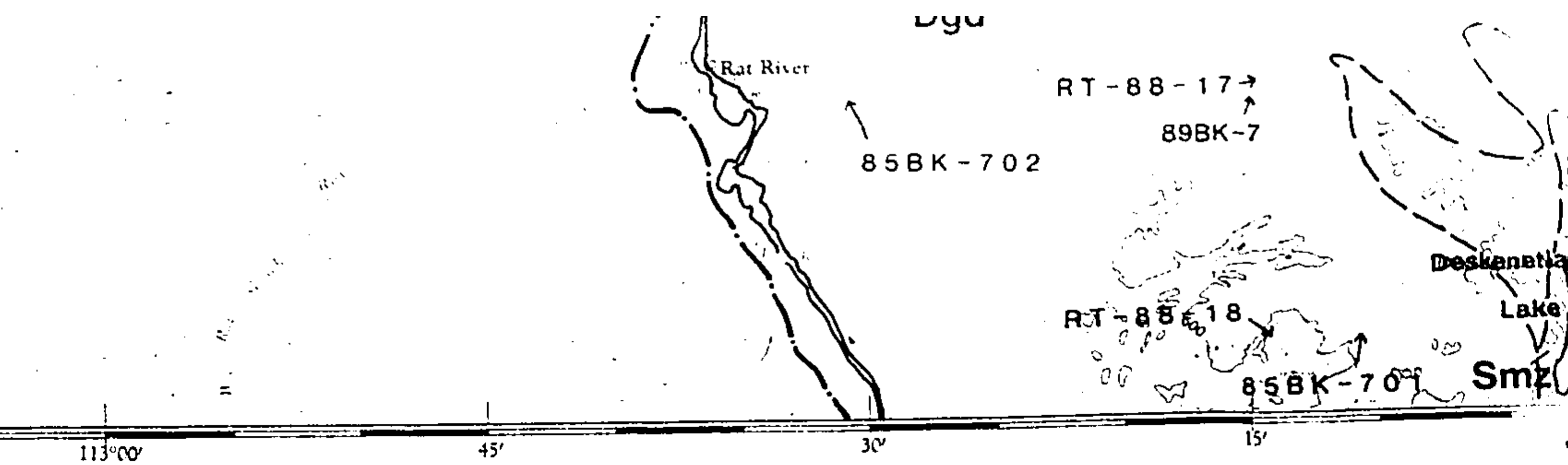
FORT R

NORTHW

DISTR

1 Inc





Contour Interval 100 Feet
Elevations in Feet above Mean Sea Level
North American Datum 1927

Copies may be obtained from the Map Distribution Office, Department of Mines and Technical Surveys, Ottawa.

RESOLUTION

HWEST TERRITORIES

TRICT OF MACKENZIE

Scale 1:250,000

Inch to 4 Miles Approximately

10 15 20 Miles

10 15 20 25 30 Kilometres

REFERENCE

City or large town — Post office — Boundary monument

Town — Church

Village or settlement

Streams: intermittent or dry; indefinite

Irrigation canal or ditch

Rapids, falls

Airport

Airfield

Intermittent lake

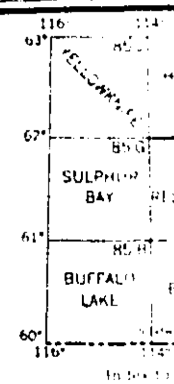
Marsh or swamp

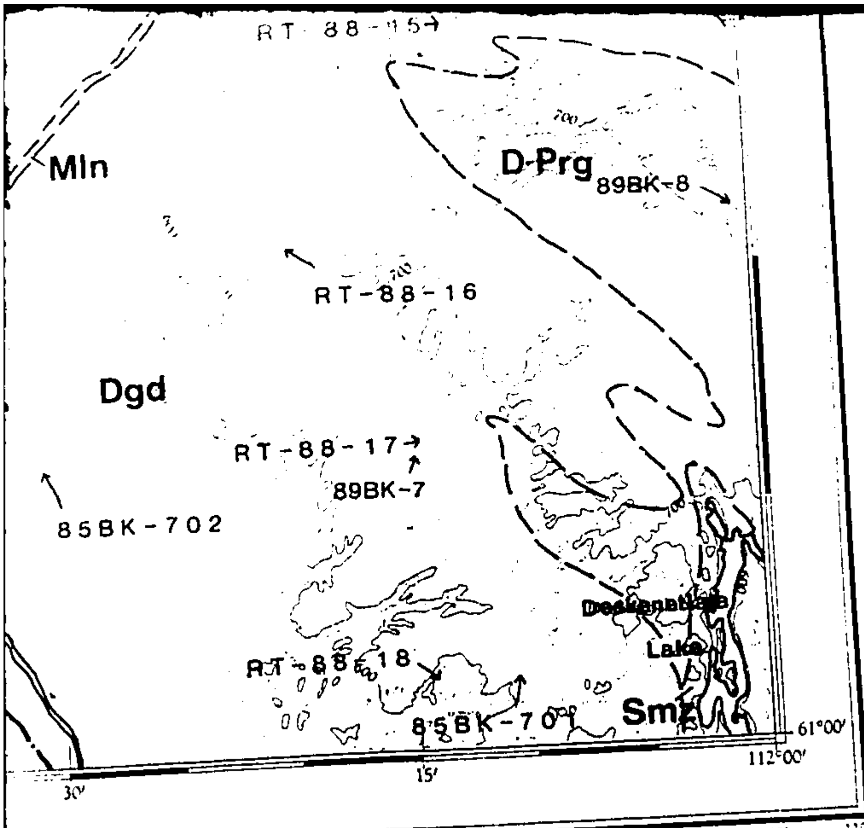
Sand, gravel or mud

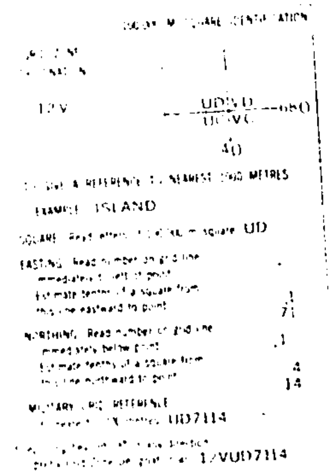
Seaplane base

Seaplane anchorage

Horizontal control point

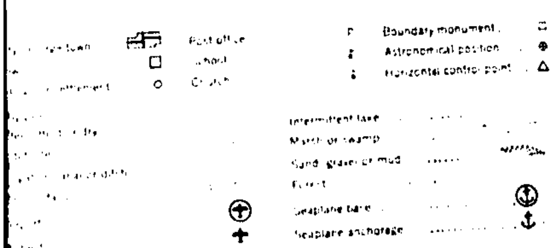


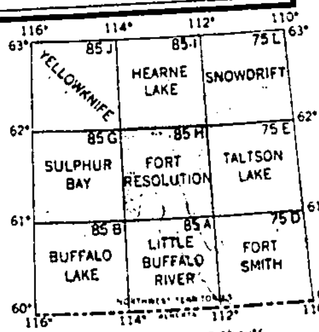




Copies may be obtained from the Map Distribution Office, Department of Mines and Technical Surveys, Ottawa.

REFERENCE





Index to adjoining sheets

FORT RESOLUTION
85H
EDITION 3 (1967)