RG 2001-06

GEOLOGY OF THE RIVIERE ARNAUD AREA AND ADJACENT COASTAL AREAS

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Louis Madore
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Accompanies maps
SI-25C-C2G-00K, SI-25D-C2G-00K
SI-25E-C2G-00K, SI-25F-C2G-00K

Fjords on Hudson Strait.

2001

Québec

Geology of the Rivière Arnaud area (NTS 25D) and adjacent coastal areas (NTS 25C, 25E et 25F)

Louis Madore[1]
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(Accompanies maps SI-25C-C2G-00K, SI-25D-C2G-00K, SI-25E-C2G-00K and SI-25F-C2G-00K)

Abstract

This new geological survey covers the Rivière Arnaud area (NTS 25D) in addition to the coastal regions of Ungava Bay (NTS 25C) and Hudson Strait (NTS 25E and 25F). The study area is underlain by Archean rocks of the Douglas Harbour domain (Superior Province). These Archean rocks are intruded by paleoproterozoic dykes (Payne River Dykes and Klotz Dykes), and partially overlain by thrust sheets. These nappes, composed of Paleoproterozoic supracrustal sequences, belong to the Labrador Trough and the Ungava Trough.

Within the study area, rocks associated to the Archean craton were subdivided into three lithodemic units: the Qimussinguat Complex (QC), the Faribault-Thury Complex (FTC) and the Diana Structural Complex (DSC). The distinction between these units is based on typical lithological assemblages, as well as differences in the metamorphic grade and tectonic style. Lithologies common to all three complexes possess similar geochemical signatures. It is therefore impossible to distinguish the complexes on the basis of geochemistry.

Rocks of the Qimussinguat Complex are generally metamorphosed to the granulite facies, whereas those of the Faribault-Thury Complex are at the amphibolite facies. The two complexes are essentially composed of orthogneisses of the tonalite-trondhjemite-granodiorite/granite (TTG) suite, which enclose mafic banded remnants of gabbroic, basaltic or metasedimentary origin. In the Qimussinguat Complex, these bands are rare and restricted in size. In the Faribault-Thury Complex, the bands of volcano-sedimentary rocks are from one to several kilometres in length and form a string of segments distributed over a distance exceeding 100 km. The Qimussinguat and Faribault-Thury complexes display structural fabrics typical of Archean deformation, dominated by a steeply-dipping foliation or gneissosity oriented NNW-SSE. The Diana Structural Complex is mainly formed of Archean tonalitic orthogneisses that were reworked during the Proterozoic. It is characterized by a generally well-developed mylonitic foliation that affects both Archean and Early Proterozoic lithologies.

Archean fabrics suggest a polyphase tectonic setting. The foliation and gneissosity are affected by complex folding of variable intensity, superimposed by ductile shear zones. Proterozoic fabrics indicate two distinct tectonic styles. The first is related to the thrusting of Early Proterozoic sequences onto the Archean basement, and the second, to dextral strike-slip movements in a transpressional setting. No evidence of Proterozoic deformation was observed in the Qimussinguat Complex. In the Faribault-Thury Complex, Early Proterozoic deformation is discrete and the associated metamorphism varies from the greenschist facies to the amphibolite facies. This deformation is restricted to the contact zone between Early Proterozoic thrust sheets and the Archean basement, or in regional scale strike-slip faults. In the Diana Structural Complex, the Proterozoic deformation is penetrative and affects all the rocks in the complex.

A preliminary geochronological study helped establish a sequence of events marking the geological history of the area. It begins with the emplacement of volcanic rocks and felsic plutonic rocks at 2.8 Ga, followed by two episodes of Archean metamorphism at 2.7 Ga and 2.6 Ga, and a Proterozoic metamorphic event at 1.8 Ga.

Mapping in Archean terrains has led to the discovery of two new mineralized showings and 10 anomalous occurrences. The mineralization essentially consists of Cu, Ag and Zn, found in bands of metavolcanic or metasedimentary rocks. Mafic and ultramafic intrusions, mainly present in volcano-sedimentary belts, were also identified. Despite their relatively high Mg content, these rocks contain very few anomalous Ni, Cu and Cr values, and only one minor Cu showing was reported. With the exception of rocks of the Labrador Trough, where Ni-Cu-PGE showings were recently discovered in mafic-ultramafic rocks, paragneiss bands located in the eastern part of the Diana Structural Complex as well as the Trempe and Buet volcano-sedimentary belts, included in the Faribault-Thury Complex, appear to represent the most interesting exploration targets outlined in the study area.

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DOCUMENT PUBLISHED BY " *GÉOLOGIE QUÉBEC* "

Director
Alain Simard

Geological inventories manager
Robert Marquis

Document accepted for publication on the 01/05/25

Critical reader
Pierre Brouillette (CGQ)

Edition and page setting
Jean-Pierre Lalonde
Kamal N. M. Sharma

Computer assisted drawing
Louis Madore
Youcef Larbi
Nathalie Drolet

Technical supervision
André Beaulé

Dépôt légal – Bibliothèque nationale du Québec
ISBN : 2-551-21405-X

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INTRODUCTION

Objectives

This new geological survey, conducted during the summer of 1999, covers the Rivière Arnaud area (NTS 25D), in addition to the coastal regions of Ungava Bay (NTS 25C) and of Hudson Strait (NTS 25E and F). It follows a mapping survey carried out in 1998 in the Lac Peters area (NTS 24M; Madore *et al.*, 1999) and forms an integral part of the Far North mapping program conducted by the MRN. The objectives of the project are to : (1) generate a geological map at a scale of 1:250,000, (2) build an exhaustive database of field observations and lithogeochemical analyses, (3) assess the mineral potential by identifying geological settings favourable to the discovery of mineral deposits, and (4) add to the general understanding of the NE Superior Province.

Location and Access

The area covered by this survey is located in northernmost Québec, in the Ungava Peninsula. It is bounded to the south by the Rivière Arnaud, to the north by Hudson Strait and to the east by Ungava Bay. The mapping coverage extends westward to the longitude 72° (Figure 1). The centre of the area is located 300 km north of Kuujjuaq, and the Inuit communities of Kangiqsujuaq, Quaqtaq and Kangirsuk are located within the perimeter of this survey. The study area is accessible by snowmobile in the winter from neighbouring communities. It is also accessible by ski-equipped aircraft from December to May, and by floatplane during the summer season. The Rivière Arnaud crosses the southern part of the area from west to east. The Rivière Buet traverses the area from north to south. The principal water bodies are Lac Ammaluttuuq, Nagvaraaluk and Roberts. With the exception of the coast of Hudson Strait, where the landscape is sculpted into a series of fjords oriented NNW-SSE, the topographic relief is low and the land has a gently rolling topography. The average altitude gradually increases northward, from 180 to 460 m above sea level. The area is located north of the tree line. Rock outcrops are numerous and extensive, but are generally covered with lichen.

Methodology

Field work consisted in a geological mapping survey at a scale of 1:250,000, sampling of lithodemic units and mineralized zones for lithogeochemical analyses, and sampling of six units for geochronological analysis. Traverses averaging 10 km long were spaced every 8 km. The spacing was reduced in more interesting areas, namely in volcano-sedimentary sequences. Geoscience data from previous studies were integrated with newly collected data. All this information is available through the SIGÉOM (Québec's geomining information system).

Previous Work

In the 1960s, the Geological Survey of Canada (Stevenson, 1968) carried out a reconnaissance survey at a scale of 1:1,000,000. This survey covers a major portion of the Ungava Peninsula and extends from Lac Nantais to the north to Lac à l'Eau-Claire to the south (area between longitudes 70°00' and 79°00' W and between latitudes 56°00' and 61°00' N). More detailed work, focussing on Paleoproterozoic rocks was subsequently performed, namely a geological survey at a scale of 1:63,360 by the Ministère des Richesses naturelles du Québec (Hardy, 1976), which covers the Lac Roberts and Lac des Chefs area. A second survey, conducted by the Geological Survey of Canada (St-Onge and Lucas, 1990a, 1990b; St-Onge and Lucas, 1997) at 1:50,000 scale in Paleoproterozoic rocks and at 1:100,000 scale in Archean rocks, covers the Wakeham Bay, Joy Bay and Burgoyne Bay areas. The map area was also covered by a lake sediment survey (MRN, 1998), a gravity survey with stations spaced every 10 km (GSC, 1994) and a regional aeromagnetic survey (Dion and Dumont, 1994). Despite these studies, the present map area remained poorly known and the Archean basement rocks were considered as a vast relatively homogeneous plutonic domain.

Acknowledgements

We wish to thank the members of our field crew, who carried out remarkable work throughout the field season: Valérie Bécu (geologist), Jason Bennett (geological assistant), Christiane Bochud (geological assistant), Nathalie Bouchard (geologist), Marie-Josée Claveau (geologist), Sandy Forbes (geological assistant), Monic Landry (helicopter mechanic), Louis-Pierre Laurendeau (geological assistant), Nicolas Lavoie (geological assistant), Aurèle Noël (camp manager), Martin Plante (geological assistant), Patrice Roy (geologist), Luc Therrien (cook), Cynthia Tremblay (geological assistant), and Michel Viens (helicopter pilot). We also wish to thank Jean Bédard (Geological Survey of Canada) and Don Francis (McGill University) for their participation, which was greatly appreciated. We extend our gratitude to Daniel Bandyayera (Ministère des Ressources naturelles) for his participation in the fieldwork and his interest throughout the entire project.

GENERAL GEOLOGY

The NE part of the Superior Province which includes our study area consists mainly of Archean plutonic and gneissic

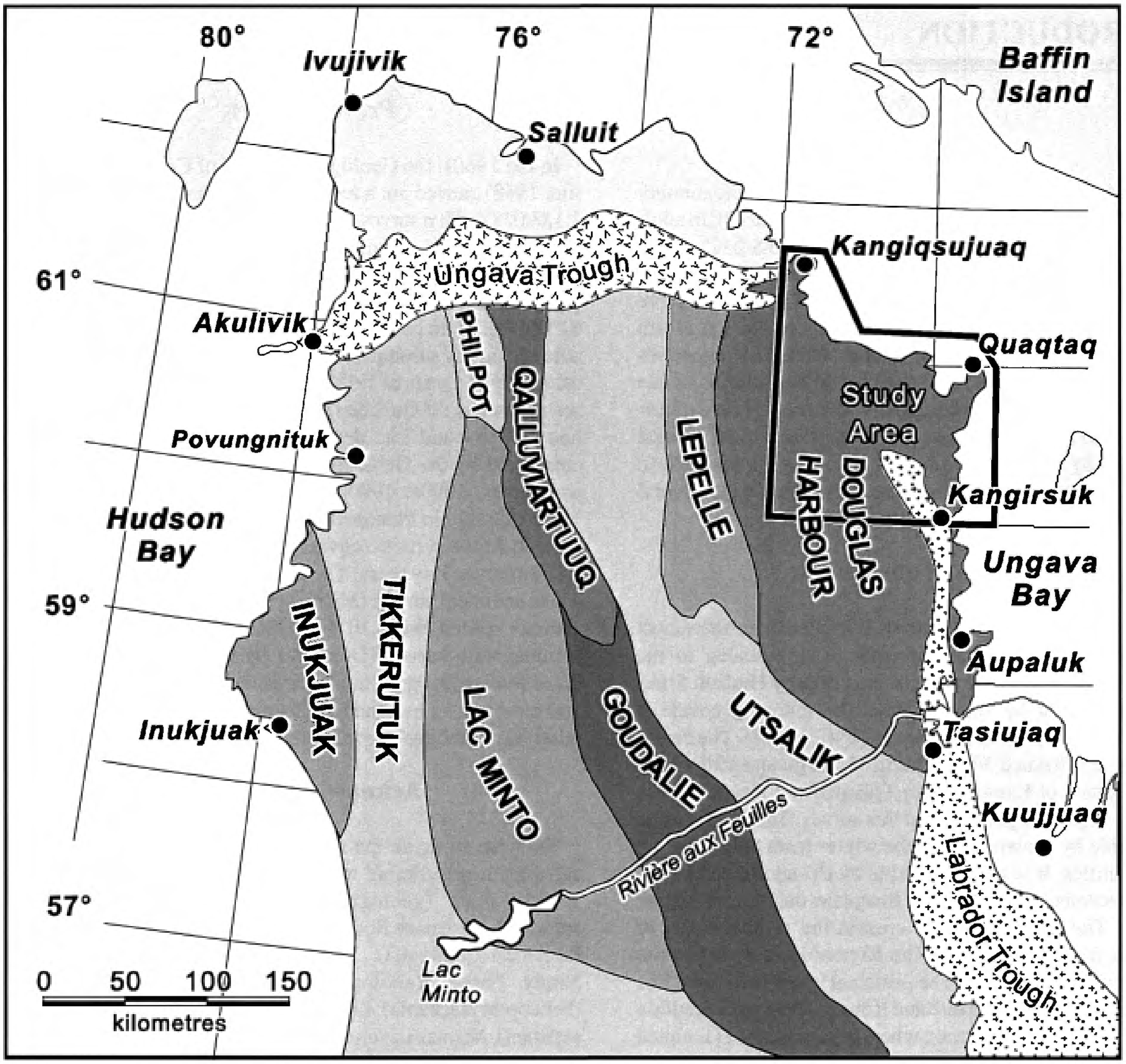

FIGURE 1 – Location of the study area and the lithotectonic domains (from Percival *et al.*, 1991, 1992, 1997).

rocks with a few volcano-sedimentary belt segments. The rocks are typically metamorphosed to the amphibolite or granulite facies. The general NNW-SSE orientation of major lithological assemblages in this part of the Superior Province clearly stands out on the regional maps of the total magnetic field and of the magnetic gradient. This vast Archean region is bounded by Paleoproterozoic rocks of the Labrador Trough to the east, and of the Ungava Trough to the north. The Paleoproterozoic rock cover is, at least in its northern part, allochthonous and tectonically overlies the Archean craton of the Superior Province (St-Onge *et al.*, 1988; St-Onge and Lucas, 1990c; Bouchard *et al.*, 1999).

Based on reconnaissance work along the Rivière aux Feuilles, Percival *et al.* (1991) proposed a subdivision of the NE Superior Province into four lithotectonic domains. Results from later studies modified this subdivision to six, then to nine domains (Percival *et al.*, 1992 and 1997). These domains are shown in Figure 1. The Inukjuak domain consists of plutonic rocks with metasedimentary enclaves. The Tikkerutuk domain is formed of plutonic rocks (2707-2693 Ma). The Lac Minto domain is composed of calc-alkaline granodiorite (2780-2693 Ma), peraluminous granodiorite (2725-2696 Ma), monzogranite (2690 Ma) and supracrustal rocks dominated by sediments including the Kugaluk volcano-sedimentary belt (~2760 Ma). The Goudalie domain contains tonalites (3010-2900 Ma) and volcano-sedimentary belts including the Vizien belt (2700 Ma), interpreted by Skulski and Percival (1996) as an assemblage of oceanic and continental arc fragments. The Philpot domain is composed of gneiss and intrusive rocks (2755 Ma). The Qalluviartuuq domain, of intrusive rocks and evolved volcanic rocks (~2800 Ma), the Lepelle domain, of intrusive rocks, and the Utsalik domain, of calc-alkaline granodiorite and granite (2755-2725 Ma). The Douglas Harbour domain was until recently considered as a lithological assemblage exclusively composed of plutonic rocks (2880-2780 Ma). However, geological mapping in the Lac Peters area (Madore *et al.*, 1999) helped identify several volcano-sedimentary belt segments within this domain.

STRATIGRAPHY

(Chapter written in collaboration with Kamal N.M. Sharma)

The study area is underlain by Archean rocks of the NE Douglas Harbour domain (Superior Province). These Archean rocks are intruded by Paleoproterozoic dykes (Payne River Dykes and Klotz Dykes; Figure 2). They are partially overlain by Paleoproterozoic supracrustal sequences of the Labrador Trough and of the Ungava Trough (Figure 2). In this report, the description of units will mainly focus on Archean rocks, since Paleoproterozoic rocks have already been described in publications by St-Onge and Lucas (1990a, 1990b) and Hardy (1976). However, particular attention will be paid to the boundary zone between the Archean basement and the Paleoproterozoic sequences in order to establish the nature of this contact.

In the study area, rocks associated with the Archean craton were subdivided into three lithodemic units. The distinction between these units is based on typical lithological assemblages and differences in the metamorphic grade and tectonic style. These lithodemic units are, from west to east, the Qimussinguat Complex (QC), the Faribault-Thury Complex (FTC) and the Diana Structural Complex (DSC) (Figure 2).

The magnetic signature of the three complexes is quite distinctive (Figure 3). In the Qimussinguat Complex, the magnetic field is high. The Faribault-Thury Complex is characterized by a variable magnetic field with NW-SE oriented magnetic troughs. The Diana Structural Complex displays a moderate magnetic field. In the eastern part of the Diana Structural Complex, strong narrow and linear positive anomalies cross the area in a NW-SE direction. These positive anomalies correspond to rusty paragneiss bands. A very narrow and high magnetic field, corresponding to iron formations, delineates Paleoproterozoic sequences from the Archean basement.

The Qimussinguat Complex is essentially composed of orthogneisses of the tonalite-trondhjemite-granodiorite/granite (TTG) suite (see Ridley and Kramers, 1990; Martin, 1994; Rudnick, 1995; Rollinson, 1996). These orthogneisses generally contain clinopyroxene and orthopyroxene. Granulite-facies metamorphism is predominant. The structural fabric consists of a N-S oriented gneissosity that defines the regional tectonic pattern. This planar fabric is locally reworked by non-planar folds (folds with non-planar axial surfaces) indicating a polyphase Archean tectonic setting.

The Faribault-Thury Complex consists of orthogneisses of the TTG suite. It contrasts with neighbouring units due to the large volume of bands of volcano-sedimentary rocks. These bands are incorporated in the orthogneisses, and distributed along a NW-SE axis, over a distance exceeding 100 km. Orthogneisses and supracrustal rocks of the Faribault-Thury Complex are generally metamorphosed to the amphibolite facies. The Archean structural fabric and folding observed in the Faribault-Thury Complex are comparable to those in the Qimussinguat Complex. Archean structures in the Faribault-Thury Complex are however locally affected by Proterozoic ductile shearing. The intensity of this Proterozoic deformation increases eastward.

The Diana Structural Complex is essentially composed of Archean orthogneisses that were reworked during the Proterozoic. These orthogneisses are generally strongly deformed. They display a penetrative foliation or a mylonitic fabric as well as a well developed stretching lineation. The Diana Structural Complex also includes a minor proportion of paragneisses of uncertain age and amphibolite dykes. These amphibolite dykes are metamorphosed and strongly deformed equivalents of Early Proterozoic Payne River dykes (pPpay). The majority of the rocks of this complex are metamorphosed to the amphibolite facies. However, the metamorphic grade tends to increase eastward, and granulite-grade assemblages are locally observed in the eastern part of the complex.

Archean

Qimussinguat Complex (Aqim)

Initially introduced to describe units mapped in the Lac Peters area (Madore *et al.*, 1999), the term Qimussinguat Complex designates a lithodemic unit mainly composed of granulitic orthogneisses containing clinopyroxene and orthopyroxene. The felsic igneous rocks are locally massive to weakly foliated and display evidence of magmatic textures. These facies are mainly observed in granodiorites and granites. The Qimussinguat Complex also contains a minor proportion of gabbronorite intrusions, small ultramafic bodies as well as a few rare supracrustal rock bands (biotite-garnet paragneiss, mafic gneiss/metavolcanic rocks). Supracrustal rock bands outcrop in the southern part of the complex, but their limited size makes it impossible to represent them on our map at a scale of 1:250,000.

Ultramafic Rocks (Aqim3a)

Ultramafic rocks form small bodies (<1 km^2) spatially associated with gabbronorite intrusions (Aqim6). However, further south in the Lac Peters area (Madore *et al.*, 1999), these ultramafic rocks are associated with mafic metavolcanic rocks. Ultramafic rocks essentially consist of websterite and minor dunite. These may be either intrusive rocks, or cumulates derived from volcanic flows.

Under the microscope, the mineral composition of ultramafic rocks consists of variable proportions of hypidiomorphic crystals (2 to 5 mm) of clinopyroxene, orthopyroxene and olivine. These primary minerals are partially recrystallized and altered. They are then replaced by serpentine, chlorite and magnetite.

Granulitic Orthogneiss (Aqim4)

Granulitic orthogneisses are characterized by the presence of two pyroxenes (clinopyroxene and orthopyroxene). These orthogneisses mainly consist of tonalite, which may contain cm-scale dioritic bands that represent between 1 and 25 % of the rock. This type of gneiss constitutes about 70 % of this unit. Granulitic orthogneisses also include trondhjemitic, granodioritic and granitic phases. Granulitic orthogneisses are migmatized and contain between 10 to 60 % felsic mobilizate. They locally host mafic enclaves composed of metagabbro, amphibolite or mafic gneiss. These enclaves account for less than 10 % of the unit, and are generally of small size (< 2 m^2). Hornblende-epidote-biotite bearing amphibolitic orthogneisses are also included in this unit (Aqim4).

In thin section, the orthogneisses are medium-grained (0.5 to 2.0 mm) and display a granoblastic texture. The rock is locally coarser-grained (1 to 4 mm) and more massive. These massive facies, generally observed in more potassic rocks (granodiorite, granite) contain, despite the recrystallization, a relic coarse texture of magmatic origin. In gneissic rocks, the mafic minerals tend to concentrate in bands of dioritic composition. These ferromagnesian minerals, commonly present as porphyroblasts, include reddish biotite, clinopyroxene, orthopyroxene and green hornblende. Garnet porphyroblasts (~2 %) are rarely observed. Between 1 to 10 % opaque minerals, essentially magnetite, are disseminated throughout the rock. The most commonly observed accessory minerals are apatite and zircon.

Granodiorite, Granite (Aqim5a)

Granodiorite and granite intrusions, large enough to be represented on our map at a scale of 1:250,000, were individualized. These felsic intrusions with diffuse contacts were emplaced after the orthogneisses since, on the one hand, they cross-cut the latter, and on the other hand, they are not as deformed. Lithologies included in unit Aqim5a are generally massive to weakly foliated and contain idiomorphic potash feldspar crystals. They are moderately migmatized (5 to 35 % felsic mobilizate) and contain very little (<5 %) mafic enclaves.

In thin section, both the granodiorite and the granite display a coarse igneous texture. Static (thermal) recrystallization has partially obliterated the latter. The average grain size varies from 2 to 4 mm, and phenocrysts observed in porphyritic varieties may reach up to 15 mm. These rocks contain between 1 and 15 % ferromagnesian minerals, mainly biotite and hornblende. Secondary epidote, generally associated with mafic minerals, is frequently observed. The most common accessory minerals are allanite, apatite and zircon.

Gabbronorite (Aqim6)

Small gabbronorite bodies are associated with the granulitic orthogneisses. They outcrop in the southern part of the Qimussinguat Complex. The gabbronorite is generally foliated and contains between 1 and 10 % felsic mobilizate. Under the microscope, it shows a polygonal granoblastic texture and is medium-grained (1 to 2 mm). The gabbronorite is composed of clinopyroxene (10 to 30 %), orthopyroxene (10 to 25 %), hornblende (10 to 40 %) and plagioclase (25 to 35 %). It contains between 1 and 10 % opaque minerals, mainly magnetite, disseminated throughout the rock.

Faribault-Thury Complex (Afth)

The Faribault-Thury Complex is a lithodemic unit originally defined in the Lac Peters area (Madore *et al.*, 1999). This unit mainly consists of amphibolitic orthogneisses hosting volcano-sedimentary rocks. These volcano-sedimentary rocks form a string of bands distributed along a NW-SE axis. The bands vary between 0.5 and 4.0 km in width, and do not exceed 15 km in length. Two bands, more extensive than all the others, were given informal names. These are: the Buet belt, located in the northern part of the area, and the Trempe belt, in the south, located near the community of Kangirsuk. The Faribault-Thury Complex also includes weakly foliated granodiorite and granite, as well as tabular monzonitic intrusions.

Paragneiss, marble and iron formation (Afth2)

Metasediments grouped in unit Afth2 consist of paragneiss, as well as rare horizons of iron formation and marble. These rocks occur as small bands (<1 km^2) whose restricted volume makes it impossible to represent them on our map at a scale of 1:250,000 and to differentiate them from volcanic rocks of unit Afth3. These metasediments are migmatized and display a tectonometamorphic banding.

In thin section, the paragneiss exhibits a granoblastic quartzofeldspathic matrix. Biotite (15 to 30 %) and garnet (1 to 5 %) are commonly observed in these rocks. The paragneiss also contains variable proportions of sillimanite, graphite, muscovite, rutile and tourmaline. Garnet porphyroblasts, generally poikilitic, contain small inclusions of biotite, sillimanite, quartz, plagioclase or graphite. Chlorite locally replaces biotite.

The marble has undergone complete static recrystallization of its constituent minerals. The average grain size of neoblasts is about 2 mm, but may reach up to 10 mm. The marble is composed of calcite or dolomite, and contains about 15 % accessory minerals such as diopside, forsterite (Mg-olivine), sphene, humite-group minerals and magnetite. These minerals are concentrated in mm-scale to cm-scale bands that define a tectonometamorphic banding.

Iron formations are metamorphosed and characterized in thin section by a well-developed granoblastic texture. They are generally banded, but may also be homogeneous or foliated. Their composition varies from one location to the next, but two principal facies were recognized: 1) the silicate facies, composed of quartz and iron silicates such as garnet and grunerite, and 2) the oxide facies, composed of magnetite and quartz.

Amphibolitic Metavolcanic Rocks (Afth3)

Metavolcanic rocks represent over 90 % of the volume of rocks composing volcano-sedimentary sequences in the Faribault-Thury Complex. They are mafic or intermediate in composition, although locally minor ultramafic rocks are also present. Small gabbroic intrusions with pyroxenitic phases locally outcrop in metavolcanic belts. This spatial association suggests a cogenetic link between these intrusive rocks and the volcanic rocks. These gabbros and pyroxenites may represent the feeder systems of volcanic edifices. Rocks of unit Afth3 are metamorphosed to the amphibolite facies. At a mesoscopic scale, the metavolcanic rocks display a penetrative foliation, accentuated by a cm-scale banding. They are locally little deformed, and may preserve volcanic textures and structures such as pillowed flows and flow breccias.

In thin section, mafic and intermediate volcanic rocks of the Faribault-Thury Complex are fine to medium-grained (0.2 to 3.0 mm) and have a granoblastic texture. The principal mineral phases are: green hornblende (55 to 75 %) and plagioclase (20 to 45 %). In many cases, hypidiomorphic hornblende porphyroblasts (2 to 3 mm) are oriented parallel to the fabric. Biotite is rare (<5 %) and is locally chloritized. Quartz (<5 %), epidote (<1 to 10 %), sphene (<1 to 5 %), garnet (<1 to 3 %) and clinopyroxene relics, almost entirely replaced by hornblende, are observed in minor proportions. Between 1 and 5 % opaque minerals, consisting of ilmenite and hematite, are scattered throughout the rock. Traces of secondary carbonates are present in several locations.

Ultramafic Rocks (Afth3a)

Ultramafic rocks in the Faribault-Thury Complex are spatially associated with mafic and intermediate metavolcanic rocks. Field relationships are not always helpful in confirming the intrusive or effusive nature of these ultramafic rocks. However, their interbedded occurrence with basic metavolcanic rocks, observed in a few locations, suggests an effusive origin for these rocks. In other areas, ultramafic rocks form km-scale intrusions that clearly cross-cut metavolcanic sequences.

Ultramafic outcrops generally have a positive relief relative to surrounding country rocks, and they form small hills. The ultramafic rocks have a buff-brown weathered surface. They are metamorphosed, generally massive and altered. They are locally fine-grained, but more typically medium-grained (1 to 5 mm). Ultramafic rocks consist of peridotite, pyroxenite and minor dunite.

Under the microscope, peridotites and dunites consist of a network of microcrystalline serpentine fibres that form up to 75 % of the rock. Olivine or pyroxene relics are present. The serpentinized matrix is disseminated with magnetite (~15 %) and contains pods of clinochlore (Mg-chlorite) and calcite. In pyroxenites, primary pyroxene crystals are variably replaced by green hornblende. Acicular tremolite porphyroblasts are also locally observed. Minor epidote, magnetite and sphene are generally present in these rocks.

Ultramafic rocks that clearly appear to be effusive in nature, have an aphanitic matrix mainly composed of chlorite, replacing ferromagnesian minerals. Olivine, where present, may form up to 15 % of the rock. It occurs as phenocrysts (1 to 8 mm) partially replaced by chlorite and with magnetite-filled fractures. These ultramafic rocks also contain a significant proportion of fine-grained (0.1 to 1.0 mm) tremolite (20 to 40 %). Anthophyllite, epidote, talc and sphene are the most common accessory minerals observed in these rocks.

Amphibolitic Orthogneiss (Afth4)

Amphibolitic orthogneisses of unit Afth4 are largely predominant in the Faribault-Thury Complex. This unit mainly consists of tonalitic orthogneiss intercalated with trondhjemitic, granodioritic and less commonly, granitic phases. These rocks generally contain dioritic ribbons and schlieren rich in ferromagnesian minerals such as biotite. They are migmatized and contain between 5 to 50 % felsic mobilizate as well as 5 to 25 % mafic enclaves (amphibolitic, dioritic and gabbroic). Rocks of unit Afth4 are for the most part metamorphosed to the amphibolite facies.

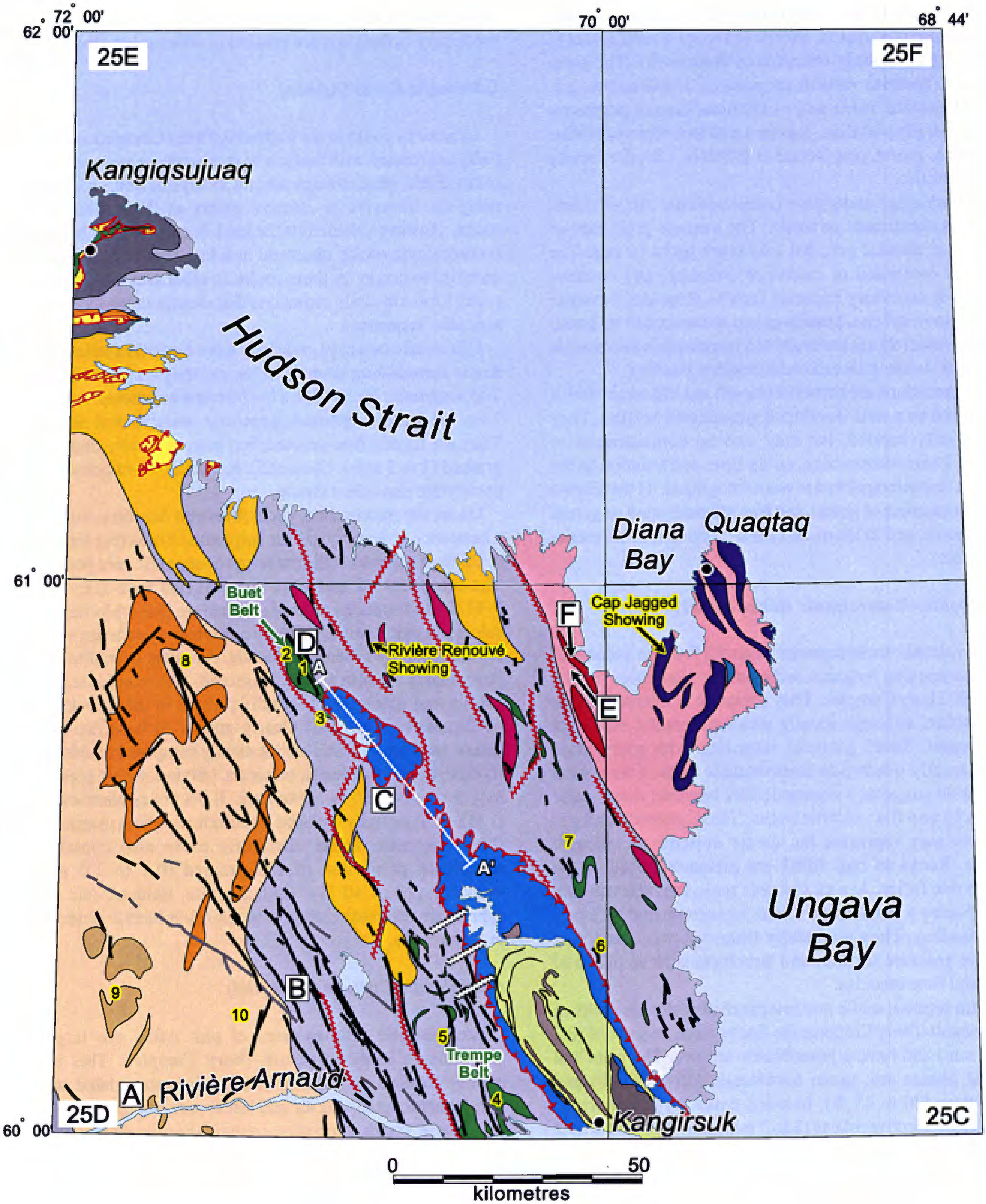

FIGURE 2 – Simplified geology of the rivière Arnaud area (NTS 25D) and adjacent coastal areas (NTS 25C, 25E and 25F).

STRATIGRAPHIC LEGEND

UNGAVA TROUGH

PALEOPROTEROZOIC

Povungnituk Group

- Basalt, gabbro, peridotite, amphibolite
- Semi-pelite, quartzite, iron formation, pelite

LABRADOR TROUGH

MESOPROTEROZOIC

Kyak Gabbro

- Hypersthene gabbro, peridotite

PALEOPROTEROZOIC

Montagnais Sills

- Gabbro, chlorite-actinolite schist

Kaniapiskau Supergroup

- Basalt, tuff and mudrock
- Pelitic schist, quartzite, arenite and iron formation

REMOBILIZED SUPERIOR PROVINCE

ARCHEAN TO PROTEROZOIC

Diana Strutural Complex

- Porphyritic monzonite and quartz monzonite (APdia4)
- Mylonitic tonalitic orthogneiss (APdia3)
- Amphibolite, mafic gneiss, ultramafic rocks (APdia2)
- Paragneiss, marble and calc-silicate rocks (APdia1)

DYKE SWARMS

PALEOPROTEROZOIC

- Payne River Dykes (pPpay)
- Klotz Dykes (pPktz)

SUPERIOR PROVINCE

ARCHEAN

Faribault-Thury Complex

- Porphyritic monzonite, quartz monzonite (Afth6)
- Granodiorite, granite (Afth5a)
- Gneissic tonalite with mafic enclaves (Afth4a)
- TTG-suite amphibolitic orthogneiss (Afth4)
- Metavolcanic, ultramafic and metasedimentary rocks (Afth3, 3a and 2)

Qimussinguat Complex

- Gabbronorite (Aqim6), ultramafic rocks (Aqim3a)
- Granodiorite, granite (Aqim5a)
- TTG-suite granulitic orthogneiss (Aqim4)

	Thrust fault
	Shear zone with dextral movement
	Shear zone with sinistral movement
F	Geochronological sample location
A—A'	Geological cross-section (figure 6)
Rivière Renouvé Showing	Mineral occurrence*
10	Lithogeochemical anomaly*

** See tables 2 and 3 for grades*

FIGURE 2 (continued) – Simplified geological legend.

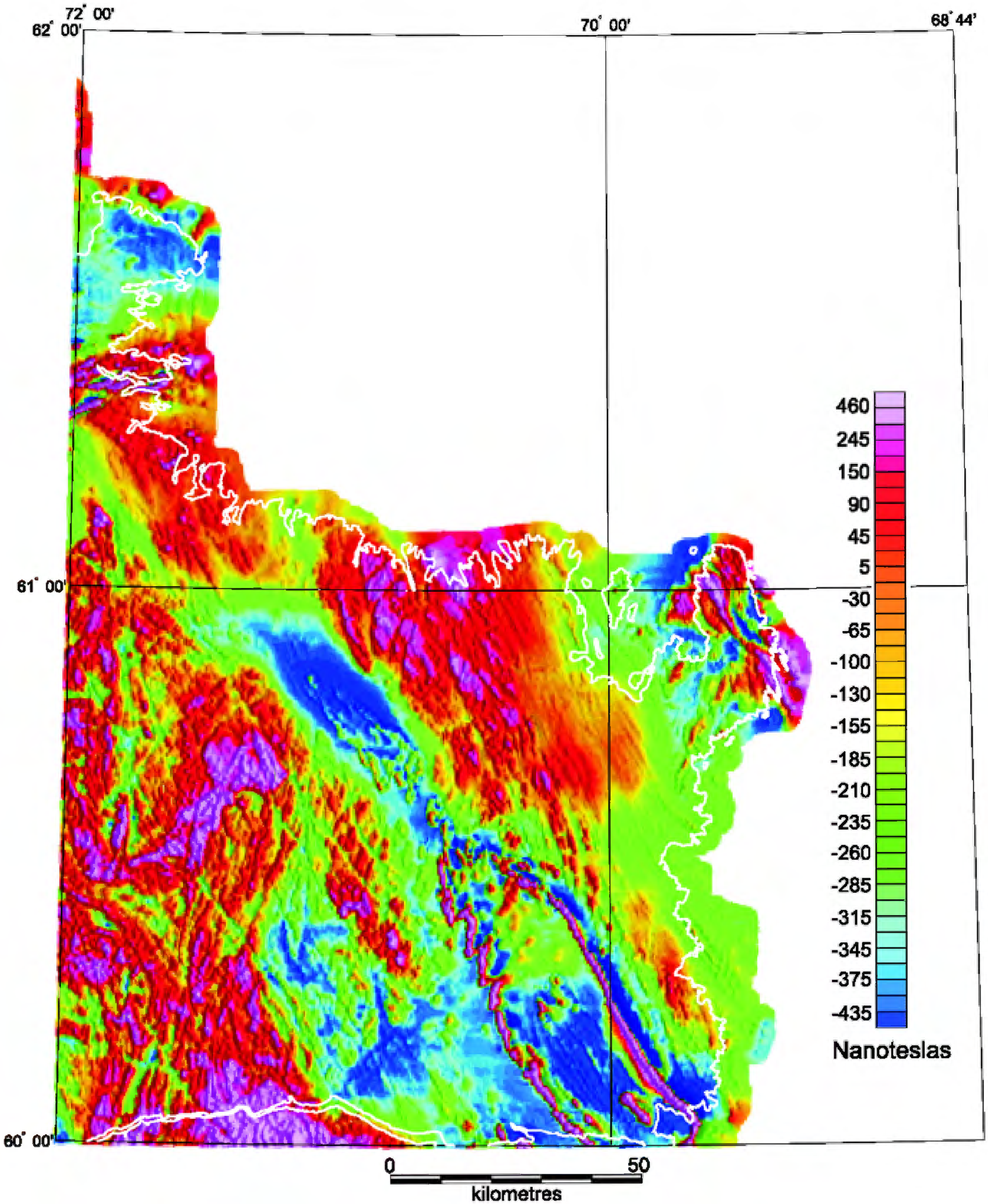

FIGURE 3 – Shaded total magnétic field, NTS sheets 25C, 25D, 25E et 25F. Map prepared by D.J. Dion and M. Copti.

In thin section, most rocks in this unit display a granoblastic texture. Microfabrics are affected by a deformation of variable intensity. Less deformed rocks locally contain idiomorphic antiperthitic plagioclase grains that were preserved from deformation and recrystallization. More deformed rocks have a mylonitic foliation partially obliterated by static recrystallization.

Quartz generally occurs as polycrystalline ribbons. Plagioclase crystals are sericitized and contain small grains of secondary epidote and calcite. Tonalitic, granodioritic and granitic phases contain between 10 and 40 % ferromagnesian minerals, whereas trondhjemitic phases contain less than 10 %. Biotite and hornblende are the most common ferromagnesian minerals observed in these rocks. Dioritic ribbons present in the orthogneisses are composed of plagioclase, hornblende and biotite as well as amphibolitized clinopyroxene relics. Locally, the orthogneisses contain muscovite and garnet. Accessory minerals are: oxides (magnetite and ilmenite), zircon, sphene (<8 %), apatite and allanite.

Gneissic Tonalite with Mafic Enclaves (Afth4a)

This facies was originally identified in a geological survey at 1:100,000 scale conducted by the Geological Survey of Canada (St-Onge and Lucas, 1997). The gneissic tonalite of this unit is petrographically similar to the tonalitic orthogneiss previously described in unit Afth4. However, it contains abundant mafic and ultramafic enclaves. The gneissic tonalite with mafic and ultramafic enclaves outcrops in the northwestern quadrant of the study area, near the village of Kangiqsujuaq.

Granodiorite, Granite (Afth5a)

On a regional scale, large intrusive bodies of granodiorite and granite are observed. These intrusions with diffuse contacts were emplaced in amphibolitic orthogneisses of unit Afth4. The granodiorite and granite of unit Afth5a contain very little felsic mobilizate, and generally less than 5 % mafic enclaves. These intrusive rocks are locally massive but often display a mineral foliation essentially defined by the orientation of biotite.

From a petrographic standpoint, the granodiorite and granite of unit Afth5a are comparable to those of unit Aqim5a observed in the Qimussinguat Complex. These rocks have a coarse igneous texture, partially obliterated by static recrystallization. They are medium-grained (between 2 to 4 mm) and contain between 1 to 15 % ferromagnesian minerals such as biotite and hornblende. They also contain traces of allanite, apatite and zircon.

Porphyritic Monzonite and Quartz Monzonite (Afth6)

Monzonitic rocks of unit Afth6 intrude orthogneisses of unit Afth4. These monzonitic intrusions with sharp contacts form tabular bodies several kilometres in size oriented parallel to the regional fabric. Typically, these rocks, which consist of monzonite and quartz monzonite, display a porphyritic texture. They are generally deformed, with a foliation defined by the alignment of feldspar phenocrysts and ferromagnesian minerals. They may also appear massive locally.

In thin section, monzonitic rocks are affected by a recrystallization process preferentially near the margins of feldspar phenocrysts as well as in the quartzofeldspathic matrix. The preferential orientation of quartz neoblasts indicates that recrystallization took place during an episode of ductile deformation (dynamic recrystallization). However, idiomorphic feldspar phenocrysts are preferentially oriented. This type of fabric, typical of syntectonic intrusions, generally forms in magmatic or sub-magmatic conditions. Monzonitic rocks contain between 25 to 50 % idiomorphic orthoclase and microcline phenocrysts (1-5 cm). They also contain smaller plagioclase phenocrysts (20 to 35 %) that are generally sericitized. The groundmass consists of quartz (5 to 20 %), biotite (5 to 15 %) and green hornblende (<1 to 10 %). Hornblende and biotite are locally chloritized. Accessory minerals are: apatite, sphene, epidote and zircon. Between 1 to 3 % oxides (magnetite and ilmenite) are present as small grains disseminated in the rock.

Paleoproterozoic

Payne River Dykes (pPpay), Klotz Dykes (pPktz)

Archean rocks in the area are intruded by two Paleoproterozoic dyke swarms; the Payne River Dykes and the Klotz Dykes, two lithodemic terms respectively introduced by Fahrig *et al.* (1985) and Buchan *et al.* (1998). The Payne River Dykes are clearly predominant and cross the entire area with a principal orientation at 330° N. Klotz Dykes, generally oriented 310°N, occur in the southern part of the area, in the vicinity of the Rivière Arnaud. They are abundant further south, in the Lac Peters area (Madore *et al.*, 1999). K-Ar isotopic analyses of two samples from chilled margins suggest, for the Payne River Dykes, an emplacement age slightly older than 2000 Ma (Fahrig *et al.*, 1985). A sample from the Klotz Dykes yielded a U-Pb age of 2209±1 Ma (Buchan *et al.*, 1998).

Paleoproterozoic dykes, which vary in thickness between 15 and 100 m, transect the area over distances reaching up to 50 km. They are excellent markers which help identify the effects of Proterozoic deformation affecting the rocks in the area. In the western part of the area, essentially underlain by rocks of the Qimussinguat Complex, Paleoproterozoic dykes are neither deformed nor metamorphosed. Further east, in the Faribault-Thury Complex, these dykes are locally deformed and metamorphosed to the greenschist facies. The deformation and metamorphism observed in the dykes tend to increase eastward. In the Diana Structural Complex located in the eastern part of the area, these dykes lose their original igneous attributes. They display a fabric and metamorphic assemblages typical of deformation under amphibolite facies conditions.

The freshest Paleoproterozoic dykes are medium to coarse-grained gabbro with an ophitic texture. These rocks contain idiomorphic plagioclase crystals surrounded by a clinopyroxene matrix. Fe-Ti oxides, minor quartz and biotite are also present. Dyke margins are chilled over about 10 cm. Their mineralogy is characterized by idiomorphic plagioclase and augite microcrystals, aligned parallel to the dyke margins. Dykes are locally altered and contain minor chlorite and amphibole, partially replacing ferromagnesian minerals, as well as sericite and epidote associated with plagioclase.

Archean to Proterozoic

Diana Structural Complex (APdia)

The Diana Structural Complex is a new lithodemic unit that designates a lithological assemblage mostly Archean in age but that was tectonically reworked during the Proterozoic. This complex essentially consists of tonalitic orthogneisses, which contain bands of paragneiss, amphibolite and ultramafic rocks. Rocks of the Diana Structural Complex are generally mylonitized and migmatized. These rocks are for the most part metamorphosed to the amphibolite facies. The metamorphic grade locally reaches the granulite facies in the eastern part of the complex.

Paragneiss, Marble and Calc-Silicate Rocks (APdia1)

Unit APdia1 forms bands about 5 km wide. These bands may have a lateral extension reaching up to 40 km in length. This unit is mainly composed of paragneiss with intercalated marble and calc-silicate rock horizons. These layers are on the order of one metre thick, and generally do not exceed 50 metres in length. All the lithologies display a tectonometamorphic banding. Metasediments of unit APdia1 are migmatized and contain between 10 to 50 % granitic mobilizate. Metasedimentary bands, inserted in the tonalitic orthogneisses (APdia3), are tectonically transposed parallel to the structural fabric.

Under the microscope, paragneisses display a heterogranular granoblastic texture. The quartzofeldspathic matrix is fine-grained (0.2 to 1.0 mm). Biotite porphyroblasts, for the most part oriented parallel to the foliation, vary between 0.5 to 2.0 mm in size, and form between 15 and 40 % of the rock. Locally, chlorite replaces biotite. Garnet porphyroblasts between 1 to 5 mm, are frequently observed in these rocks. These porphyroblasts are generally poikilitic, and contain small inclusions of biotite, quartz or plagioclase. The paragneiss also contains variable proportions of epidote, calcite, muscovite, green hornblende and sphene. Small quantities of fine-grained opaque minerals (<5 %) are scattered throughout the rock.

Amphibolite, Mafic Gneiss, Ultramafic Rocks (APdia2)

The Diana Structural Complex contains a restricted volume of mafic and ultramafic rocks. These are spatially associated with paragneiss bands. They occur as small bands inserted within paragneiss assemblages, or as small elongate bodies with a surface expression of 30 km^2 or less.

Amphibolites are generally homogeneous and well foliated. These rocks are essentially composed of hornblende (45 to 75 %) and plagioclase (25 to 40 %). Minor proportions of sphene, biotite or garnet are also present locally. Under the microscope, amphibolites exhibit a grano/nematoblastic texture outlined by the preferential orientation of hornblende crystals. These rocks are generally fine-grained (0.5 to 1.0 mm).

Mafic gneisses are mineralogically similar to amphibolites. However, they contain more garnet (5 to 15 %) and biotite (1 to 10 %). They are characterized by a tectonometamorphic segregation producing a cm-scale banding. In thin section, these gneisses exhibit a fine-grained (0.5 to 1.0 mm) polygonal granoblastic texture. In many cases, prismatic hornblende crystals are oriented parallel to the foliation and to the lineation, thus defining a nematoblastic texture.

Ultramafic rocks constitute a very minor proportion of unit APdia2. They are metamorphosed, foliated and generally altered. Under the microscope, ultramafic rocks display a fine-grained matrix formed of an intricate network of chlorite, serpentine and talc crystals. The matrix locally contains relic clinopyroxene, orthopyroxene or olivine grains. Acicular tremolite porphyroblasts (1 to 5 mm long) are observed in these rocks. Minor quantities of biotite and hercynite (green spinel) may also be present in these rocks.

Mylonitic Tonalitic Orthogneiss (APdia3)

This unit constitutes the principal lithological assemblage of the Diana Structural Complex. It is mainly composed of tonalitic orthogneiss, along with dioritic, trondhjemitic and granodioritic phases. These orthogneisses are, for the most part, strongly deformed and typically display a planar mylonitic fabric accompanied by a well-developed stretching lineation. The mylonitic fabric is outlined by injections of granitic mobilizate transposed parallel to the structural fabric. These orthogneisses locally contain boudined horizons or mafic enclaves transposed and stretched parallel to the foliation.

In thin section, orthogneisses of unit APdia3 have a well-developed granoblastic texture, and are fine-grained (0.5 to 2.0 mm). Despite this anealed texture, relic quartz ribbons and plagioclase porphyroclasts have survived, and provide evidence of ductile deformation. Porphyroblasts of biotite (5 to 15 %), muscovite (1 to 5 %) and epidote (<1 to 3 %), are dispersed and oriented parallel to the foliation plane. Green hornblende porphyroblasts (<1 to 10 %) and small calcite patches (<1 %) are also observed locally. The most common accessory minerals are zircon, allanite, apatite and sphene.

Foliated or Mylonitic Porphyritic Monzonite and Quartz Monzonite (APdia4)

Monzonitic rocks in unit APdia4 form large km-scale tabular bodies oriented parallel to the regional fabric. These monzonitic rocks with sharp contacts intrude tonalitic orthogneisses of unit APdia3. Although they share numerous textural and mineralogical characteristics with monzonites of unit Afth6 (Faribault-Thury Complex), monzonitic rocks in the Diana Structural Complex are more strongly deformed and exhibit a very well-developed planar fabric. Relics of the porphyritic texture are however preserved. The planar fabric is characterized by the development of a protomylonitic to mylonitic foliation defined by the alignment of potash feldspar porphyroclasts and ferromagnesian minerals.

In thin section, monzonitic rocks display evidence of intense static recrystallization that has obliterated mylonitic textures. The quartzofeldspathic matrix is fine-grained (0.5 to 2.0 mm) and displays a granoblastic texture. Relic quartz ribbons are observed in the matrix. These monzonitic rocks contain between 20 to 40 % potash feldspar porphyroclasts (1 to 15 mm). Biotite (5 to 10 %), muscovite (1 to 5 %), green hornblende (<1 to 10 %) and epidote (1 to 5 %) are generally present. The most common accessory minerals are apatite, sphene, allanite and zircon.

METAMORPHISM

In the Rivière Arnaud area, the regional Archean metamorphism varies from the amphibolite facies to the granulite facies. U-Pb analyses were carried out on three monazites and two titanites. These analyses yielded metamorphic ages of 2707±3 Ma for the monazites (Madore *et al.*, 1999) and 2701±1 Ma for the titanites (David, personal communication). In the western part of the area, rocks of the Qimussinguat Complex are typically metamorphosed to the granulite facies. This granulitic metamorphism is represented by an orthopyroxene + clinopyroxene + hornblende + plagioclase + quartz ± biotite assemblage observed in the orthogneisses. Pyroxenes often display a polygonal granoblastic texture, indicating syntectonic recrystallization under high pressure and temperature conditions. Locally, primary (igneous) pyroxene relics are observed. These are coarse-grained and subhedral. The pyroxenes may be mechanically broken into small fragments and distributed along strings following the foliation planes, or they may also be recrystallized into small polygonal grains. These observations indicate that pyroxenes of igneous origin and of metamorphic origin, both coexist in the igneous rocks of the Qimussinguat Complex. The tectonometamorphic event responsible for the recrystallization and the disaggregation of pyroxene grains took place under granulite facies conditions.

Further east, in the Faribault-Thury Complex, regional Archean metamorphism is outlined by metamorphic assemblages typical of the middle amphibolite facies. Orthogneisses and metavolcanic rocks generally contain mineral assemblages comprising hornblende + biotite + garnet ± muscovite + plagioclase + quartz. Archean rocks of the Faribault-Thury Complex are locally retrograded to the upper greenschist facies or to the lower amphibolite facies. This retrograde metamorphism is related to the Paleoproterozoic tectonometamorphic events that affected this part of the Archean basement. This phenomenon is mostly manifested in shear zones which put the Paleoproterozoic supracrustal rocks (Ungava Trough to the north and Labrador Trough to the east) in contact with rocks of the Archean basement, as well as in the major strike-slip faults that cross the area. These shear zones generally form muscovite + biotite ± epidote ± chlorite schists.

The imprint of this Paleoproterozoic metamorphism increases eastward, and becomes penetrative in the Diana Structural Complex. Rocks in the Diana Structural Complex contain metamorphic assemblages consisting of biotite + muscovite + hornblende + epidote, typical of the amphibolite facies. Locally, at the eastern edge of the complex, the Paleoproterozoic metamorphism reaches the granulite facies, with the presence of granoblastic and poikiloblastic orthopyroxene crystals.

STRUCTURAL GEOLOGY

(Chapter written in collaboration with Normand Goulet)

A structural study, supported by cross-cutting relationships, has helped distinguish two major episodes of polyphase deformation. The first episode of deformation, which is essentially recorded in a structural fabric indicating a compression-driven regime, is Archean in age and affects the craton. The second episode of deformation corresponds to the collisional events that took place during the Paleoproterozoic (Ungava and New Québec orogens). The imprint of these deformational events is recorded in the Archean basement as well as in Paleoproterozoic dykes and supracrustal rocks. Between these two major deformation episodes, the emplacement of diabase dykes (Payne River

Dykes and Klotz Dykes) and the formation of volcano-sedimentary basins of the Ungava Trough and of the Labrador Trough indicate the occurrence of tectonic extension processes (rifting, between 2.2 and 1.9 Ga; see Van Kranendonk *et al.*, 1993 as well as St-Onge *et al.*, 2000).

Fabrics associated with Archean deformational events are well-developed in the western part of the area. They are however obliterated by Paleoproterozoic structures and progressively disappear eastward and northward to blend into the Ungava and Labrador orogenic belts. Archean fabrics form the tectonic pattern in the Qimussinguat and Faribault-Thury complexes. In the Qimussinguat Complex, this fabric is represented by a steeply-dipping foliation or gneissosity oriented N-S (Figures 4a and 5a). Mineral lineations, defined by the orientation of ferromagnesian minerals, are observed in the Qimussinguat Complex. They generally plunge steeply to the NW (Figure 5b). The Faribault-Thury Complex is characterized by a steeply-dipping structural fabric oriented NNW-SSE (Figures 4a and 5c). A mineral lineation defined by the orientation of metamorphic minerals such as biotite, hornblende and muscovite, accompanies the planar fabric. This lineation plunges steeply to the NW (Figure 5d). In the Qimussinguat and Faribault-Thury complexes, the planar fabrics (foliation and gneissosity) outline, both at the scale of the outcrop and at a regional scale, folds upon which ductile shear zones are superimposed. Regional folds have N-S oriented axial surfaces (Figure 4a). These folds are generally tight, upright or slightly overturned to the east and are locally disturbed by an undulation of their axial surface (Figure 4a).

The different Proterozoic regional structures help define two distinct styles of deformation. The first consists of structures associated with the thrusting of Paleoproterozoic sequences onto the Archean basement, and the second, of structures related to dextral strike-slip movements in a transpressional setting.

Structures associated with Proterozoic thrusting processes are characterized by shallowly-dipping shear zones (Figure 5g) between 5 and 10 metres thick. These shear zones are observed at the base of the Paleoproterozoic Lac Nagvaraaluk sequence and in the northern part of the Labrador Trough (Figure 4a). They affect both the Paleoproterozoic rocks and the Archean basement. Numerous kinematic indicators as well as stretching lineations shallowly plunging to the NW (Figure 5h) are observed in these detachment zones. These shear sense indicators lead us to conclude that tectonic transport of Paleoproterozoic supracrustal sequences onto the Archean basement took place from the NW towards the SE. Large amplitude folds, upright or slightly overturned to the SE with axial planes oriented NE-SW are associated with the detachment structures (Figure 4a). The geological cross-section shown in Figure 6 illustrates allochthonous Paleoproterozoic supracrustal sequences (Lac Nagvaraaluk sequence and northern tip of the Labrador Trough) resting on the Archean basement, separated by a basal detachment. In the north part of the area, Paleoproterozoic rocks of the Ungava Trough are also allochthonous relative to the Archean basement, and were affected by a tectonic transport towards the south and southeast (Lucas, 1989; St-Onge and Lucas, 1990c).

The regional transpressional deformation regime is manifested by several families of sub-vertical ductile faults between 10 to 100 metres thick. These faults are characterized by a mylonitic planar fabric associated with a well-developed subhorizontal stretching lineation (Figure 5j). Regional scale major faults are oriented ~320°N (Figures 4a and 5i) and show a dextral strike-slip movement. Subsidiary faults showing dextral movement (~30°N) and locally sinistral movement (~50°N) are associated with the major faults (Figure 4a). This family of contemporaneous faults affects the Archean rocks of the Faribault-Thury Complex as well as the Payne River and Klotz dykes. The effects of this deformation become more intense eastward, where the strike-slip faults become more frequent. These faults also locally affect detachment zones at the base of the Proterozoic Lac Nagvaraaluk sequence and the northern part of the Labrador Trough. Large amplitude regional folds with NW-SE oriented axial planes (Figure 4a), probably contemporaneous with the dextral strike-slip fault system, also affect the major detachment structures. The Proterozoic deformation sequence confers to Paleoproterozoic nappes believed to be associated with the Labrador Trough a narrow shape oriented along a NW-SE axis, with festooned flanks in the northernmost part (Figure 4a).

From the eastern boundary of the Faribault-Thury Complex and going eastward in the Diana Structural Complex, the regional fabric undergoes substantial modification (Figure 4a). In the Diana Structural Complex, expressions of the Archean deformation are completely obliterated by a Proterozoic penetrative deformation. This Proterozoic deformation is characterized by a mylonitic planar fabric oriented NW and shallowly dipping to the NE (average strike/dip of 320°N/27°; Figure 5e). All lithologies are transposed along this fabric, and the metamorphosed equivalents of the Payne River Dykes occur as amphibolite boudins parallel to the foliation. A well-developed stretching lineation accompanies the planar fabric. This stretching lineation is subhorizontal and oriented NW-SE (Figure 5f). Isoclinal folds are present along the regional planar fabric (Figure 4a).

The characteristics of Proterozoic structures, as well as the cross-cutting relationships between the various types of structures lead us to conclude that the tectonic regime changed from a thrust-driven regime with the formation of thrust sheets, to a transpression regime with the formation of major strike-slip faults. This suggests that the orientation of the tectonic stresses varied through time, the principal stress direction (σ^1) changing from a SE orientation to a SW orientation (Figure 4b). This variation in the orientation of tectonic stresses may have been inherited from the original geometry of the different "cratons" that collided in the North Atlantic region during the Proterozoic.

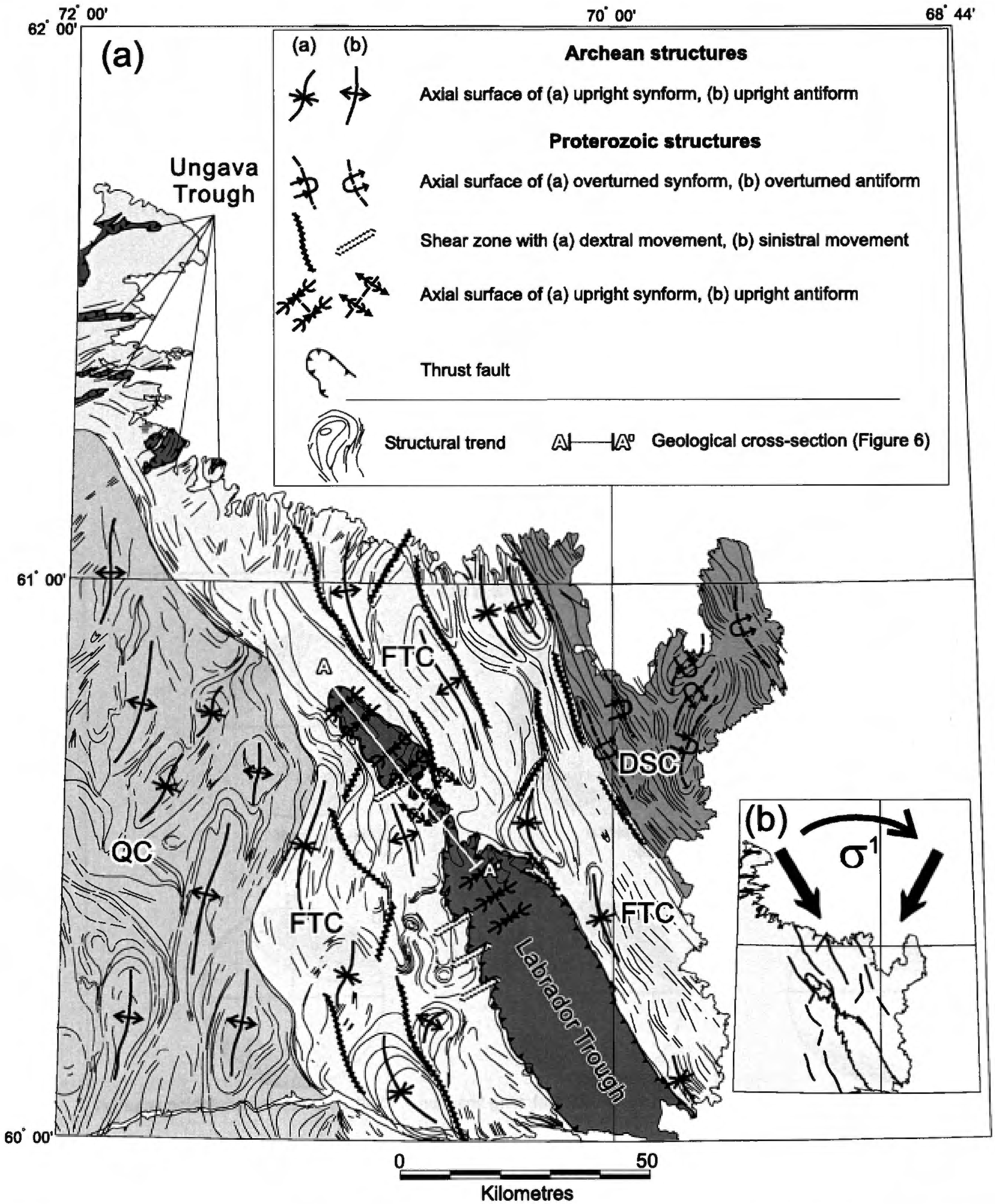

FIGURE 4 – a) Simplified representation of structural trends and regional structures. The structural trends are derived from the combined analysis of aerial photographs, magnetic field maps, remote sensing data (Landsat TM) and planar structural data measured in the field. QC = Qimussinguat Complex, FTC = Faribault-Thury Complex and et DSC = Diana structutral Complex. **b)** Orientation of the principal stress direction (σ^1) through time.

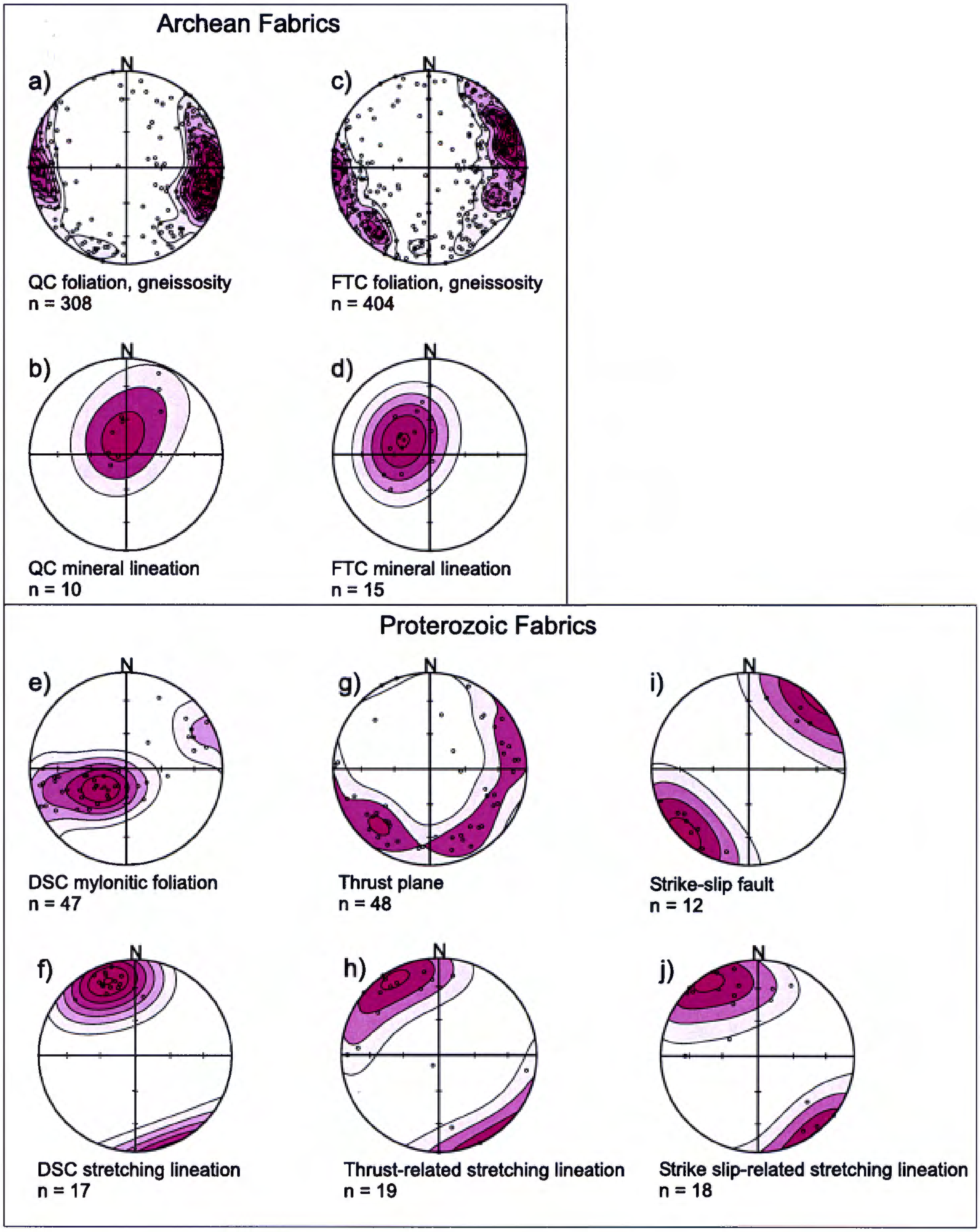

FIGURE 5 – Equi-area stereographic projections. The contours were drawn according to a method proposed by Robin and Jowett (1986). Stereograms a, c, e, g and i contain pole projections ofmeasured planes. Stereograms b, d, f, h and j show the projections of measured lineations. (n = number of measurements)

LITHOGEOCHEMISTRY

(Chapter written in collaboration with Charles Maurice)

During the geological survey, 147 rock samples were collected and analyzed for major and trace elements including rare earth elements (REEs). This sampling is representative of the principal lithologies present in the Rivière Arnaud area. Felsic intrusive rock samples essentially consist of tonalite, granodiorite and monzonite. Mafic intrusive rock samples are composed of gabbro, diabase, diorite and amphibolite whereas ultramafic intrusive rock samples consist of dunite and pyroxenite. Lavas were also sampled; these include basalts, andesites and komatiites. Most of the analyses were carried out by the Consortium de Recherche minérale of the Ministère des Ressources naturelles du Québec (COREM), and about twenty samples of mafic and ultramafic rocks were analyzed at McGill University. Major elements as well as trace elements Nb, Rb, Sm, Sr, Zr and Y were analyzed by X-ray fluorescence (XRF). REEs and the remaining trace elements were analyzed by neutron activation (INAA). Typical analytical results are listed in Table 1. Analytical results produced by the COREM are available via SIGÉOM, the database of Géologie Québec.

Felsic Intrusive Rocks

Results of lithogeochemical analyses carried out on felsic intrusive rocks are plotted on the diagram by O'Connor (1965) (Figure 7a). It shows a normative composition varying between the granite and the tonalite fields. These rocks have a calc-alkaline affinity (Figure 7b). They are metaluminous to peraluminous ($Al_2O_3 > CaO + Na_2O + K_2O$; Figure 7c), and are saturated in alumina ($0.95 < Al_2O_3/CaO+Na_2O+K_2O<1.14$; Zen, 1988). The parent magmas were probably derived from the anatexis of peraluminous and metaluminous (White and Chappell, 1977) and calcic (Peacock, 1931) crustal rocks. These felsic plutonic rocks have high Al_2O_3 (12 to 18 %) and SiO_2 (66 to 76 %) contents, and low MgO contents (0.10 to 4.74 %) and their Na_2O/K_2O ratio is high (between 1.0 and 8.5 for tonalite-enderbite samples and between 0.2 and 4.0 for granodiorite-monzonite-granite samples). Binary diagrams showing major elements Al_2O_3, CaO, FeOt, TiO_2 and MgO versus SiO_2 show negatively sloped correlations (Figure 8). This suggests that felsic plutonic rocks of the Rivière Arnaud area are composed of highly differentiated phases. The diagram K_2O versus SiO_2 (Figure 9) shows groupings in the low-K tholeiitic series, the calc-alkaline series, the high-K calc-alkaline series and the shoshonitic series. Granodiorite and monzonite samples containing about 70 % SiO_2 are enriched in potassium, whereas tonalite and enderbite samples with a similar SiO_2 content are depleted. Two hypotheses may explain the differences in K_2O content: a) all felsic plutonic rocks have undergone fractional crystallization from a similar source, or b) the granodiorite and the monzonite are derived from the partial melting and differentiation of the relatively primitive tonalite and enderbite.

The geochemical signature of trace elements in felsic plutonic rocks is similar from one complex to the other (Figures 10 a, b and c). On these diagrams, trace element patterns indicate that the rocks have undergone substantial fractionation and display positive anomalies in Rb, Ba, La, Nd and Eu. The negative Sm anomaly, supported by a slight

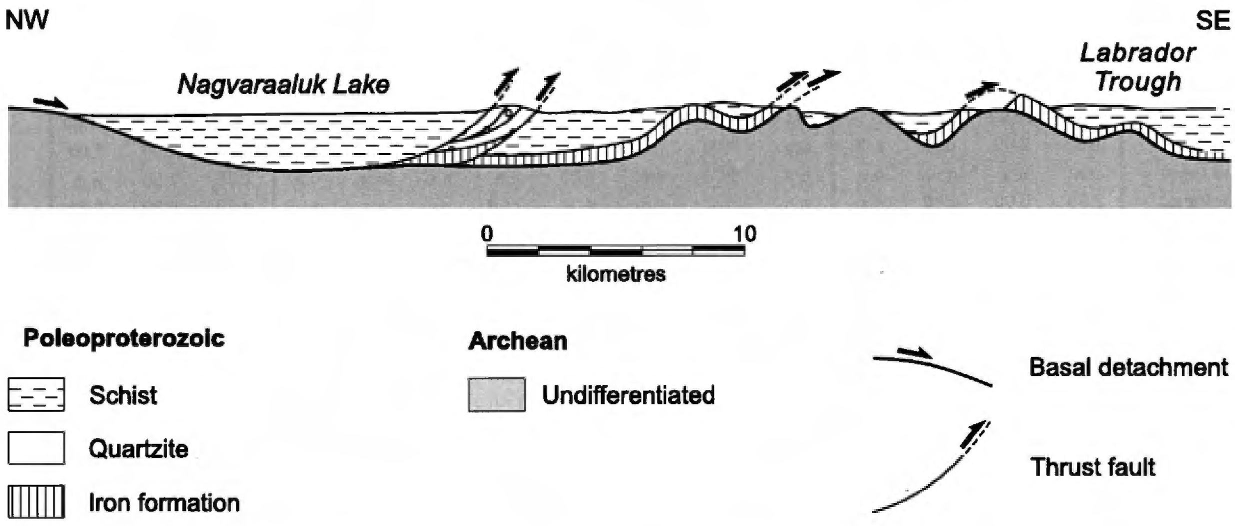

FIGURE 6 – NW-SE geological cross-section showing the structural relationship between Paleoproterozoic supracrustal sequences of the Lac Nagvaraaluk area and the Archean basement. The cross-section location is shown in Figures 2 and 4a.

TABLE 1 – Results of chemical analyses carried out on representative rock samples from the Rivière Arnaud area.

	Qimussinguat Complex				Faribault-Thury Complex								Diana structural Complex		
Sample	1016A	2105A	1006A	2212B	5113A	5206A	2080A	3237A	6171B	63	74	68	1131A	2250A	2218B
Lithology	I1D	I1T	I1C	V3	I1T	I1E	I1C	I2F	I2J	I3A	V3	I4	I1D	I2F	M4
SiO_2 (%)	67.90	68.22	70.41	48.86	67.16	77.32	72.34	40.96	49.35	48.62	46.47	37.17	66.34	49.06	67.01
TiO_2 (%)	0.40	0.48	0.37	1.00	0.74	0.05	0.25	3.85	0.65	0.31	0.73	3.07	0.33	0.17	0.52
Al_2O_3 (%)	16.42	15.25	15.86	14.75	15.33	13.56	15.13	16.28	18.01	17.21	15.21	4.89	15.90	19.56	16.30
Fe_2O_3t (%)	3.72	3.73	2.76	14.03	4.86	0.37	1.77	13.60	12.11	8.09	11.75	11.94	2.40	5.52	4.26
MnO (%)	0.05	0.06	0.05	0.26	0.06	0.01	0.03	0.14	0.18	0.16	0.18	0.14	0.04	0.11	0.05
MgO (%)	1.43	0.88	0.92	6.74	1.21	0.10	0.56	6.33	6.11	10.52	8.95	35.45	1.27	7.62	1.88
CaO (%)	4.09	2.75	3.08	8.77	3.14	2.57	1.49	7.48	8.20	10.19	13.03	0.85	3.71	11.60	4.16
Na_2O (%)	4.91	3.66	4.94	2.87	3.94	5.29	4.52	1.90	3.62	1.45	1.35	0.11	4.80	2.50	4.83
K_2O (%)	0.95	4.79	1.48	2.62	3.36	0.50	3.74	5.25	1.01	0.99	0.72	0.20	1.45	0.50	0.85
P_2O_5 (%)	0.12	0.17	0.11	0.07	0.20	0.01	0.05	0.41	0.02	0.02	0.05	0.25	0.06	0.01	0.13
LOI (%)	0.02	0.05	0.10	0.15	0.02	0.28	0.20	3.86	0.92	2.60	1.63	6.00	3.80	2.43	0.73
Total (%)	100.0	100.0	100.1	100.1	100.0	100.1	100.1	100.1	100.2	100.2	100.1	100.1	100.1	99.1	100.7
As (ppm)	0.50	0.50	0.50	4.20	2.30	370.0	0.50	0.50	0.50	n.a.	n.a.	n.a.	0.50	0.70	0.50
Co (ppm)	8.00	n.a.	6.00	49.00	9.00	320.0	n.a.	41.00	39.00	39	54	145	7.00	39.00	13.00
Cr (ppm)	n.a.	n.a.	n.a.	200.0	n.a.	520.0	n.a.	20.00	110.0	n.a.	n.a.	n.a.	21.00	49.00	28.00
Ni (ppm)	n.a.	250.0	n.a.	n.a.	n.a.	300.0	n.a.	100.0	n.a.	123	354	1375	100.0	120.00	n.a.
Cu (ppm)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	49	216	53	n.a.	n.a.	n.a.
Zn (ppm)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	48	54	104	n.a.	n.a.	n.a.
Sc (ppm)	5.60	21.00	5.60	42.00	7.20	1.30	2.80	27.00	35.00	n.a.	n.a.	n.a.	6.10	30.00	10.00
Cs (ppm)	n.a.	0.70	1.60	1.00	2.10	n.a.	1.60	15.00	n.a.	5.63	2.81	0.23	0.50	0.50	2.90
Rb (ppm)	18.00	77.00	59.00	67.00	94.00	17.00	140.0	339.0	11.00	61.2	54.2	2.2	56.00	8.00	31.00
Ba (ppm)	340.0	1400	280.0	400.0	1100	420.0	950.0	760.0	310.0	n.a.	n.a.	n.a.	260.0	80.00	210.0
Sr (ppm)	454.0	288.0	369.0	156.0	320.0	129.0	362.0	852.0	233.0	84.7	105.9	7.9	430.0	392.0	229.0
Nb (ppm)	3.00	12.00	6.00	6.00	14.00	9.00	8.00	10.00	6.00	3.9	4.3	0.5	4.00	n.a.	5.00
Ta (ppm)	0.70	1.20	1.20	0.70	0.60	n.a.	0.70	1.40	1.90	n.a.	n.a.	n.a.	n.a.	n.a.	0.70
Th (ppm)	n.a.	11.00	6.90	1.40	20.00	0.50	15.00	2.90	1.00	0.15	0.21	0.06	1.40	0.40	2.70
U (ppm)	n.a.	n.a.	n.a.	0.70	0.60	n.a.	1.60	1.00	n.a.	n.a.	0.05	0.05	0.50	0.50	n.a.
Zr (ppm)	113.0	327.0	143.0	65.00	277.0	57.00	126.0	106.0	87.00	14.0	30.5	3.0	106.0	30.00	125.0
Hf (ppm)	3.50	11.00	3.50	1.80	8.70	n.a.	4.90	2.70	3.00	0.46	1.00	0.13	3.00	n.a.	3.10
Y (ppm)	3.00	28.00	5.00	20.00	22.00	4.00	21.00	2.70	23.00	10.5	15.1	1.3	5.00	5.00	9.00
Pb (ppm)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	5.51	11.41	n.a.	n.a.	n.a.	n.a.
Sb (ppm)	n.a.	n.a.	n.a.	n.a.	n.a.	20.00	n.a.	0.10	n.a.	n.a.	n.a.	n.a.	0.10	0.10	n.a.
Se (ppm)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	5.00	n.a.	n.a.	n.a.	n.a.	5.00	5.00	n.a.
Ga (ppm)	18.00	19.00	20.00	20.00	20.00	19.00	17.00	22.00	24.00	10.9	14.4	2.7	20.00	14.00	20.00
W (ppm)	n.a.	2.00	n.a.	8.00	n.a.	9.00	n.a.	3.00	n.a.	n.a.	n.a.	1.72	2.00	5.00	5.00
Au (ppb)	n.a.	n.a.	n.a.	n.a.	n.a.	0.01	n.a.	2.00	n.a.	n.a.	n.a.	n.a.	2.00	2.00	n.a.
Br (ppm)	2.60	0.90	0.80	n.a.	n.a.	n.a.	n.a.	0.50	2.50	n.a.	n.a.	n.a.	0.50	0.70	0.80
Ag (ppb)	n.a.	5.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	5.00	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Mo (ppm)	n.a.	9.00	2.00	1.00	n.a.	64.00	2.00	n.a.	2.00	n.a.	n.a.	n.a.	n.a.	n.a.	2.00
La (ppm)	16.00	150.0	28.00	8.00	86.00	4.00	33.00	31.00	18.00	1.03	2.01	0.26	11.00	4.00	22.00
Ce (ppm)	28.00	260.0	48.00	16.00	140.00	8.00	55.00	56.00	39.00	1.96	5.10	0.49	21.00	6.00	33.00
Nd (ppm)	10.00	94.00	18.00	10.00	51.00	n.a.	19.00	44.00	21.00	1.54	3.97	0.26	12.00	n.a.	15.00
Sm (ppm)	1.70	16.00	2.90	3.20	9.30	0.70	6.20	11.00	5.80	0.55	1.33	0.07	2.20	1.10	2.90
Eu (ppm)	0.80	0.00	0.50	1.10	1.80	0.30	0.80	3.30	1.50	0.21	0.56	0.04	0.60	0.30	0.90
Tb (ppm)	n.a.	0.40	n.a.	0.40	n.a.	n.a.	n.a.	1.00	1.10	0.17	0.36	0.02	n.a.	n.a.	n.a.
Ho (ppm)	n.a.	1.20	n.a.	1.20	n.a.	n.a.	n.a.	n.a.	0.60	0.28	0.48	0.04	n.a.	n.a.	0.70
Yb (ppm)	n.a.	1.80	0.70	2.80	1.70	n.a.	1.80	2.00	2.20	0.95	1.48	0.22	0.70	1.00	0.80
Lu (ppm)	n.a.	0.30	n.a.	0.40	0.20	n.a.	0.20	0.30	0.30	0.14	0.21	0.03	n.a.	0.10	n.a.

Fe_2O_3t = Total iron oxides expressed as Fe_2O_3

n.a. = not analyzed

Lithology : I1C = granodiorite, I1D = tonalite, I1E = trondhjemite, I2F = monzonite, I2J = diorite, I1T=hypersthene tonalite, I3A = gabbro, I4 = ultramafic rock, M4 = paragneiss, V3 = basalt.

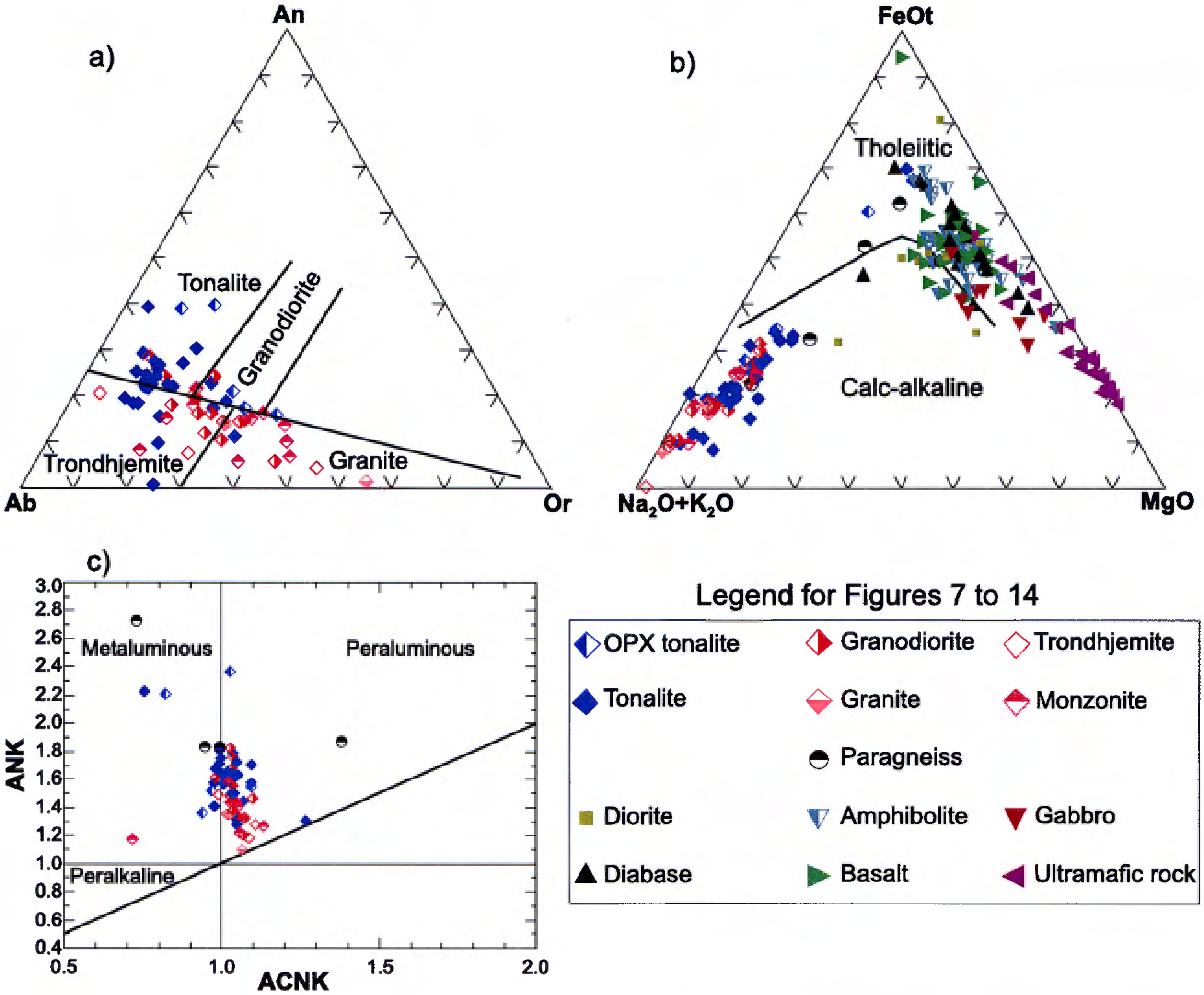

FIGURE 7 – **a)** Normative anorthite-albite-orthoclase diagram by O'Connor (1965) for felsic plutonic rocks. **b)** AFM ternary diagram by Irvine and Baragar (1971) for felsic, mafic and ultramafic rocks of the Rivière Arnaud region. **c)** Tectonic environment discrimination diagram by Maniar and Piccoli (1989) for felsic plutonic rocks, A/NK (Al_2O_3/Na_2O+K_2O) versus A/CNK ($Al_2O_3/CaO+Na_2O+K_2O$).

positive Nd anomaly (the latter being more incompatible than Sm), suggests that the felsic plutonic rocks underwent magmatic differentiation during their emplacement. Negative Nb and Ti anomalies are probably due to the fractionation of minerals such as sphene. The positive Ta anomaly suggests that the parent magma of the felsic plutonic rocks assimilated Ta-rich minerals and mafic material from the lower crust.

Mafic Rocks

Volcano-sedimentary rock sequences are essentially located in the Faribault-Thury Complex. Analyzed mafic and ultramafic rock samples were mainly collected in these sequences. A few rare mafic and ultramafic rock samples, which probably belong to highly dismembered volcano-sedimentary sequences, were also collected in the Qimussinguat Complex and the Diana Structural Complex.

Major element analyses identify most of the mafic rock samples as tholeiitic, with MgO contents varying between 3.6 to 29.4 wt %. The remaining samples fall in the calc-alkaline field (Figure 7b). Figure 11a shows that the mafic rocks are largely subalkaline, and that a small number of samples is scattered between the alkaline basalt field and the andesitic basalt field. These mafic rocks are characteristic of oceanic floor basalts (Figure 11b). A few samples fall in the fields for island arc basalts and continental arc basalts. This variation in composition is probably due to contamination during the ascension of lavas and the emplacement of mafic intrusive rocks.

Mafic rocks from the Qimussinguat, Faribault-Thury and Diana complexes have similar REE geochemical signatures (Figures 12a, b and c). REE patterns for these mafic rocks do not contain significant anomalies (Figures 12a, b and c). Mafic lavas have a flat pattern, typical of basaltic rocks.

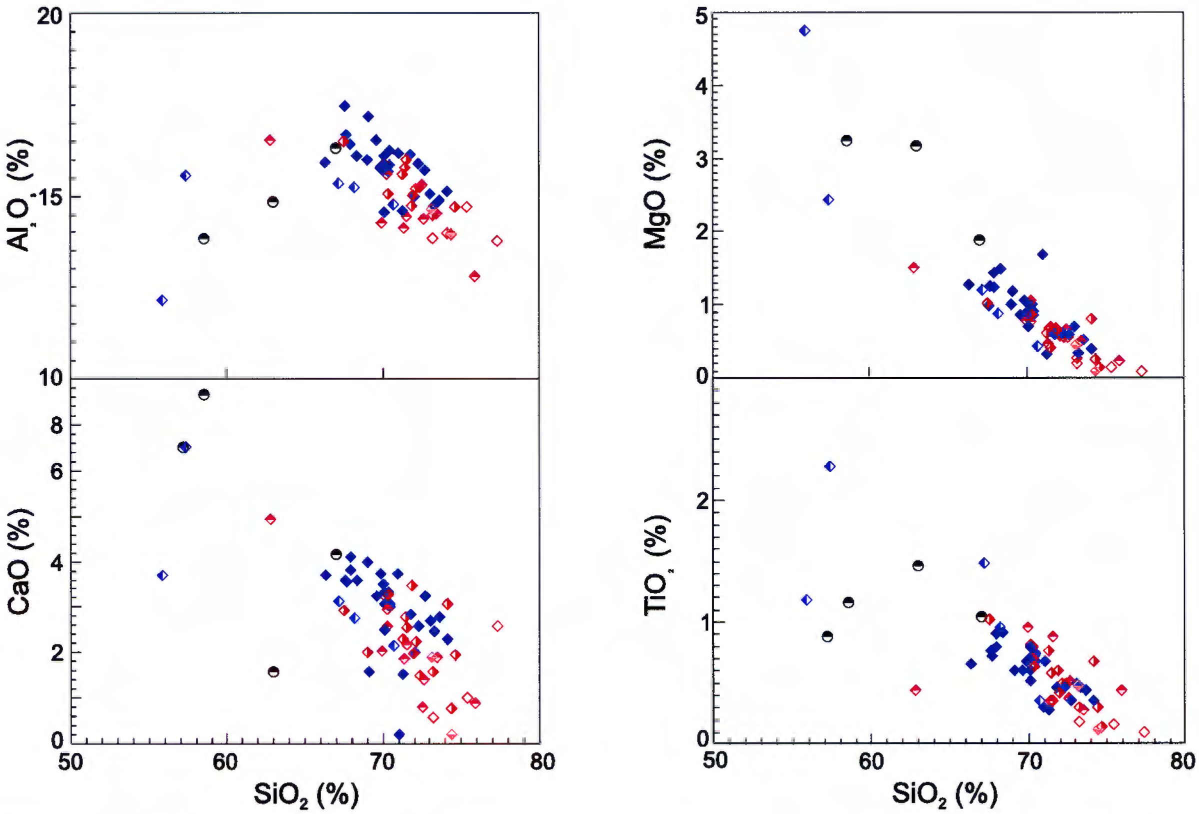

FIGURE 8 – Binary diagrams showing Al_2O_3, CaO, MgO and TiO_2 versus SiO_2 used to characterize the magmatic evolution of felsic plutonics rocks. See Figure 7 for legend.

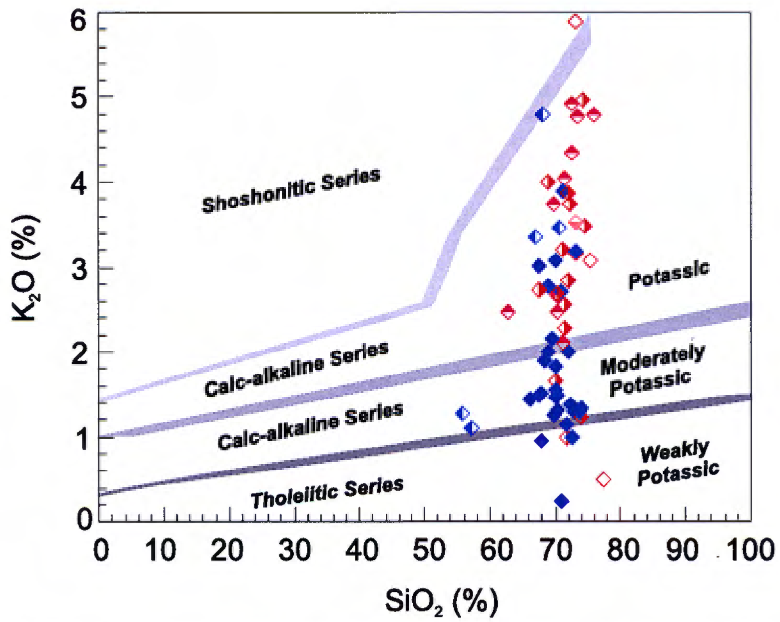

FIGURE 9 – Binary diagram by Rickwood (1989) showing K_2O versus SiO_2 to characterize felsic plutonic rocks. See Figure 7 for legend.

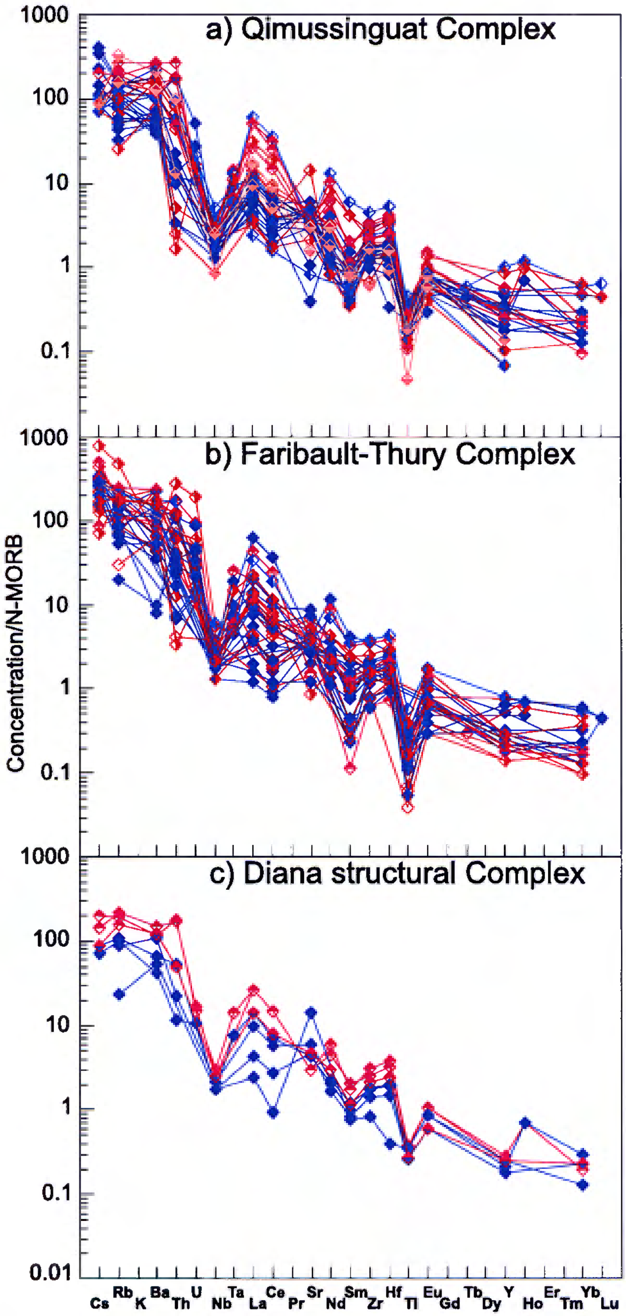

FIGURE 10 – N-MORB-normalized multi-element diagrams (Sun and McDonough, 1989) to characterize felsic plutonic rocks : **a)** Qimussinguat Complex, **b)** Faribault-Thury Complex and **c)** Diana Structural Complex. See Figure 7 for legend.

Gabbros and amphibolites have patterns very similar to those of basalts. They are, however, enriched in heavy REEs. Assimilation of heavy minerals (for example garnet) is probably the source of this slightly enriched heavy REE content. A few samples of gabbro and amphibolite are enriched in light REEs and display a negative Eu anomaly. This is probably the result of magmatic differentiation and mineral fractionation such as that of plagioclase. Diorites have REE patterns typical of differentiated mafic rocks enriched in light REEs and depleted in heavy REEs. Paleoproterozoic diabases (Payne River Dykes; pPpay) represent the most REE-enriched mafic rocks. This enrichment is probably caused by crustal contamination which took place during the emplacement of these dykes in an ancient crust.

Ultramafic Rocks

As opposed to mafic rocks which are strongly enriched in iron, ultramafic lavas are highly magnesian (Figure 7b) and generally depleted in K_2O (Table 1). In the triangular diagram Ti-Zr-Sr (Figure 11b), analyses of ultramafic rock samples fall in the oceanic floor basalt field. Samples falling in other basaltic fields suggest crustal contamination of these rocks during their emplacement.

REE patterns help identify two types of ultramafic rocks (Figure 13); a) REE-depleted ultramafic rocks, and b) REE-enriched ultramafic rocks. Depleted ultramafic rocks have flat REE patterns similar to those of tholeiitic basalts. These basalts however have higher REE concentrations. We may therefore assume that the basalts and depleted ultramafic rocks are derived from a single source or similar sources, and that they were generated either through fractional crystallization or by melting of a depleted source. Enriched ultramafic rocks have intermingled patterns with relatively steep slopes. These rocks are characterized by an enrichment in light REEs, and by REE concentrations as high as those of tholeiitic basalts. This signature represents a parent magma contaminated by continental crust, or a parent magma evolving in an island arc environment.

Geochemical Characteristics of Lithodemic Units

Qimussinguat Complex

Felsic intrusive rocks of the Qimussinguat Complex are essentially composed of two-pyroxene-bearing tonalitic orthogneiss (Aqim4) enclosing granodioritic and granitic bodies (Aqim5a). All these rocks have similar geochemical signatures and possess trace element patterns showing a common trend (Figure 10a). This suggests that these felsic intrusive rocks were derived from a similar source. Subtle differences in trace element concentrations were noted between tonalitic rocks (Aqim4) and granodioritic and granitic rocks (Aqim5a). The latter are enriched in Ba and depleted in La and Ti relative to tonalitic rocks (Aqim4)

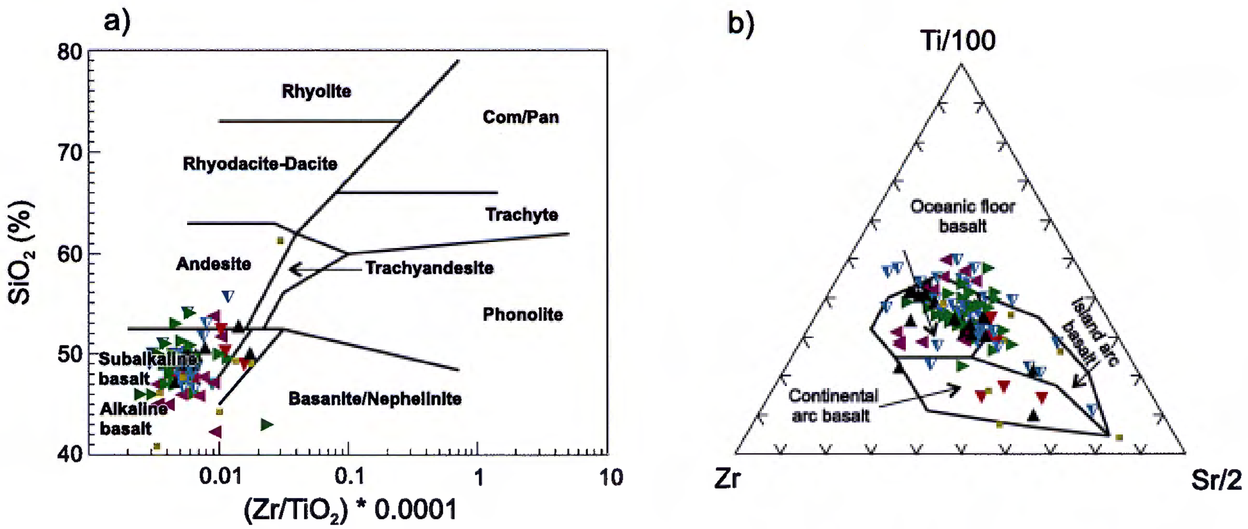

FIGURE 11 – a) SiO_2 versus Zr/TiO_2 classification diagram for mafic and ultramafic rocks of the Rivière Arnaud area (Winchester and Floyd, 1977). **b)** Ti-Zr-Sr paleotectonic diagram for mafic and ultramafic rocks (Pearce and Cann, 1973). See Figure 7 for legend.

(Table 1). These variations are probably due to the differentiation of tonalitic rocks (Aqim4).

Mafic (Aqim6) and ultramafic (Aqim3a) rocks of the Qimussinguat Complex have nearly identical geochemical signatures. Weak negative Eu anomalies were observed in REE patterns from mafic rock analyses (Aqim6) (Figure 12a). This suggests that the source underwent magmatic differentiation and a plagioclase fractionation. All ultramafic rocks in the Qimussinguat Complex fall in the enriched group. REE patterns are flat (Figure 13), typicial of undifferentiated and unfractionated mafic and ultramafic rocks (features generally associated with effusive rocks and related feeder systems).

Faribault-Thury Complex

Felsic rocks of the Faribault-Thury Complex consist of tonalitic orthogneiss (Afth4 and Afth4a), granodiorite (Afth6) and monzonite (Afth5a). These units have very similar geochemical signatures. Trace element patterns of felsic rocks belonging to the Faribault-Thury Complex are similar to those observed for felsic rocks of the Qimussinguat Complex and the Diana Structural Complex (Figures 10a, b and c). Generally, tonalitic rocks (Afth4 and Afth4a) have low Ti, Sm, Nb and Rb values (Figure 10b). Granodiorites (Afth6) are enriched in incompatible elements (Cs, Rb, Th and U) and monzonites (Afth5a) are enriched in Hf, Nd, Ce and La (Table 1).

Mafic volcanic rocks of the Faribault-Thury Complex (Afth3) all show comparable geochemical signatures (Figure 12b) whereas the geochemical signatures of ultramafic rocks (Afth3a) all appear to be distinct (Figure 13). Mafic volcanic rocks and enriched ultramafic rocks are very similar to those observed in the Qimussinguat Complex. However, depleted ultramafic rocks are characteristic of the Faribault-Thury Complex, and their REE patterns contain a positive Eu anomaly (Figure 13). This suggests that plagioclase was assimilated during the melting of the source rock. Overall, mafic rocks of the Faribault-Thury Complex are enriched in Mg (up to 30 % MgO), and depleted in Ti (<1 % TiO_2) and Zr (<89 ppm). The occurrence of Mg-rich lavas, the absence of intermediate to felsic volcanic rocks, the depletion in rare earth elements as well as the low Ti content characterize the volcanic rocks of the Faribault-Thury Complex. These observations suggest that these rocks represent the base of a large volcanic edifice where the upper portion was presumably eroded.

Diana Structural Complex

The composition of felsic intrusive rocks in the Diana Structural Complex does not show any major differences with that of other complexes. Small variations are noted on the trace element patterns (Figure 10a) of the various felsic intrusive lithologies belonging to the Diana Structural Complex. Trace element patterns from tonalite analyses (APdia3) indicate that these tonalites are more depleted than other felsic units. Monzonites (APdia4) are enriched in trace elements and are therefore more differentiated than the tonalites.

Mafic rocks (amphibolite and mafic gneiss) and associated ultramafic rocks (APdia2) represent a minute portion of the Diana Structural Complex. These rocks show a tholeiitic affinity (Figure 7b). REE patterns and concentrations observed in these rocks are similar to those observed in the Qimussinguat Complex (Figure 12a versus 12c). However, no REE anomaly was observed in mafic and ultramafic rocks of the Diana Structural Complex. These flat REE patterns indicate that these rocks did not undergo mineral fractionation or assimilation.

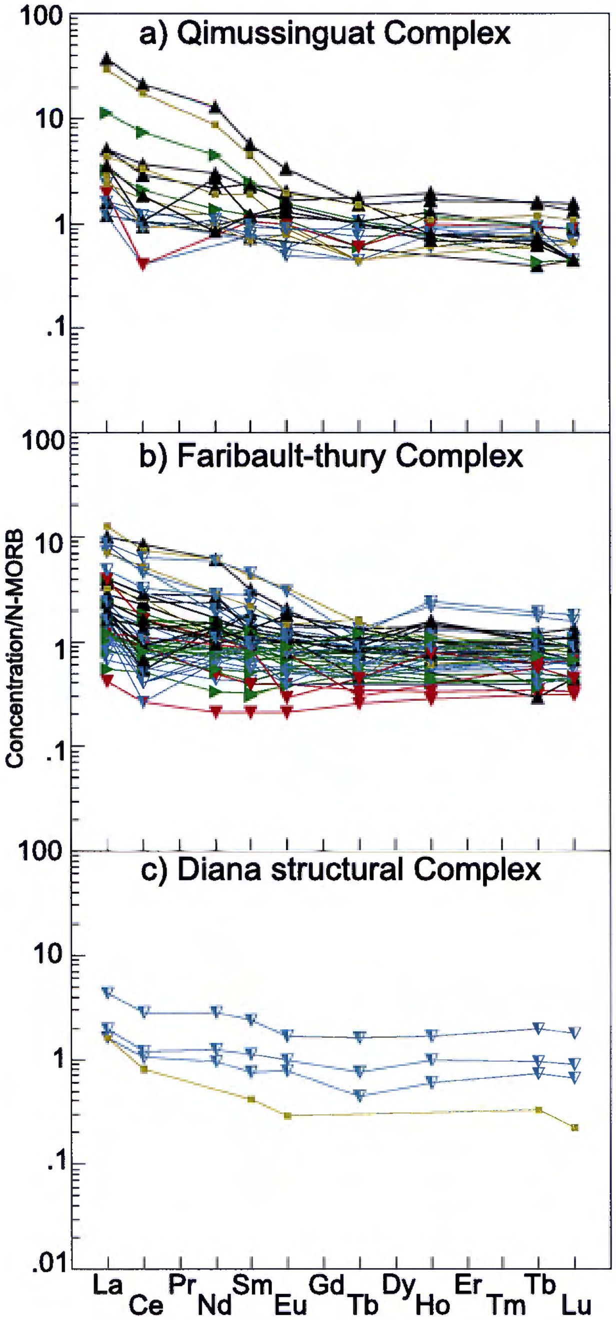

FIGURE 12 – N-MORB-normalized rare earth element concentration diagrams (Sun and McDonough, 1989) for mafic rocks : **a)** Qimussinguat Complex, **b)** Faribault-Thury Complex, **c)** Diana Structural Complex. See Figure 7 for legend.

Summary

The composition of felsic intrusions in the study area appears to be homogeneous, and only subtle differences are perceptible from one lithodemic complex to the next. These felsic rocks occur in the form of an extensive tonalite-trondhjemite-granodiorite/granite suite. These rocks probably formed in an active tectonic setting, either along an active margin, or during the collision of island arcs or micro-continents.

The diagram Ti versus Zr (Figure 14) allows to observe magmatic evolution trends for each rock type (felsic and mafic/ultramafic). For felsic rocks, the trend is typical of rocks that formed through magmatic differentiation. Mafic/ultramafic rocks, on the other hand, show a trend related to the fractionation of a parent magma and assimilation of crustal material by this magma. The latter group of rocks was therefore presumably derived by partial melting (with supporting AFC calculations) which produced mafic rocks (liquid) and ultramafic rocks (restite).

Volcano-sedimentary sequences mostly occur in the Faribault-Thury Complex. Mafic and ultramafic rocks associated with these sequences share geochemical features with MORBs. However, these Archean MORBs have much higher Fe contents and lower trace element contents (Zr, Y, REEs) than modern MORBs (Table 1). These observations suggest that the Archean upper mantle was enriched in Fe and had a chemical composition closer to that of chondrites than the modern mantle.

GEOCHRONOLOGY

(Chapter written by Jean David)

A geochronological study was undertaken on behalf of the Ministère des Ressources naturelles du Québec in the GEOTOP laboratories of the Université du Québec à Montréal. A portion of this study is based on six samples (A to F, Figure 2) collected from the three major lithodemic units present in the Rivière Arnaud area. Preliminary results from U-Pb isotopic analyses (isotopic dilution and thermal ionization mass spectrometry: TIMS) and ^{207}Pb and ^{206}Pb isotopic analyses (*in situ* analysis by laser ablation inductively coupled plasma mass spectrometry: LA-ICP-MS) helped determine emplacement and metamorphic ages as well as inherited ages. These results will also be discussed in a more detailed geochronological report (David, in preparation). This report will describe analytical methods, their respective precisions, statistical procedures used and results obtained for all samples collected under the Far North Project during the 1999 summer mapping program.

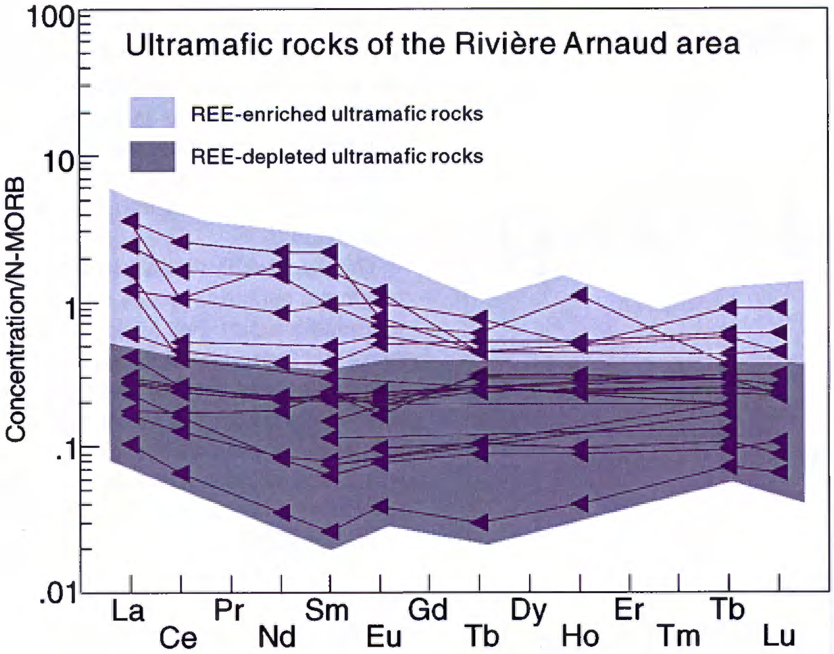

FIGURE 13 – N-MORB-normalized rare earth element concentration diagram (Sun and McDonough, 1989) for ultramafic rocks in the Rivière Arnaud area. See Figure 7 for legend.

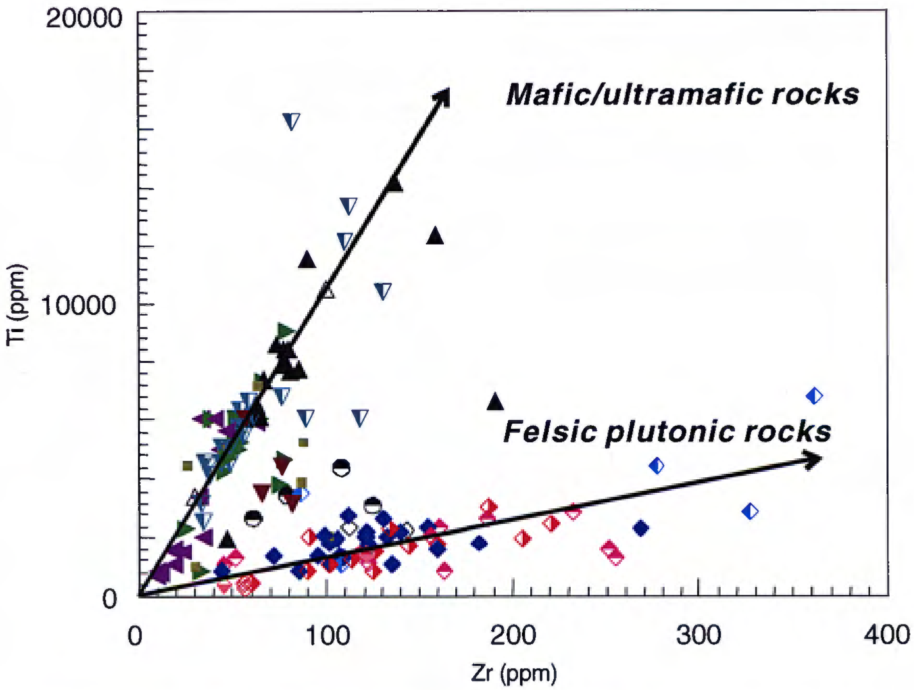

FIGURE 14 – Ti versus Zr binary diagram for felsic, mafic and ultramafic rocks of the Rivière Arnaud area. See Figure 7 for legend.

Qimussinguat Complex

Only one sample dedicated to the geochronological study was collected in the Qimussinguat Complex. It consists of a tonalitic orthogneiss from unit Aqim4, sampled near the Rivière Arnaud (site A, Figure 2; UTM coordinates, NAD83, Zone 19: 341173E, 6659535N). Orthogneisses of the Qimussinguat Complex are generally migmatized. However, the selected sample represents a homogeneous portion of the outcrop, and does not contain mobilizate. Zircons recovered from this sample form a homogeneous population of elongate prisms (proportions of 1:1:4) with dulled edges. The zircons are dark brown. More than half the crystals contain a pale brown core representing older zircons. Statistical treatment of $^{207}Pb/^{206}Pb$ isotopic ratios from 24 grains helped identify a well-defined principal mode corresponding to an age of 2857±5 Ma and a second mode associated with an age of 2809±11 Ma. Preliminary U-Pb analyses performed on fragments of prism terminations yielded minimum ages of about 2782 Ma. Despite the fact that these U-Pb results are discordant, they tend to support the $^{207}Pb/^{206}Pb$ age (LA-ICP-MS method) of 2809±11 Ma, the best indication we have for the age of emplacement of the tonalite.

Faribault-Thury Complex

Two tonalitic orthogneisses (Afth4) and a pillowed basalt (Afth3) from the Faribault-Thury Complex, as well as a dyke (pPpay) intruding orthogneisses (Afth4), were sampled for the geochronological study. The first tonalitic orthogneiss sample was collected in the south part of the area, near Lac Ammaluttuuq (site B, Figure 2; UTM coordinates, NAD83, Zone 19: 377700E, 6680409N). This tonalitic orthogneiss presents compositional variations on the scale of the outcrop, and contains a granodioritic phase. The orthogneiss is overall heterogeneous and migmatized. The sample was taken in a location where the lithology is homogeneous and free of mobilizate.

Zircons present in the tonalitic orthogneiss from site B belong to two distinct morphological populations. The first population consists of dark brown elongate prisms with a square section (proportions of 1:1:4), characterized by well-developed crystalline faces. The second population is formed of small stubby crystals, clear and pale brown. Statistical processing of $^{207}Pb/^{206}Pb$ isotopic ratios (LA-ICP-MS method) produced three distinct modes corresponding to ages of 2716±15 Ma, 2772±15 Ma and 2827±23 Ma. These ages are probably associated with three respective phenomena: lead loss possibly related to Archean metamorphism, tonalite emplacement, and finally, assimilation of inherited zircons. Results of U-Pb analyses currently underway should confirm $^{207}Pb/^{206}Pb$ ages and help provide a more accurate interpretation of these early results.

A second sample of tonalitic orthogneiss (site C, Figure 2; UTM coordinates, NAD83, Zone 19: 394,459 mE, 6,730,257 mN) was collected in the north part of the study area, bordering the Paleoproterozoic supracrustal sequences of the Labrador Trough. Despite the fact that this tonalitic orthogneiss is located near a major tectonic detachment zone separating the Paleoproterozoic cover from the Archean basement, it has preserved its Archean fabric. The orthogneiss sample was collected from a homogeneous outcrop free of mobilizate. Zircons from this sample belong to a single morphological family of square-sectioned prisms with double pyramidal terminations. Unfortunately, the vast majority of these zircons are metamict and Pb-Pb analyses (LA-ICP-MS method) did not yield reliable results. It is fairly characteristic to find this type of metamict crystals near regional faults, where hydrothermal fluid circulation is enhanced. The proximity of this tonalitic orthogneiss sample (site C) to thrust sheets will probably allow us to date, with the isotopic analysis of accessory minerals such as titanite, the thrusting episode which transported the Labrador Trough onto the Archean basement. The isotopic analysis of titanite populations present in the heavy mineral fraction of this sample is currently in preparation.

A sample of pillowed basalt was collected in the Buet volcanic belt (site D, Figure 2: UTM coordinates, NAD83, Zone 19: 390828E, 6745200N). This type of lithology is generally not favourable to find minerals that may be used in radiochronometry. Nevertheless, in a setting where felsic lavas and pyroclastic rocks are absent or impossible to identify with any confidence, the choice of a pillowed basalt becomes relevant for a geochronological study. The interest of dating this type of lithology is based on the fact that there is no ambiguity whatsoever concerning its effusive origin.

Only about twenty zircons were recovered from the basalt sample. These zircons, probably inherited from surrounding lithologies, consist of brownish xenomorphic crystal fragments with identifiable crystalline faces, except for two elongate prisms. U-Pb analyses carried out on 6 of these fragments yielded ages that vary between 2791.2 Ma (1.4 % discordant) and 2808.5 Ma (0.2 % discordant). These analyses are distributed along a single regression line with an upper intercept corresponding to an age of 2820±6 Ma, and a lower intercept at 1790±80 Ma. These results suggest that 2820±6 Ma would be the maximum age of emplacement for these lavas.

All analyzed zircons possess similar ages and identical $^{232}Th/^{238}U$ ratios. This suggests that these zircons were derived from a single crystallization event. Furthermore, the lithogeochemical study of volcanic sequences demonstrated that the basalts do not show evidence of contamination, and that very little exotic material was incorporated to the mafic volcanic rocks. The zircons did not crystallize from the basaltic magma itself, but are presumably derived from a felsic lithology belonging to the same volcanic sequence. Considering this hypothesis, the zircons could originate from a thin felsic tuff horizon that was ingested by the basaltic flow during its outpouring. The 2820±6 Ma age would therefore correspond to the age of emplacement of the basalt. As for the 1790±80 Ma age indicated by the lower intercept, although it is not precise, it is associated with a lead loss phenomena. It reflects the influence of metamorphism associated with the thrusting of Paleoproterozoic sequences onto the Archean craton.

Diana Structural Complex

A tonalitic orthogneiss (APdia3) and a porphyritic monzonite (APdia4) were sampled in the Diana Structural Complex. The tonalite (Site E, Figure 2; UTM coordinates, NAD83, Zone 19: 436445E, 6748776N) features a mylonitic fabric typical of the Diana Structural Complex. Zircons recovered from this sample form a single population of short, hexagonal uncoloured prisms (proportions of 1:2:4) with complex terminations. Results of Pb-Pb analyses (LA-ICP-MS method) yielded average ages scattered almost continuously between 2.71 and 2.99 Ga. Statistical treatment of these results did however outline two significant statistical modes. The principal mode, corresponding to a $^{207}Pb/^{206}Pb$ age (LA-ICP-MS method) of 2785±11 Ma, is interpreted as the age of emplacement. A secondary mode corresponds to an age of 3071±73 Ma.

U-Pb zircon analyses yielded results that indicate, upon regression analysis, an age of 2780±6 Ma (upper intercept) and an age of 1780 Ma (lower intercept). The age of 2780±6 Ma corresponds to the period of crystallization of the tonalite. An equivalent age was obtained through the determination of the $^{207}Pb/^{206}Pb$ ratio (LA-ICP-MS method). The age of 1780 Ma corresponds to a disturbance in the U-Pb isotopic system caused by Proterozoic metamorphism.

The analysis of 2 titanite fractions yielded discordant U-Pb results with minimum ages of 2598 Ma and 2610 Ma that are distributed on a Concordia diagram, along a reference line between 1785 Ma and 2670 Ma. These results indicate once more the influence of Proterozoic metamorphism around 1780 Ma. Furthermore, these results suggest the interaction of an older Archean metamorphic event at about 2670 Ma. Evidence of this Archean metamorphic event is observed in various locations throughout the NE Superior Province.

The porphyritic monzonite sampled near the western margin of the Diana Structural Complex (Site F, Figure 2; UTM coordinates, NAD83, Zone 19: 438130E, 6748329N) is characterized by a protomylonitic fabric. This monzonite forms part of a km-scale tabular intrusion oriented parallel to the regional fabric. Zircons recovered from this sample belong to a single population of brown idiomorphic elongate prisms. Statistical treatment of $^{207}Pb/^{206}Pb$ isotopic ratios (LA-ICP-MS method) produced two modes. The principal mode is associated with an age of 2731±3 Ma and the secondary mode, to an age of 2691±8 Ma.

U-Pb analytical results indicate an important loss of lead affecting zircon crystals, with the consequence that discordant ages between 2717 and 2735 Ma were obtained. These ages are comparable to those obtained from Pb-Pb analyses (LA-ICP-MS method). U-Pb analyses are scattered along a single isochron and regression analysis helped establish a lower intercept at 1787±20 Ma and an upper intercept at 2755±5 Ma. Consequently, the age of emplacement of the monzonite is estimated at 2755±5 Ma. This felsic magmatic age corresponds to a late phase that postdates the emplacement of Archean tonalites in the area.

ECONOMIC GEOLOGY

With the exception of exploration work carried out in the Paleoproterozoic supracrustal sequences of the Ungava Trough and the Labrador Trough, and of reconnaissance of Archean rocks by exploration companies, the mineral potential of the Rivière Arnaud area was poorly known. In 1997, the Ministère des Ressources naturelles completed, in collaboration with *Cambior*, *Falconbridge*, *Noranda*, *SOQUEM* and *Virginia Gold Mines*, a geochemical survey covering a major portion of the Ungava Peninsula, including the study area. This geochemical survey is now available to the public (MRN, 1998). Digital data of this survey are available in SIGÉOM under project number 1997-520. This geological survey covering the Rivière Arnaud area (NTS 25D) and adjacent coastal regions (NTS 25C, 25E and 25F) supports the efforts of the MRN in assessing the mineral potential of Québec's Far North region.

Economic Potential of Archean Rocks

During the geological survey, 50 samples were collected from rusty horizons containing sulphide mineralization, and analyzed for their base and precious metal contents. Two showings (Tables 2 and 4), and 10 anomalous occurrences were identified in three sectors (Tables 3 and 4) thanks to these analyses. The mineralization consists of Cu, Ag, Zn, Cr and Ni. Figure 2 shows the location of showings and anomalous occurrences. The principal geological environment hosting showings and anomalies consists of volcano-sedimentary bands. Mafic and ultramafic intrusions were also identified. Despite their high Mg content, only one minor showing was identified in these intrusions, which contain very few anomalous metal values.

Cap Jagged Showing

The Cap Jagged showing is located in the Diana Structural Complex, near Baie Diana (Figure 2, Table 2). It consists of biotite-garnet paragneiss that forms m-scale bands which extend for about 5 km and are surrounded by tonalitic country rocks. The paragneisses are cut by an abundance of m-scale quartz veins. They contain cm-scale sulphide-rich horizons (>20 % pyrite and chalcopyrite) and quartz vein wallrocks are mineralized in chalcopyrite. The analysis of surface samples yielded grades of 0.1 % Cu, 0.08 % Zn and 7 g/t Ag.

Rivière Renouvé Showing

The Rivière Renouvé showing is located at the contact between a Paleoproterozoic gabbro (pPpay) and the tonalitic country rock (Afth4). The sulphide zone (~10 % pyrite and chalcopyrite) is sheared and injected with quartz veins, indicating intense hydrothermal activity. The sulphides are disseminated in the gabbro and in the tonalite. An assay of 1.4 % Cu and 5 g/t Ag was obtained.

Anomalous Occurrences

About ten anomalous occurrences, from which were collected one or more mineralized samples, were identified in the study area (Figure 2, Table 3). Analytical results from rock samples collected at these locations contain anomalous base and precious metal values (Cu, Cr, Ni, Zn, Ag and Au) that are significant for mineral exploration. The majority of the anomalous occurrences (sites 1 to 7) are found in supracrustal rocks (volcanic rocks or paragneisses). Sites 8, 9 and 10 are associated with mafic rocks (enclaves or bands) enclosed in granulitic gneisses.

Anomalous occurrences 1, 2 and 3 are located in the northern part of the Faribault-Thury Complex, in the Buet belt (Figure 2, Table 3). Analytical results from basaltic (Afth3) and ultramafic (Afth3a) samples yielded grades on the order of 0.4 % Cu, 0.5 % Cr, 6 g/t Ag and 0.04 % As. The mineralization occurs as 5-10 % pyrite, ~5 % pyrrhotite and <5 % chalcopyrite disseminated in the rocks.

Anomalous occurrences 4 and 5 are located in the Trempe belt, in the southern part of the Faribault-Thury Complex (Figure 2, Table 3). Ni-Cr mineralization (0.2 % Ni and 0.4 % Cr) is present in talc-tremolite ultramafic lavas (Afth3a) and Zn mineralization (0.02 %) was found in m-scale rusty paragneiss bands. The mineralization consists of 5 to 15 % pyrite and <1 % pyrrhotite disseminated in the rocks.

Anomalous occurrences 6 and 7 (Figure 2, Table 3) are located in the eastern part of the Faribault-Thury Complex, in a volcano-sedimentary belt segment along the Rivière Trail. Cu mineralization (0.2 %) is found in metavolcanic rocks (mafic gneiss). This mineralization consists of <10 % pyrite and ~10 % chalcopyrite disseminated in the rock. An anomalous Ag occurrence (5 g/t) occurs in a diorite associated with metavolcanic rocks, and contains minor disseminated pyrite.

Anomalous occurrences 8, 9 and 10 (Figure 2, Table 3) are scattered in the granulitic gneisses of the Qimussinguat Complex. Anomalous Cu, Cr and Ag values are observed in samples from gabbronorite intrusions (Aqim6) or from mafic and ultramafic enclaves included in the granulitic gneisses (Aqim4). Analytical results for these mineralized samples are on the order of 0.15 % Cu, 0.5 % Cr, 3 g/t Ag and 0.08 g/t Au. The mineralization consists of pyrite (<15 %), pyrrhotite (~5 %) and chalcopyrite (<5 %) disseminated in the host rocks.

Economic Potential of Paleoproterozoic Sequences

As early as the 1930s, Paleoproterozoic sequences in the Lac Nagvaraaluk area and the northern part of the Labrador Trough (Figure 2) were prospected for iron. Iron formations of the Kaniapiscau Supergroup, located near the base of these sequences, were the focus of surface work and drilling

TABLE 2 – Characteristics of mineral occurrences. Showing locations are shown in Figure 2.

Showing	Location UTM NAD83	Substance and grade	Description
Rivière Renouvé	NTS 25D 398.055 mE, 6.753.342 mN	Cu = 1.4 % Ag = 5 g/t	Rusty horizon (>5 % disseminated sulphides) in a gabbro injected by cm-scale quartz veins, located east of the Buet volcano-sedimentary belt, Faribault-Thury Complex.
Cap Jagged	NTS 25C 358.132 mE,	Ag = 7 g/t Cu = 0.1 % Zn = 0.08 %	Garnet-bearing paragneiss cut by m-scale quartz veins. These rocks contain up to 30 % PY and 15 % CP.

TABLE 3 – Characteristics of anomalous sites. Site locations are shown in Figure 2.

1	*NTS 25D* 385.874 mE, 6.746.064 mN.	Cu = 0.3 % Cr = 0.5 %	Meter scale rusty horizons in a conformable or semi-conformable basaltic-ultramafic sequence, containing up to 10 % PY, 5 % CP and traces of PO.
2	*NTS 25D* 331.625 mE, 6.601.959 mN.	Ag = 6 g/t Cu = 0.2 % As = 0.04 %	Rusty contact zone between basalts and tonalites bordering the Buet volcano-sedimentary belt, containing disseminated sulphides. (< 10 % PY, ~ 15 % PO and < 5 % CP).
3	*NTS 25D* 390.449 mE, 6.737.644 mN.	Ag = 6 g/t Cu = 0.4 %	Basalt with disseminated PY (~5 %) and PO (10 %) mineralization. The rusty horizon extends along a shear zone separating Archean rocks and Proterozoic rocks of the Labrador Trough.
4	*NTS 25D* 420.728 mE, 6.659.833 mN.	Ni = 0.2 % Cr = 0.4 %	Disseminated sulphides (15 % PO) in talc-tremolite-bearing ultramafic rocks.
5	*NTS 25D* 412.090 mE, 6.672.130 mN.	Zn = 0.2 %	Fine disseminated sulphide mineralization (<5 % PY) in m-scale rusty paragneiss bands.
6	*NTS 25C* 442.917 mE, 6.690.422 mN.	Ag = 5 g/t	Rusty diorite with disseminated sulphides (<10 % PY, <1 % PO and <1 % CP).
7	*NTS 25D* 435.477 mE, 6.712.211 mN.	Cu = 0.2 %	Altered, rusty and weakly mineralized mafic gneiss. The mineralization becomes semi-massive in more intensely deformed zones of the outcrop.
8	*NTS 25D* 360.895 mE, 6.748.849 mN.	Cu = 0.15 %	Mafic gneiss enclaves (metavolcanic rock) in granulitic gneiss. Enclaves host PY (2 %), PO (2 %) and CP (trace) mineralization.
9	*NTS 25D* 345.881 mE, 6.682.577 mN.	Ag = 3 g/t Cu = 0.14 % Cr = 0.5 %	Disseminated PY (<10 %) and PO (~5 %) in km-scale lenses of mafic gneiss (metalavas) and ultramafic rocks.
10	*NTS 25D* 371.514 mE, 6.675. 413 mN.	Au = 0.08 g/t Cr = 0.5 %	Meter scale ultramafic enclaves in sheared granulitic gneiss. Enclaves are rusty and contain PY (~10 %) mineralization.

TABLE 4 – Threshold concentrations to discriminate mineralized showings as well as the most important lithogeochemical anomalies.

Mineral Substance	Threshold value used by Descarreaux (1973) to discriminate anomalies in the **Abitibi mining camp**	Threshold value used to discriminate showings for the **Rivière Arnaud** project	Threshold value used to discriminate important anomalies for the **Rivière Arnaud** project
Au	0.5 g/t	1 g/t	0.080 g/t
Ag	2 g/t	5 g/t	3 g/t
Cu	0.30%	0.50%	0.10%
Ni	0.20%	0.25%	0.20%
Zn	0.03%	0.75%	0.05%
Pb	0.02%	0.50%	0.05%
Cr	0.20%	1%	0.20%
As	0.01%	----	0.02%
W	0.10%	----	0.10%

programs. This work continued until the end of the 1970s without ever leading to a mining operation. More recently, prospecting work carried out on mafic/ultramafic sills intercalated in Paleoproterozoic sequences of the Labrador Trough yielded interesting grades in platinum, palladium and nickel. Anomalous gold concentrations were also detected in these rocks.

No mineralized showing was discovered in the rocks of the Ungava Trough outcropping in the study area. However, Ungava Trough rocks contain, further west, important Ni-Cu-PGE and asbestos deposits. The most important Ni-Cu-PGE deposit is currently being mined by Falconbridge, at the Raglan mine, where production is focussed on massive sulphide lenses located at the base of ultramafic horizons.

CONCLUSION

The Rivière Arnaud area and adjacent coastal regions are particularly interesting in that they provide a link between the SE Rae Province (Core Zone) and the Archean craton of the Superior Province. The craton is mainly represented by Archean rocks of the Douglas Harbour domain. These Archean rocks are intruded by Paleoproterozoic dykes (Payne River Dykes and Klotz Dykes). They are also partially overlain by thrust sheets formed of Paleoproterozoic supracrustal sequences belonging to the Labrador Trough and the Ungava Trough.

In the study area, the rocks associated with the Archean craton were subdivided into three lithodemic units. The distinction between these units is based on the nature of typical lithological assemblages, and the differences in the metamorphic grade and in the tectonic style. These lithodemic units are, from west to east, the Qimussinguat Complex, the Faribault-Thury Complex and the Diana Structural Complex. Rocks of the Qimussinguat Complex are generally metamorphosed to the granulite facies whereas those of the Faribault-Thury Complex are at the amphibolite facies. The two complexes are essentially composed of orthogneisses of the TTG suite that enclose gabbroic, basaltic or metasedimentary remnants. The Qimussinguat and Faribault-Thury complexes display structural fabrics typical of Archean deformation, dominated by a steeply-dipping foliation or gneissosity oriented NW-SE. The Diana Structural Complex mainly consists of Archean tonalitic orthogneisses reworked during the Proterozoic. It is characterized by a generally well-developed mylonitic foliation that affects both Archean and Paleoproterozoic lithologies.

Archean fabrics suggest a polyphase tectonic history. The foliation and gneissosity are affected by complex folding deformation of variable intensity, superimposed by ductile shear zones. Proterozoic fabrics show two distinct tectonic styles. The first consists in thrusting of Paleoproterozoic sequences onto the Archean basement, and the second, of strike-slip movement in a transpressional setting. No evidence of Proterozoic deformation was observed in the Qimussinguat Complex. In the Faribault-Thury Complex, the Paleoproterozoic deformation is discrete, and the associated metamorphism varies from the greenschist facies to the amphibolite facies. This deformation is restricted to the contact zone between Paleoproterozoic thrust sheets and the Archean basement, or in regional scale strike-slip faults. In the Diana Structural Complex, the Proterozoic deformation is penetrative and affects all the rocks in the complex.

A preliminary geochronological study helped establish a sequence of events that marked the geological history of the area. The sequence begins with the emplacement of volcanic edifices at about 2820 Ma, followed by large scale felsic plutonism bracketed between 2857 and 2782 Ma. All these rocks were then affected by two Archean metamorphic events, at 2700 Ma and at 2600 Ma. A final metamorphic event, associated with the Proterozoic deformation (thrusting and transpression) is observed in rocks of the Faribault-Thury Complex and the Diana Structural Complex. Zircons and titanites extracted from these rocks yielded metamorphic ages varying between 1790 and 1780 Ma.

Felsic plutonic rocks in the study area display similar geochemical signatures, and only subtle differences are observed from one complex to the next. These rocks are probably derived from the same magmatic processes. They presumably formed by magmatic differentiation. Mafic and ultramafic rocks in volcanic belts are mostly present in the Faribault-Thury Complex. Their trace element geochemistry suggests that these rocks were derived from a magma similar to MORBs. They are enriched in Fe and depleted in Zr, Y and REEs relative to modern MORBs. The mafic and ultramafic rocks formed through magmatic fractionation and crustal assimilation.

Geological mapping of Archean rocks outlined two new mineralized showings, and 10 anomalous occurrences. The mineralization essentially consists of Cu, Ag, Zn, Cr and Ni found in metavolcanic or metasedimentary rock bands. Mafic and ultramafic intrusions, mainly present in volcano-sedimentary belts, were also identified. Despite their relatively high Mg content, these rocks contain very few anomalous metal values for Ni and Cu, and only one minor showing was identified. Ni-Cu-PGE showings were recently identified in mafic/ultramafic rocks of the Labrador Trough. In the Archean basement, paragneiss bands in the eastern part of the Diana Structural Complex as well as in the Trempe and Buet volcano-sedimentary belts (Faribault-Thury Complex) appear to be the most interesting targets for mineral exploration in the study area.

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Abstract

This new geological survey covers the Rivière Arnaud area (NTS 25D) in addition to the coastal regions of Ungava Bay (NTS 25C) and Hudson Strait (NTS 25E and 25F). The study area is underlain by Archean rocks of the Douglas Harbour domain (Superior Province). These Archean rocks are intruded by Early Proterozoic dykes (Payne River Dykes and Klotz Dykes), and partially overlain by thrust sheets. These nappes, composed of Early Proterozoic supracrustal sequences, belong to the Labrador Trough and the Ungava Trough.

Within the study area, rocks associated to the Archean craton were subdivided into three lithodemic units: the Qimussinguat Complex, the Faribault-Thury Complex and the Diana structural Complex. The distinction between these units is based on typical lithological assemblages, as well as differences in the metamorphic grade and tectonic style.

Rocks of the Qimussinguat Complex are generally metamorphosed to the granulite facies, whereas those of the Faribault-Thury Complex are at the amphibolite facies. The two complexes are essentially composed of orthogneisses of the tonalite-trondhjemite-granodiorite/granite suite, which enclose mafic remnants of gabbroic, basaltic or metasedimentary origin. In the Qimussinguat Complex, these remnants are rare and restricted in size. In the Faribault-Thury Complex, volcano-sedimentary rocks form a string of segments one to several kilometres in size, distributed over a distance exceeding 100 km. The Qimussinguat and Faribault-Thury complexes display structural fabrics typical of Archean deformation, dominated by a steeply-dipping foliation or gneissosity oriented NNW-SSE. The Diana structural Complex is mainly formed of Archean tonalitic orthogneisses that were reworked during the Proterozoic. It is characterized by a generally well-developed mylonitic foliation that affects both Archean and Early Proterozoic lithologies. Archean fabrics suggest a polyphase tectonic setting. The foliation and gneissosity are disturbed by complex folding of variable intensity, superimposed by ductile shear zones. Proterozoic fabrics indicate two distinct tectonic styles. The first is related to the thrusting of Early Proterozoic sequences onto the Archean basement, and the second, to dextral strike-slip movement in a transpressional setting. No evidence of Proterozoic deformation was observed in the Qimussinguat Complex. In the Faribault-Thury Complex, Early Proterozoic deformation is discrete and the associated metamorphism varies from the greenschist facies to the amphibolite facies.

A preliminary geochronological study helped establish a sequence of events marking the geological history of the area. It begins with the emplacement of volcanic rocks and felsic plutonic rocks at 2.8 Ga, followed by two episodes of Archean metamorphism at 2.7 Ga and 2.6 Ga, and a Proterozoic metamorphic event at 1.8 Ga.

Mapping has led to the discovery of two new mineralized showings and 10 anomalous occurrences. The mineralization essentially consists of Cu, Ag and Zn, found in metavolcanic or metasedimentary rock remnants. Mafic and ultramafic intrusions, mainly present in volcano-sedimentary belts, were also identified. Despite their relatively high Mg content, these rocks contain very few anomalous Ni, Cu and Cr values, and only one minor Cu showing was reported. With the exception of rocks in the Labrador Trough, where Ni-Cu-PGE showings were recently discovered in mafic-ultramafic rocks, paragneiss bands located in the eastern part of the Diana structural Complex as well as the Trempe and Buet volcano-sedimentary belts, included in the Faribault-Thury Complex, appear to represent the most interesting exploration targets.

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