GEOLOGICAL STUDIES OF THE LATE PRECAMBRIAN SUPRACRUSTAL ROCKS AND UNDERLYING GRANITIC BASEMENT, FURY AND HECLA STRAIT AREA, BAFFIN ISLAND, DISTRICT OF FRANKLIN

Projects 790016, 760045, 790029, and 760047

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Abstract

For about 150 km along the north shore of Fury and Hecla Strait, and extending up to 50 km inland lies a belt of mainly clastic sedimentary rocks. This unmetamorphosed Helikian and/or Hadrynian sequence, about 6000 m thick, is divided into five conformable units, described in ascending stratigraphic order. The lowest unit consists of red sandstone and shale with minor quartz-pebble conglomerate and stromatolitic dolomite passing up into white quartzite. The second unit consists of a coarsening-upward sequence of red shale and sandstone, with black shale and stromatolitic dolomite at its base. A westward-thinning pink quartzite unit is followed by a varicoloured sandstone-shale unit, transitional into a black shale unit. Both alluvial and marine depositional environments are represented in the sediments, and paleocurrents flowed broadly westward. Deformation is limited to faulting and gentle southward tilting.

Lying nonconformably beneath the sediments are granitic and gneissic rocks of Archean and/or Aphebian age. Mapping, concentrated about two large radiometric anomalies situated in the east and west of the area, showed them to be broadly coincident with weakly-deformed pink biotite-hornblende granite, cut by granitic pegmatite. The granite, present as a batholith in the east, is also present as smaller bodies in the west. The eastern granite is margined by pre- to syntectonic porphyritic monzonite(?) that cuts widespread surrounding mesocratic tonalitic gneiss. A thick sequence of orthogneiss and paragneiss, partly of sedimentary origin in the western area is varied in composition and fabric. Deformation in both areas is intense except in the case of the granite and pegmatite. Geochronological and paleomagnetic studies of these rocks are in progress.

Ground radiometric and geochemical analyses show that the two previously discovered large uranium-thorium radiometric anomalies are caused by underlying pink basement granite. Whereas surrounding gneisses and late Precambrian supracrustal rocks give a weak radioactive response. Proximity of the anomalies to an Early Helikian(?) unconformity is significant for mining exploration. A core zone and some other locations within the eastern granite batholith are considerably more radioactive than the bulk of the body. Uranium and thorium concentrations are also present in pegmatite bodies, filling shear zones in the basement near and within the Proterozoic sediments and associated with quartz-pebble conglomerate in the sediments.

Introduction

In 1979 a multidisciplinary study of Late Precambrian sedimentary rocks and nearby subjacent gneiss of the Churchill Province was undertaken in the region of Fury and Hecla Strait. The sedimentary rocks were examined as part of a continuing Geological Survey of Canada study of redbeds. The study of the basement rocks will contribute to an international study of granites, jointly sponsored by the Nuclear Energy Agency (N.E.A.) and the International Atomic Energy Agency (I.A.E.A.). The aim of this study is to establish criteria that will help recognize granitoids likely to contain economic mineralization, particularly uranium mineralization.

The area is of particular interest because the nonconformity separating the sedimentary rocks and gneiss is broadly similar in age to the sub-Athabasca nonconformity of Saskatchewan – one so productive of uranium. Added impetus came from identification of large-scale radiometric uranium and thorium anomalies (Fig. 20.2) in the gneiss adjacent to the nonconformity as a result of the Canadian Uranium Reconnaissance Program. Recent geological work in the area includes that of Blackadar (1958) and Blackadar et al. (1968a, b). Blackadar (1970) summarized early work.

The supracrustal rocks were studied by F. Chandler, A. Legun, B. Zaitlin, Q. Gall, and G. Griesbach. The basement rocks were examined by A. Ciesielski, J. Maley, J. MacManus, and R. Christie. Radiometric studies were carried out by B.W. Charbonneau, G. Bernius, K. Ford, and R. Shives, and geochemical work by Y.T. Maurice and M. Wadleigh. Samples of dykes, sills and redbeds were collected for paleomagnetic study by S. White and H.C. Palmer. Organization was handled by F.W. Chandler, and R. Senneville cooked ably at base camp.

The field season lasted through July and the first half of August. A Twin Otter aircraft from Bradley Air Services was used for transporting fuel and equipment. A Bell Jet Ranger 206B helicopter from Okanagan Helicopters Ltd. provided daily transport of personnel. These aircrafts were chartered through the Polar Continental Shelf Project of the Department of Energy, Mines and Resources. Logistical support was also given by Dr. Andris Rode of the Eastern Arctic Research Laboratory of the Department of Indian and Northern Affairs at Igloolik about 150 km to the southeast.

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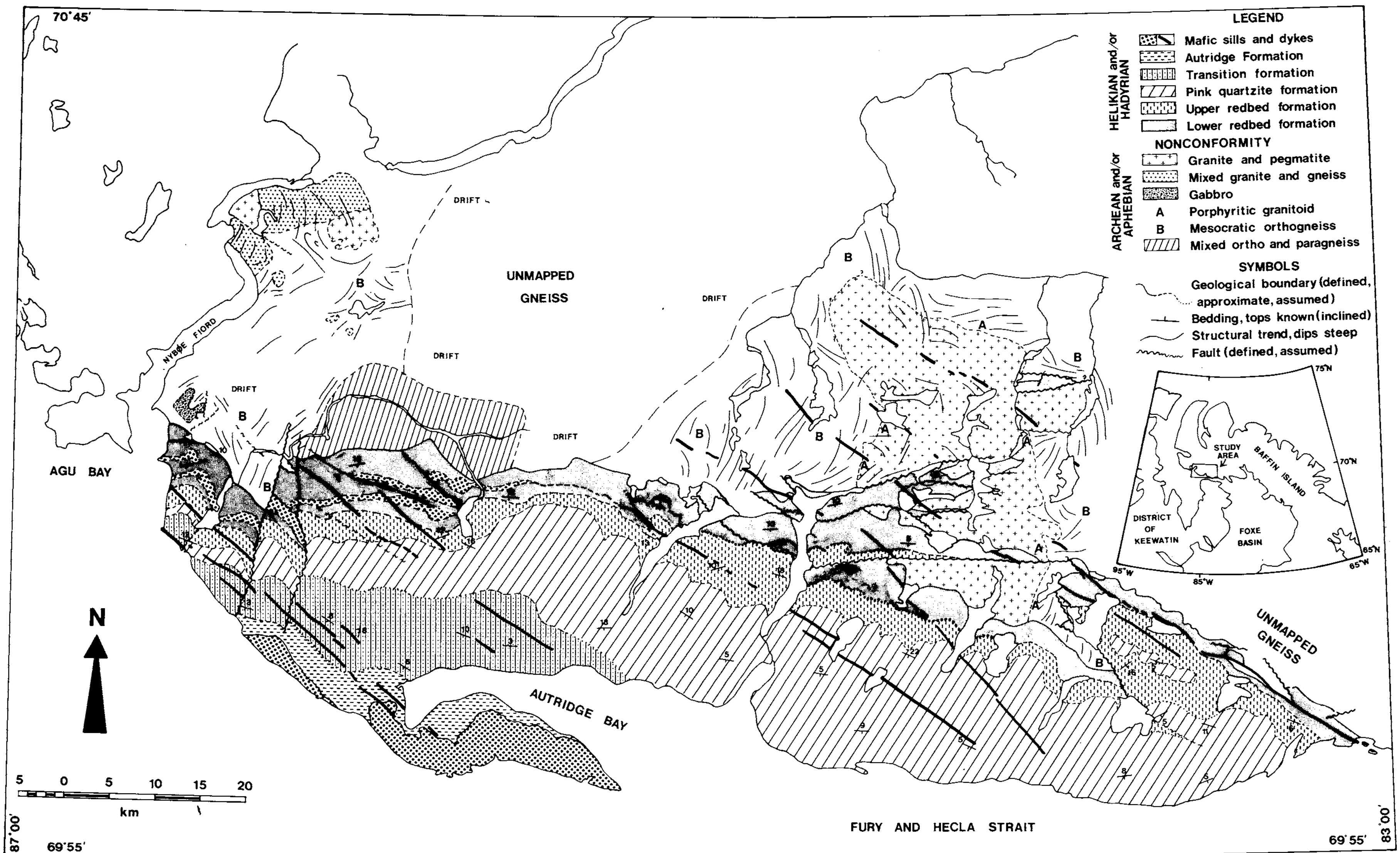

Figure 20.1. *Sketch map of the geology of the Fury and Hecla Strait area, north Baffin Island, by F.W. Chandler (supracrustal rocks) and A. Ciesielski (basement gneiss).*

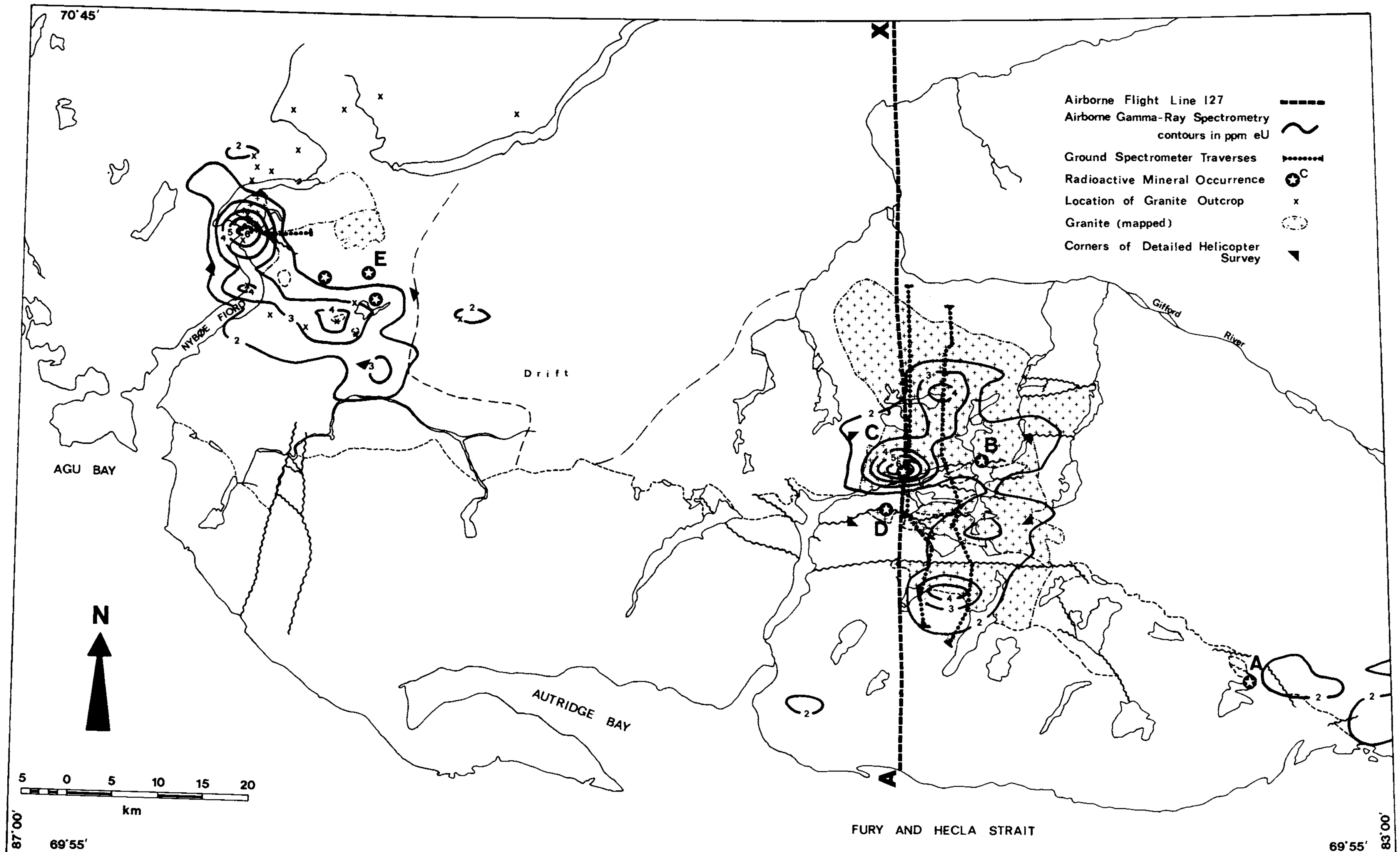

Figure 20.2. Regional airborne radiometric pattern in uranium superimposed on the major geological contacts and showing the locations of detailed studies and type-examples of radioactive mineralization.

Geology of the Supracrustal Rocks[1]

The area underlain by the supracrustals is thickly blanketed by felsenmeer. Consequently many geological boundaries were traced by drift and feature mapping. Although only five sedimentary units are mappable with reasonable confidence (Fig. 20.1), subdivisions into members were made where outcrop permitted. The roughly calculated thickness of 6000 m is not greatly different from the 4575 m estimated by Blackadar (1970) who also assumed an average dip southward of 10°. The boundary with the underlying gneiss in general appears undisturbed, although in the central part of the area it is repeated by east-striking faults.

The basal sedimentary unit, the lower redbed formation is about 700 m thick and commences with red sandstone or grit. Basal polymictic breccia in two localities at the western end of the area might be fault-related. In the eastern part of the area the lower redbed formation consists of a red sandstone member overlain by a white quartzite member. Separation of these two members becomes more difficult westward. The red sandstone member consists of friable crossbedded grit and sandstone with interlayered units several metres thick of friable mudcracked red siltstone – shale. White, cream, and orange weathered sandstone and quartzite are also present. About 15 m of oligomictic hematitic quartz-cobble to boulder-orthoconglomerate in the upper part of the red sandstone member, thins and fines westward to possibly 15 cm of pebble conglomerate. Clasts include some from a previous cycle of quartz-pebble conglomerate deposition. In the east the conglomerate is unstratified or crudely size-stratified. Clast imbrication of $a_t b_i$ type, typical of alluvial environments (Harms et al., 1975) is common and indicates paleotransport from the southeast. Above the conglomerate, within the red sandstone member lies a zone about 60 m thick rich in red crossbedded and wave-rippled dolomitic sandstone beds. Stromatolites were found in this zone at two localities. The white quartzite member is white to pink, fine- to coarse-grained and abundantly wave rippled.

The upper redbed formation, about 500 m thick, consists mainly of a coarsening-upward red shale – red sandstone megacycle including similar second order cycles. The base of the megacycle is marked by discontinuous development of a stromatolitic dolomite member overlain by a continuous black shale member. The dolomite member, at most 5 m thick contains stromatolites of LLH type (Logan et al., 1964), some oval and oriented along azimuth 060°. Associated sediments include mudcracked shale and oolitic and oncolitic carbonate. The overlying black shale member, about 60 m thick contains minor red shale and isolated units of rippled black siltstone and grey sandstone. Trough crossbeds in the upper redbed formation indicate westward paleotransport.

Interbedded pink quartzite, bright red sandstone, and shiny red mudcracked shale mark transition to the overlying pink quartzite formation. This resistant formation is about 2800 m thick in the centre of the area, thins westward, and underlies a range of hills that runs east-west through the area. It is generally quartz-rich and may be fine grained to gritty with scattered quartz pebbles. Slack-water clay drapes are absent from the quartzite. Minor colours include white, puce, red and cream. Sedimentary structures include ripples and crossbeds, the latter indicating paleotransport to the southwest.

The pink quartzite formation is overlain by a transition formation, about 1500 m thick and composed of shale, siltstone and crossbedded sandstone. Recessive weathering of the finer grained clastics gives the unit a ribbed appearance in outcrop. The unit is strongly colour layered in white, grey, pink, red, green, and black. Sediment transport was to the southwest.

The sedimentary units described above comprise the Fury and Hecla Formation of Blackadar (1970). The overlying unit, the Autridge Formation of Blackadar (1970), is the highest stratigraphic unit in the area. It is composed of about 500 m of fissile black shale, with several per cent of grey rippled siltstone and sandstone beds dispersed through it. Syneresis cracks are common in the shale.

Two mafic sills are present in the western and central part of the area. The lower sill, about 6 m thick, consists of fine grained diabase with chlorite amygdules, and occurs close to the dolomitic sandstone zone of the lower redbed formation. The upper sill, possibly up to 30 m thick, occurs within the white quartzite member of the lower redbed formation. A third, mafic sill overlies the Autridge Formation on Autridge Peninsula and on the nearby coast to the west. Northwest-striking magnetic mafic dykes cut the sediments and may be of Franklin age (Fahrig et al., 1971).

Apart from local contact effects from the mafic intrusives, the sedimentary rocks are unmetamorphosed. Strata dip gently southward except adjacent to faults. Some of the faults strike east-west and are upthrown to the south, repeating the basement gneiss and part of the basal redbed formation. The basement is generally unaltered but adjacent to one of these faults it is strongly hematized. Two other faults contain uranium mineralization in quartz-cemented quartzite stockwork. Near these the gneiss is friable and rusty-weathered. Thorium is present in sand beds interlayered with quartz cobble-boulder conglomerate in the lower redbed formation. Mineralization is dealt with at greater length in subsequent sections of this paper.

Blackadar (1970) commented on lithological similarity between the sequence at Fury and Hecla Strait and one 300 km to the north but was reluctant to support their correlation on account of the great separation of the sequences. Later work (Geldsetzer, 1973; Jackson et al., 1978) on the northern sequence reaffirms the similarity. Specifically, the basal redbed formation is similar to the basal Nauyat Formation of the northern area. Likewise the pink quartzite formation, transition formation and Autridge Formation have features in common with the younger Adams Sound and Arctic Bay formations to the north. Paleocurrent directions from trough crossbeds in the two areas are also similar.

Geology of the Basement Gneisses[2]

Mapping was carried out over the areas surrounding the two radiometric anomalies (Fig. 20.1, 20.2). The better exposed eastern area comprises a central part of granitic composition, surrounded by mesocratic gneisses probably of tonalitic composition (B, Fig. 20.1). The unusually radioactive pink granite is medium grained and contains as mafic minerals rare biotite and hornblende. Nearly all outcrops are cut by dykes of usually coarse grained and commonly quartz-rich pegmatite. In wide shear zones the pink granite acquires a gneissic texture and is normally biotite-bearing. The presence of other femic minerals arises from assimilation of more mafic inclusions. Within the pink granite deformation is weak, however one phase of folding and foliation is apparent. Outcrop of the granite is extended southward of the basal contact of the Proterozoic sediments by several east-striking faults. The pink granite contains at least five types of inclusions: (a) porphyritic monzonite, (b) mesocratic tonalitic gneiss, (c) paragneiss, (d) amphibolite, and (e) ultrabasic rocks of varied composition. Within the first two types of inclusion lie smaller inclusions of the last three lithologies. In the western area the pink granite is present as batholiths and also is widespread as mappable stocks and bodies or dykes of outcrop scale. In certain places the granite pegmatite dykes

[1] by F.W. Chandler (Project 790016)

[2] by André Ciesielski (Project 790029)

are very thick and abundant. These and pink granite dykes both parallel and transect the foliation of the surrounding gneisses and are probably of syn- and late-tectonic origin.

Within and mostly at the margin of the pink granite batholith of the eastern area there is a granitoid of probable monzonitic composition (A, Fig. 20.1). This medium-to coarse-grained rock contains potash feldspar phenocrysts and a significant amount of biotite. Well-developed foliation locally makes the rock an augen gneiss. This rock type has mainly amphibolite inclusions and is likely to be pre- and syntectonic. Surrounding the massive pink granite there is a widespread gneiss (B, Fig. 20.1) that is intruded by the above monzonitic granitoid. Generally it is mesocratic, fine- to medium-grained, strongly foliated and has many types of inclusions. Schlieren and other signs of assimilation of more mafic material are numerous. As in the case of the pink granite, inclusions include paragneiss of varied composition and thickness, and various amphibolitic and ultrabasic rocks. The rock also contains masses of differing size of dioritic or hybrid affinity.

In the western area the above gneisses show varied composition and fabric, including lit-par-lit layering involving biotite and hornblende, fine foliation or augen structure. Masses or dykes of amphibolite are numerous. The gneisses are in general highly deformed and migmatoid in some places. Small scale folds are common though some with dimensions greater than 12 m were seen. Structural data indicate at least two phases of deformation. Present only in the western area is a unit of mixed orthogneiss and paragneiss, differing in texture and structure from the mesocratic orthogneiss (B). This unit (Fig. 20.1) is a very thick sequence partly of sedimentary origin, with a fine compositional layering and includes banded iron formation incorporated within felsic rocks. No marker units were found that would suggest repetition of the sequence by folding. Amphibolite, gabbro and ultrabasic rocks are also interbedded within the unit. In the field distinction between the orthogneiss and paragneiss of this unit is difficult because of the fine parallel layering. Deformation is marked by vertical foliation planes and assymetrical folds.

Generally, deformation in the eastern and western areas is intense except in the granite and pegmatite. Folds are uncommon and lineations are absent. A stratigraphic column is shown in Table 20.1.

Table 20.1

Stratigraphic column to show the relative age and deformation of the basement rocks

Diabase dykes and sills
Proterozoic sediments
— — — — — — — — — — —
Pink granite and pegmatite (γ_2)
Gabbro and porphyritic monzonite
— — — — — — — — — — —
Basic dykes
Tonalite/granodiorite (mesocratic gneiss) (γ_1) ?
Gabbro and diorite ?
Volcanic/sedimentary series
Greywackes (paragneiss)
Basic volcanics (amphibolites)
Ultrabasics
Katarchean basement??

----- : discordance
γ_{1-2} : deformation phase

Radiometric Studies[1]

General

During 1977, an airborne gamma ray spectrometric survey was carried out in the area in accordance with Uranium Reconnaissance Program specifications (Darnley et al., 1975). The results were published in 1979 as Geophysical Series Maps 35647-G – Agu Bay and 35547-G – Erichsen Lake. Results for each sheet comprise seven contoured maps: K%, eU ppm, eTh ppm, eU/eTh, eU/K, eTh/K and Total Count. Data along the individual flight lines were published as stacked profiles of the seven parameters listed above as well as a magnetometer trace.

Regional Pattern

The reconnaissance airborne radiometric survey revealed two major anomalies (Fig. 20.2), one in the eastern part of the area and the other, in the west. Both the eastern and western anomalies are predominantly underlain by bodies of granite described in the previous section. The mapped contacts of these granites are shown on Figure 20.2. A number of granite outcrops found by helicopter landings outside the area of detailed mapping in the western area are also shown on Figure 20.2. The 2 ppm eU contour shown in Figure 20.2 outlines the southwest quarter of a ring shaped anomaly which is clearly delineated by contours on the equivalent thorium and total count maps (not included in this paper). The distribution of granite outcrops coincides with this ring of high radioactivity. The areas inside and outside the ring appear to be underlain by mesocratic to mafic gneiss with considerable drift cover. The southern half of the ring is more uraniferous than the northern half (Fig. 20.2).

The area situated between the two anomalies is extensively drift covered, however, geological mapping suggests that this region is underlain by the gneiss. Thus the low radiometric response is thought to be due to generally low radioactivity of the rocks and the associated glacial detritus. The southern part of the area is generally low in radioactivity because of the low overall radioelement concentrations in the sediments.

The proximity of the anomalously radioactive granites to the probably Helikian nonconformity accentuates the favourability of this area for uranium exploration. The proximity of the anomalous granite basement to the nonconformity is illustrated by the eastern anomaly. Figure 20.3, an airborne radiometric profile from the regional survey, cuts across the most radioactive portion of the eastern granite (see A-X, Fig. 20.2). This profile shows values as high as 10 ppm eU. The area of maximum radioactivity lies within the granite near the nonconformity. A sharp drop in radiometric levels occurs at the contact with the overlying sedimentary rocks. The uranium levels on the profile (> 10 ppm) are higher than on the contour maps, the latter showing maximum values of > 6 ppm. This discrepancy results from smoothing of the data in the computer contouring process. For this reason the contour maps should always be examined in combination with the profiles. The contour pattern outlines the regional picture whereas the profiles give more detailed information about the area along the flight path. Cameron et al. (1976) and Charbonneau et al. (1976) have discussed the above relationships.

Detailed Studies

Detailed studies carried out in the Fury and Hecla Strait area consisted of:

1. Three ground traverses, totalling about 80 km, along which gamma ray spectrometry, scintillometry and geological sampling were carried out. Two of the traverses were in the east and the other in the west (see dotted lines, Fig. 20.2). Stations were located at 100 m intervals.

[1] B.W. Charbonneau (Project 760045)

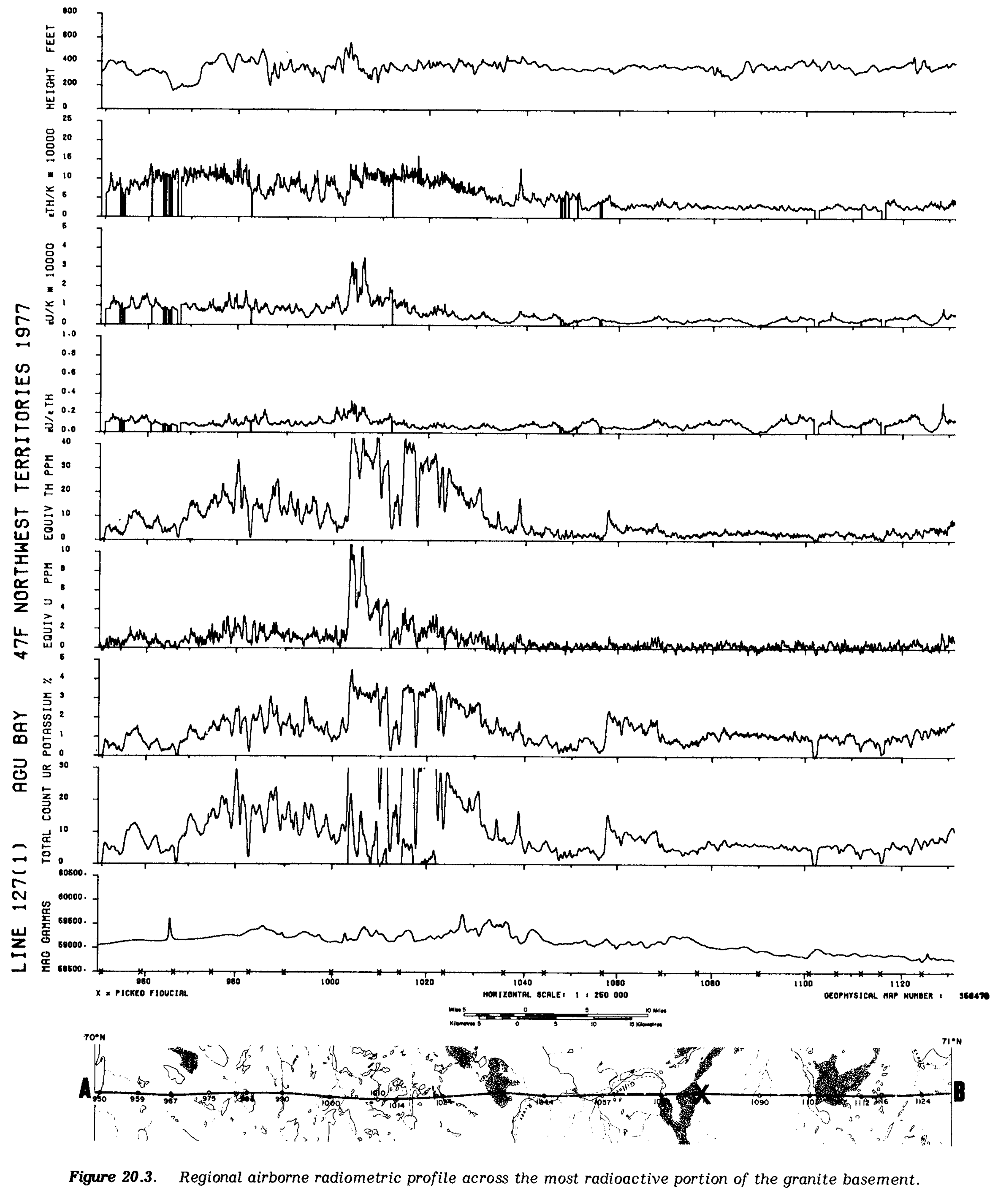

Figure 20.3. *Regional airborne radiometric profile across the most radioactive portion of the granite basement.*

2. Two 200 km^2 detailed airborne gamma spectrometry surveys flown over the most eastern and western anomalies to locate the most radioactive portions. These surveys were flown at 30 m terrain clearance with a crystal volume of 1.6 Litres, and a line spacing of 1 km (0.5 km in the area of greatest interest). The locations of the surveys are indicated on Figure 20.2 by corner marks.
3. Spot landings, to examine specific features and search for uranium enrichment.

In all, about 1000 in situ radioelement determinations were made and about 200 samples were collected.

Results of the ground traversing will enable a relationship between the radiometric response over the granites and their petrology to be established. Compilation of in situ determinations of potassium, uranium, and thorium values has not yet been completed. Initial indications based on preliminary reduction of the data show that the granites underlying the eastern and western anomalies contain about twice the concentration of uranium and thorium of average granite, whereas levels in the gneissic complex are below average granite values (Clarke et al., 1966).

Some portions of the granites are considerably more radioactive than the above levels. For example, the core of the eastern radiometric anomaly (eU > 6 ppm, Fig. 20.2) averages about five times the Clarke values for uranium and thorium. An average value of 22 ppm equivalent uranium and 104 ppm equivalent thorium was calculated across 3 km of the core zone on the ground. Values of equivalent uranium and equivalent thorium across 3 km of the core of the western granite (eU > 6 ppm, Fig. 20.2) average 12 ppm eU and 65 ppm eTh, nearly three times Clarke values. The uranium concentrations reported here have been substantiated by chemical analyses (see section on geochemistry).

Radioactive Occurrences

Various types of uranium and thorium occurrences were found and the locations of type examples are shown on Figure 20.2.

A. Clastic (placer type) concentrations in the basal Helikian conglomerates.
B. Veins in shear zones associated with quartz stockwork in the uppermost basement.
C. Zones of enrichment within the granitoid bodies in the basement.
D. Veins in shear zones associated with quartz stockwork in the Helikian sediments.
E. Pegmatites associated with the granitoids.

Mineralogical studies and autoradiography have not yet been completed on samples from these occurrences. The concentrations reported below are based on in situ gamma spectrometric analyses and thus represent large sample volumes (> 100 kg of rock). Direct uranium determinations on some of these showings are presented in the section on geochemistry (see Table 20.2).

Locality A is a thorium occurrence in conglomerate. Low concentrations of uranium (a few tens of ppm) and up to 170 ppm eTh have been found.

Locality B is a uranium occurrence along approximately 30 m of a shear zone in the granite. This zone is filled with a quartz stockwork and hydrothermal alteration of the granite wall rock was noted. Maximum values measured were 270 ppm eU and 90 ppm eTh. The thorium concentration is probably derived from the host granite.

Table 20.2

Uranium Content* of Granitic and Other Radioactive Rocks in the Fury and Hecla Strait Area (see Fig. 20.2 for locations)

Rock Type	Area km^2	Number of Samples	Uranium in ppm Arith. Mean	Range
Eastern granite				
- regional	≈500	23	8.2	1 - 26
- intermediate area	1	17	13.0	3 - 31
- core (Loc. C)	0.1	17	22.2	6 - 42
Western granite (regional)	≈500	14	7.2	1 - 15
Pegmatites and related rocks (Loc. E)		35	-	1 - 10 400
Shear zone (Loc. B)		3	-	127 - 302
Shear zone (Loc. D)		1	-	1490
Conglomerate (Loc. A)		1	-	32

*Determined by delayed neutron activation.

Locality C is in the core of the eastern granite. The rock is a subporphyritic pink granite. Maximum radioelement concentrations measured were 80 ppm eU and 160 ppm eTh. Hydrothermal alteration was noted in places.

Locality D is a uranium occurrence which is localized along 40 m of a major fault cutting Helikian sandstone. This shear zone also contains a well developed quartz stockwork and is hydrothermally altered. Maximum in situ values recorded were 660 ppm eU and 100 ppm eTh.

Locality E is representative of a number of radioactive pegmatities near the western granite. These bodies typically are up to 30 m in length by 1-2 m in width. Maximum radioelement values measured in situ were 2300 ppm eU and 1200 ppm eTh.

The results of this work illustrate the general relationship of uranium occurrences to areas of anomalous radioactivity as discussed by Darnley et al. (1977).

In addition to the above types of uranium occurrences concentrations in structural and lithological traps under the Helikian basement nonconformity might be expected as well as concentrations within the Helikian sediments in reduced facies. However no indications of the latter two types were found in this study.

Geochemistry[1]

Systematic sampling of the various types of radioactive rocks occurring in the area was carried out in an attempt to characterize them chemically. The eastern granite was sampled with the sample density increasing towards the core of the radiometric anomaly (Locality C, Fig. 20.2). The sampling scheme was designed to investigate the chemical variance within outcrops (3 to 10 m) and between outcrops (30 to 50 m) and compare these with the regional variance. The analytical variance will also be estimated by means of blind duplicate samples.

The western granite was sampled in the same way as the eastern granite but with a slightly wider interval. Denser sampling of the eastern granite was carried out by foot traverses. Widely spaced sampling was done by helicopter, using information from a mapping crew.

[1] by Y.T. Maurice (Project 760047)

The zones of anomalous radioactivity associated with quartz pebble conglomerates (Locality A, Figure 20.2), shearing (Localities B and D), and pegmatites (Localities E) were also sampled. The main radioactive shear zone associated with the eastern granite (Locality B, Fig. 20.2) was sampled along a traverse running at a right angle to the strike of the mineralization to investigate the nature and extent of the alteration that is associated with this zone. Other less radioactive zones that display similar alteration near the core of the eastern anomaly were also sampled.

In the western anomaly, 35 pegmatite bodies and related rocks, some radioactive, others barren, have been examined and sampled.

All samples collected will be analyzed for the major elements, uranium and thorium. A selection will also be analyzed for other elements including, Sn, W, Pb, Mo, F, Rb, Ba, Sr, Y, La, rare earth elements, and Zr. Microprobe analyses of selected specimens will also be carried out.

Preliminary Results

Uranium values are being determined by neutron activation/delayed neutron counting at Atomic Energy of Canada Limited. Available data (Table 20.2) are in agreement with the ground radiometric measurements. With an average uranium content of 8.2 ppm and 7.2 ppm respectively, both the eastern and the western granites are anomalously high in uranium. The substantial increase in the uranium content (22 ppm) of the rocks towards the core of the eastern granite is noteworthy. It has yet to be determined whether this pattern in the uranium distribution corresponds to variations in the major element composition of the rock and whether minor and trace elements show distributions that are sympathetic to that of uranium. These observations along with a study of samples from the radioactive shear zones and associated alterations will help to determine the mechanism responsible for the uranium enrichment of the granites and fault zones. The major and trace element concentrations of the radioactive pegmatites should establish their genetic derivation.

Paleomagnetic Studies[1]

Samples were collected from the lower and upper redbed formations, from the pink quartzite formation, from the two lower mafic sills, and from mafic dykes. Twenty-two sites were drilled, each usually composed of six cores. Each core subsequently gave two paleomagnetic specimens. Two block samples taken from one site yielded five individual cores which were drilled vertically in the lab. The horizontal component of orientation was obtained in the field by all or two of the following methods: sun bearing, magnetic bearing or land sight. All cores were sawn into one inch specimens of which 235 are ready for measurement.

This study was undertaken to find the age and correlation of the sedimentary and igneous rocks and the paleolatitude of deposition of the sedimentary rocks.

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