Presentation of Integrated Geoscientific Map Products

A. Rencz, J. Harris, J. Glynn, G. Labelle,
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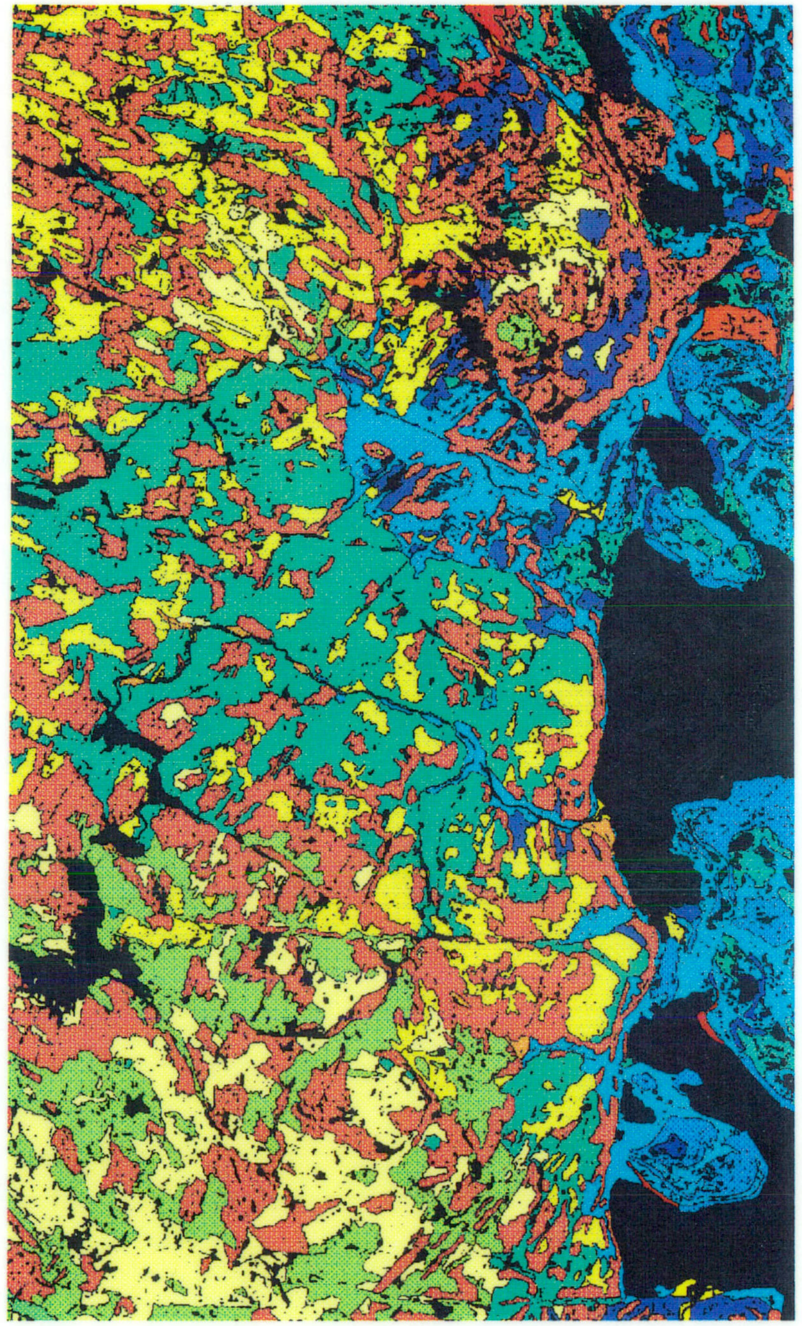
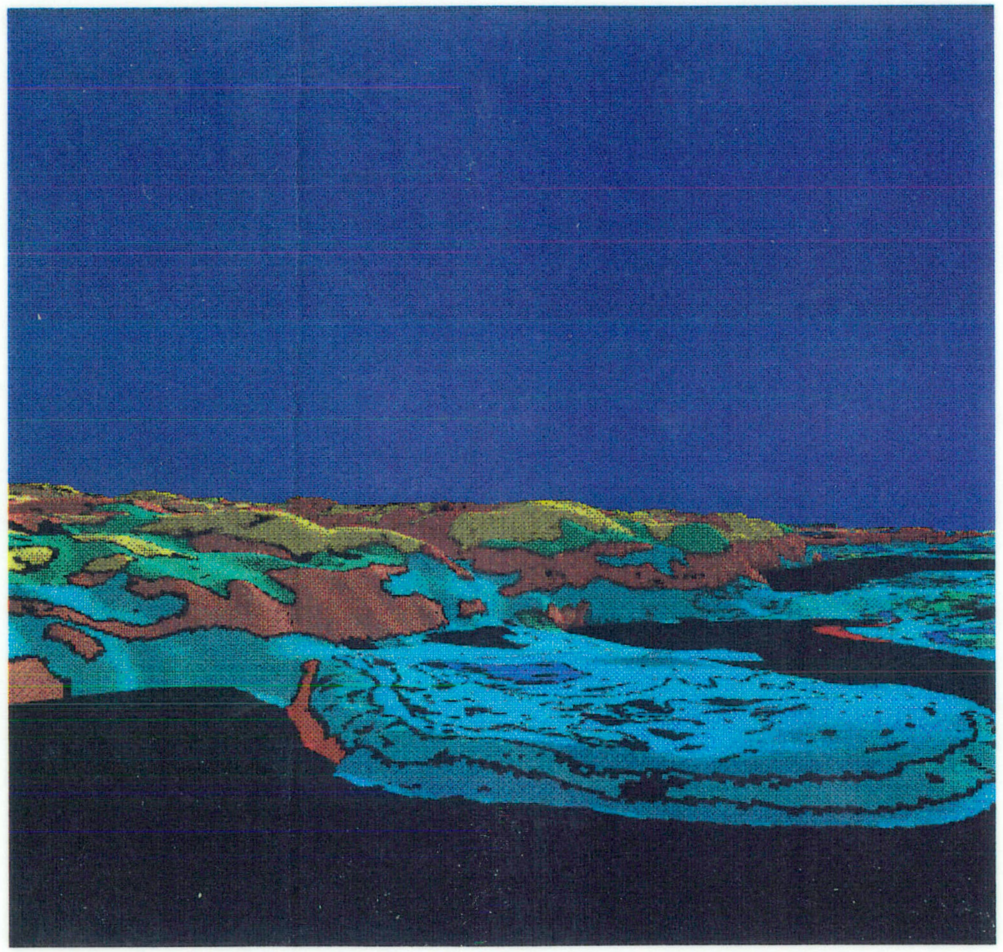
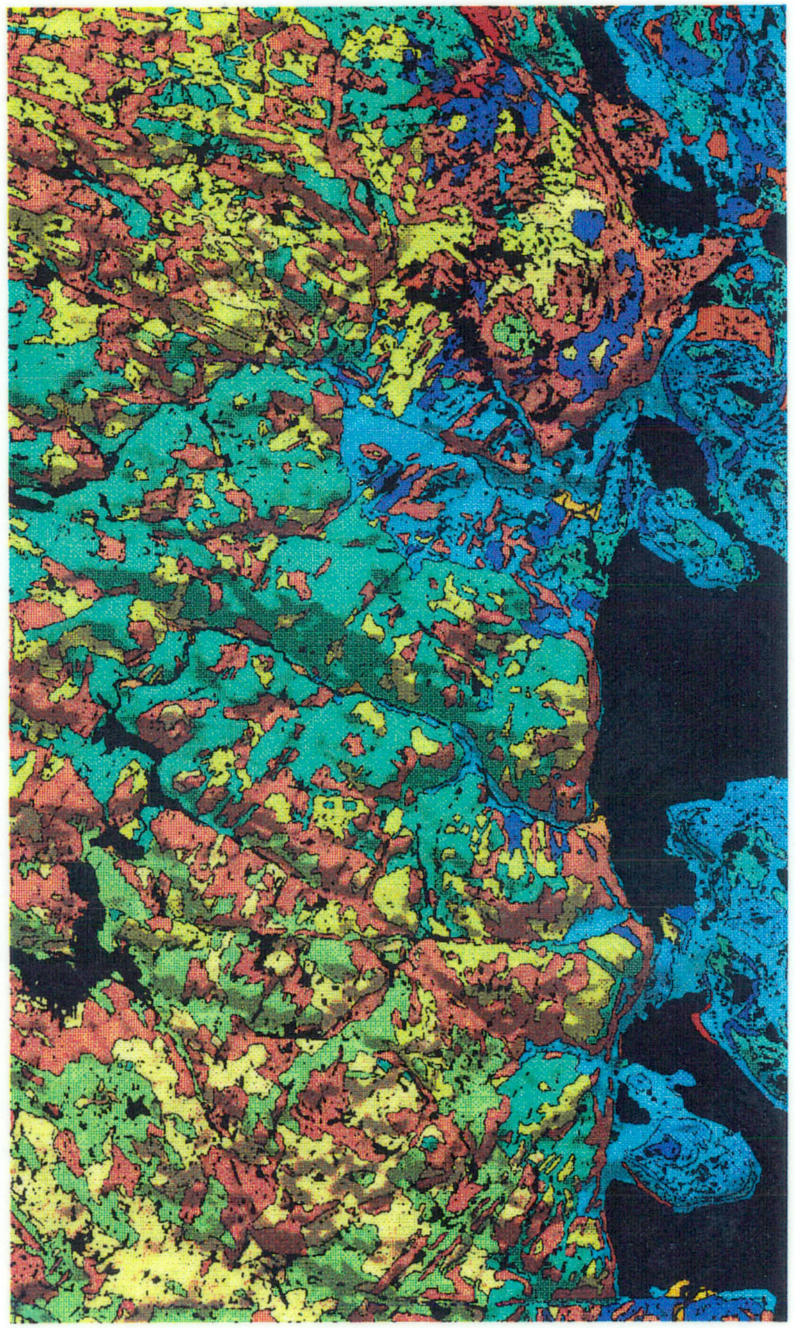
Geological Survey of Canada

A.B. Baker
Intera Information Technologies Ltd.







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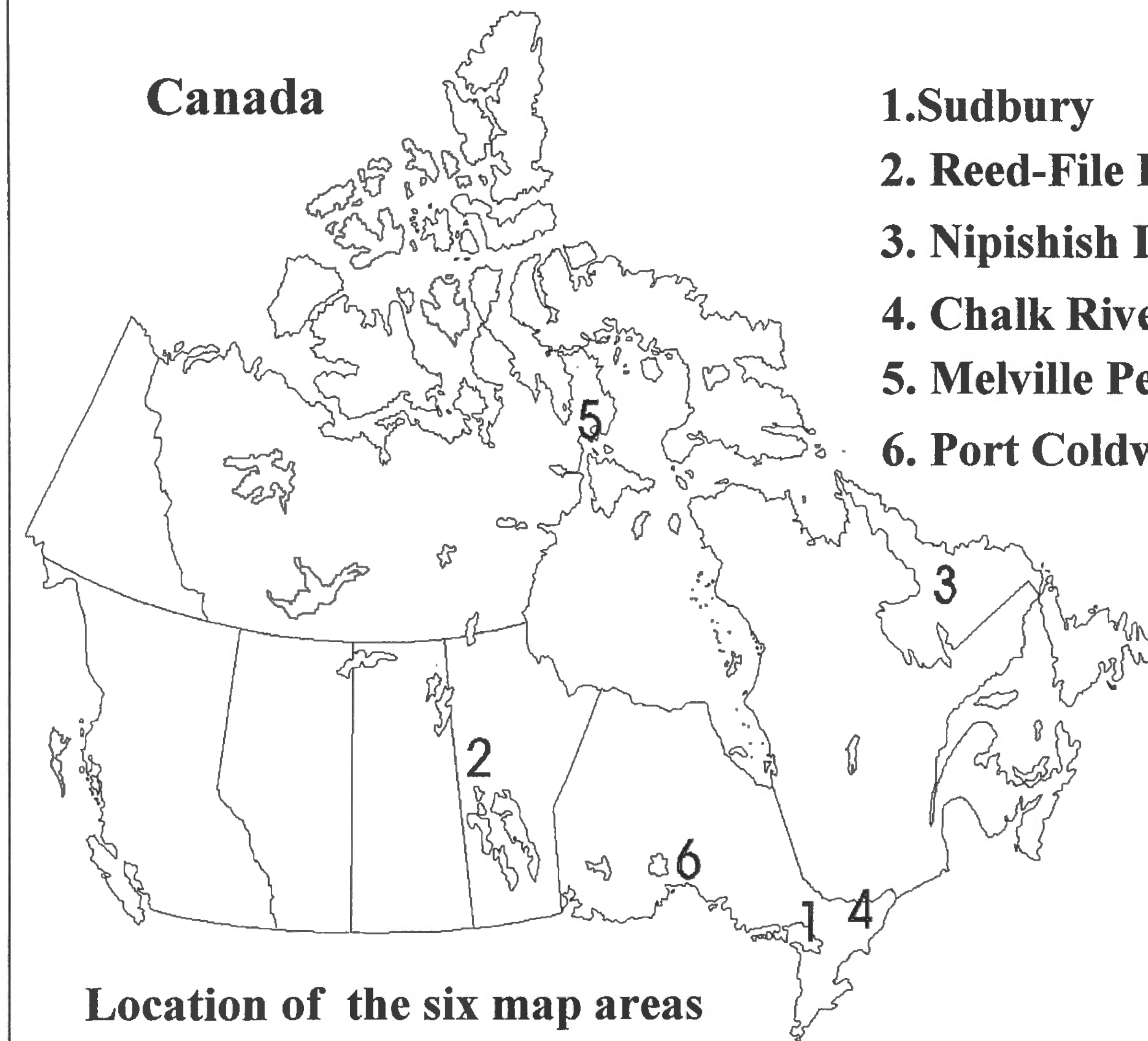


Location of the six map areas

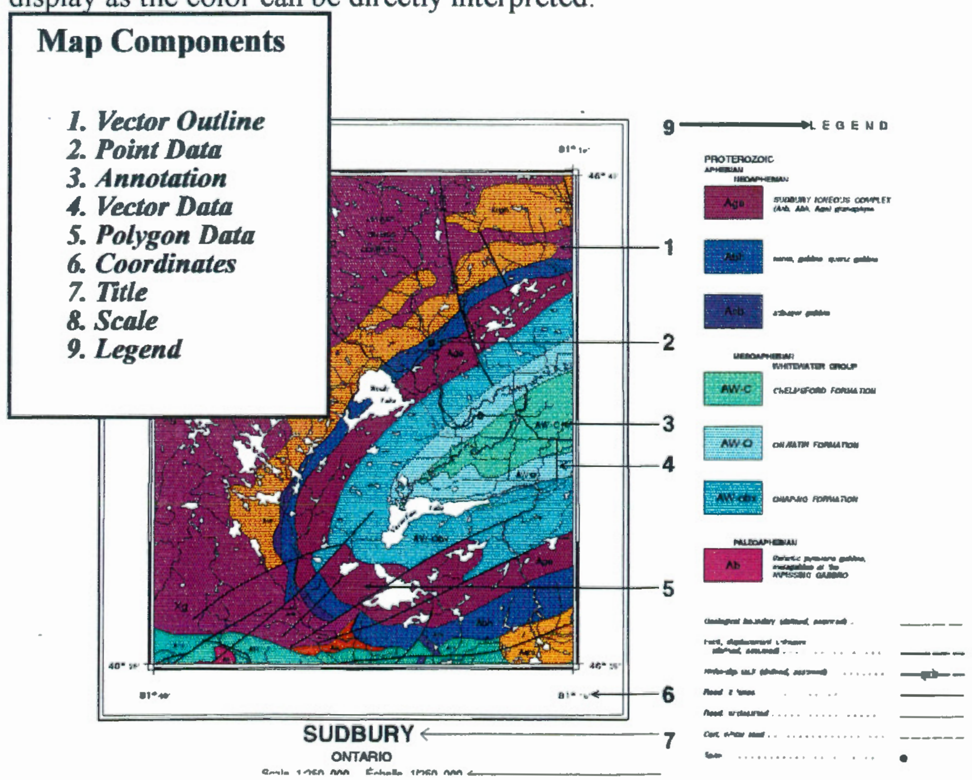
INTRODUCTION

A. Rencz, J. Harris, J. Glynn, G. Labelle

A picture is worth 1000 words.

Maps are designed to effectively display the information content to a specific audience. Typically maps portray one type of information such as geochemical, lithologic or geophysical. Information on GEOSCIENTIFIC maps, as well as other types, may be better portrayed by combining the data with information from an ancillary data base. For example, lithologic information on a map may be enhanced if the map contains topographic information, thereby highlighting structural information such as faults or folds. In this way a synergism between the data sets may visually enhance the derived map product and aid in geologic interpretation.

Functions to digitally combine spatial data are normally part of an image analysis system. There are numerous techniques to combine and enhance data. A common technique for visualizing two or more data sets, and one used in several examples in this study, is the **I**ntensity-**H**ue-**S**aturation transform (Gillespie, 1980). This color system is defined by three orthogonal components. **Intensity** provides the brightness, **Hue** provides the average wavelength or color and **Saturation** provides the purity of the color. Typically the color information is derived from one map (for example a geology map provides the basic color) and this "color" is modified by either or both the intensity and saturation component. It has proven an effective display as the color can be directly interpreted.



In addition to the image component, a map must contain descriptive information which surrounds the image (this includes such items as a scale bar, legend, credits and other) and other text information on the image (this includes labels, symbols and others). The GSC has developed numerous procedures that permit the user to interactively annotate map products. These have been developed through a series of AMLs *(ARC/INFO macro-language)* that permit the cartographer to finalize the map for publication (Figure 1).

In order to produce integrated maps an organization must have capabilities in image analysis, digital cartography and geographic information systems. It is also fundamental that a smooth link be made between each of these systems.

The objective of this work is to illustrate the effectiveness of integrated map products in presenting map information. To do this, examples from six geoscientific applications were selected along with a series of maps showing the original information plus the derived integrated products. These include examples from geochemistry, Quaternary mapping, lithologic mapping, and airborne geophysical data. This Open File presents the "map images" and provides some background on the maps and their utility. Details of the image processing techniques; information on the cartographic procedures and a further assessment of the map products are presented in a separate GSC Open File (Harris et al, 1993).

BIBLIOGRAPHY

Harris, J., Rencz, A.N., C. Bowie, D. Viljoen, and P. Huppé. 1993. Presentation of integrated geoscientific map products: technical document. GSC Open File 2742.

Cover Page

The cover page illustrates three images of the surficial geology of Melville Peninsula (also see section 5 in this report). The image on the left is a color representation of the surficial geology. The image on the right 'shades' the geology map based on digital elevation data. The center image is a birds-eye perspective of the shaded relief geology with the viewer being situated in the southeast corner of the geology map at a height of about 500m.

BEDROCK GEOLOGY/AIRBORNE RADAR
Sudbury

Card K., P. Huppé, C. Bowie and J. Harris

The Sudbury map-sheet includes parts of three major geological provinces of the Canadian Shield, the Archean Superior Province in the northwest, the Early Proterozoic Southern Province in the south and northeast, and the Middle Proterozoic Grenville Province in the southeast. At the center lies the enigmatic Sudbury structure, possibly in astrobleme, the site of an ancient meteorite impact. The Precambrian rocks are overlain in the southwest by flat-lying Paleozoic strata of the Michigan Basin.

Archean rocks of the Superior Province form a rolling upland with subdued relief and include folded metavolcanic-metasedimentary sequences of the Benny greenstone belt, high grade gneisses immediately north of the Sudbury structure, the Levack gneiss complex, and massive granitic intrusions, the Algoman batholiths. The Archean rocks are cut by NW trending faults of the Onaping system and dykes of the Matachewan and Sudbury swarms.

Early Proterozoic strata of the Huronian Supergroup, mainly clastic sediments with local basal volcanic accumulations, form a southward thickening wedge resting unconformably on the southern flank of the Archean Superior Province. The Huronian rocks are cut by Early Proterozoic mafic intrusions, the Nipissing Diabase, and by younger granitic plutons, the Killarney granites. In the south and west, the Huronian rocks are tightly folded about east-west axes and cut by easterly-trending faults of the Murray system. In the northeast, these strata are gently folded about northerly-trending axes and are cut by north- to northwest trending faults.

South of Sudbury the Archean and Early Proterozoic rocks are intersected by the Grenville Front, a northeast-trending, southeast-dipping zone of cataclasis and mylonitization. The Grenville Front Tectonic Zone (GFTZ) is the northwest limit of the Grenville Province, an orogen in which deep crustal levels were uplifted and thrust northwestward during the Middle Proterozoic. Within the GFTZ, deformed and metamorphosed equivalents of Archean and Early Proterozoic rocks exposed to the north can be recognized. Southwest of the GFTZ, gneisses of unknown affinity have been affected by similar northwest-directed thrusting and ductile folding. Late east trending faults and diabase dykes transect the rocks of the northwest Grenville Province.

The Sudbury Structure is located along the main contact between Archean plutonic rocks of the Superior Province and Early Proterozoic supracrustal rocks of the Southern Province. The structure is outlined by an Early Proterozoic composite mafic-felsic intrusion, the Sudbury Igneous Complex (SIC), which surrounds a synclinorial basin occupied by breccia, mud stone, and wacke of the Whitewater Group. Around the intrusion is a broad zone of intensely brecciated, shatter-cone bearing, shock metamorphosed country rocks. Major Ni-Cu-PGE sulfide ore bodies lie at the base of the SIC and in offset dykes that extend outward from the SIC. The Sudbury structure has been interpreted as the product of explosive volcanism and as an astrobleme, the result of meteorite impact.

To enhance the geologic information content of the bedrock map the geology map was combined with a radar image that highlights topographic features. The first map illustrates the geology for a portion of the Sudbury area. The second map is a mosaic of several airborne radar flights Radar is an active side-looking remote sensing system that generates its own energy at microwave wavelengths The energy interacts with the ground and a portion of it is reflected back to the radar antennae. The proportion of energy reflected back is determined by several factors including terrain factors. As a result radar provides an excellent image of the surface topography. Airborne sensors have the advantage that look direction and incidence angle can be chosen to highlight structural features of a known orientation. The third map is an **IHS** composite in which the hue was derived from the geology map and the intensity was derived from the radar. In this fashion the radar was intended to highlight structural features on the geology while retaining the color integrity of the geology map.

Correlation of Geology and SAR Imagery

The major geological elements outlined in the foregoing are reflected, to variable degrees, in the SAR imagery. For example, in the northwest, the massive Archean granitic rocks yield generally low-relief, "hummocky" patterns whereas the greenstone belts and Huronian outliers have higher relief and more linear aspects. Numerous NNW and NW lineaments delineate faults and dykes. The origin of several prominent EW to NE trending SAR lineaments is not evident from the geology; they may represent unmapped faults.

The Huronian areas have generally moderate to locally high relief, linear SAR imagery that reflects the dominant fold and fault trends. Resistant formations that form rugged hills, for example the Lorrain and Bar River formations that form the La Cloche Hills in the Georgian Bay area are particularly striking.

The elliptical Sudbury Structure is nicely outlined by ranges of hills developed on the SIC and lower part of the Whitewater Group. Fold structures in the upper Whitewater Group in the central part of the structure are also evident.

Probably the greatest contrast in the SAR imagery is associated with the contact between the Grenville Province and the other provinces, the GFTZ, which is expressed by changes in orientation and relief. Further into the Grenville Province, the dominant northwest trending folds and east trending faults and dykes are prominently reflected.

In summary, SAR imagery can be used in the same way as detailed topographic data to delineate differing structural trends and lithologies, insofar as these are expressed topographically. It is especially useful in delineating brittle structures such as faults and joints.

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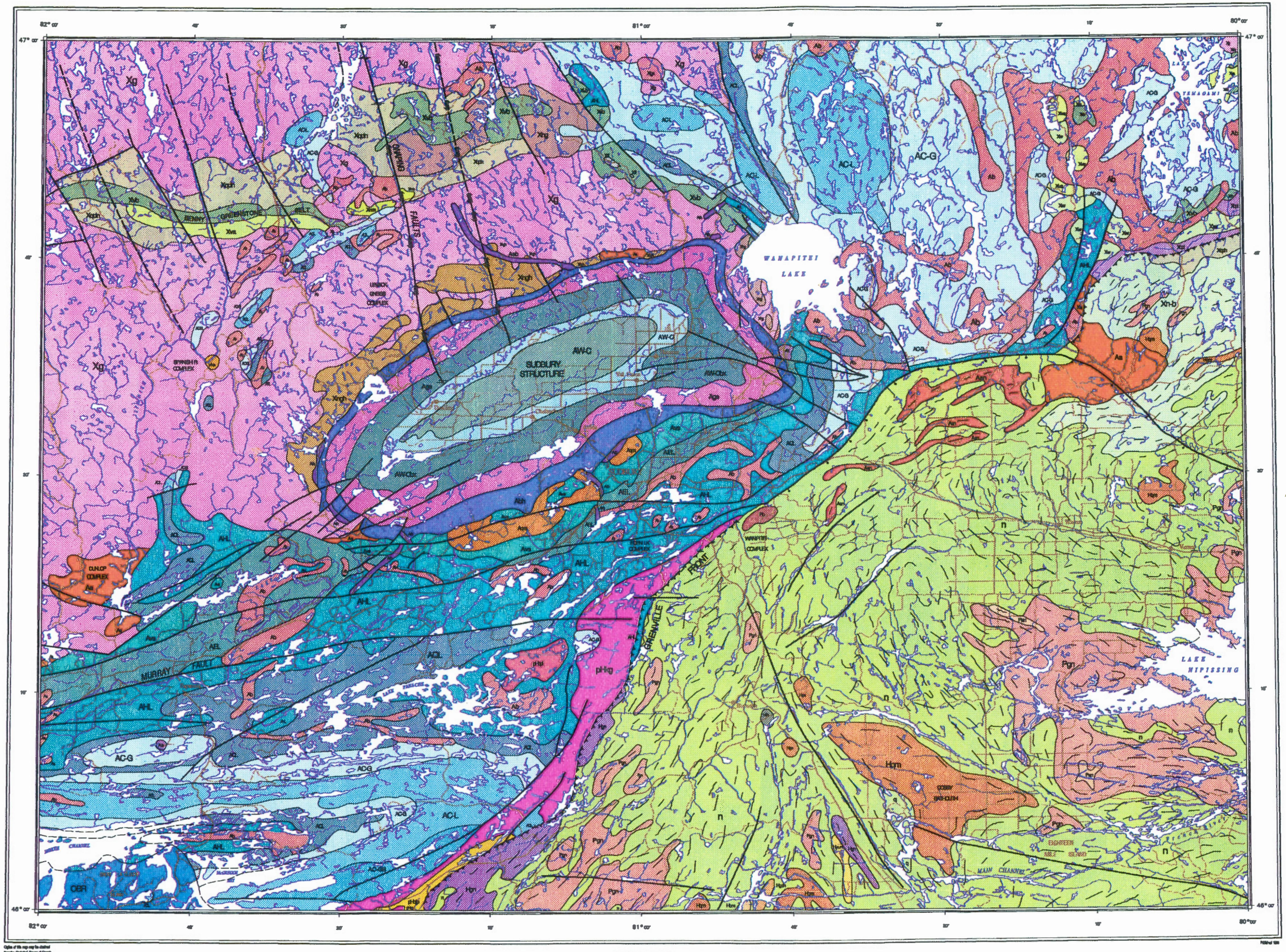


LEGEND

PHANEROZOIC
PALEOZOIC
MIDDLE ORDOVICIAN

- OBR — BLACK RIVER GROUP

PROTEROZOIC
HELIKIAN
(relative ages uncertain)

- Hyun — gneissic nepheline syenite
- Hgn — gneissic biotite granite, leucogranite
- Hgdn — gneissic hornblende-biotite and biotite granodiorite with k-feldspar megacrysts and augen; partly migmatitic
- Hqm — garnet-bearing quartz monzonite; locally with augite
- Hdn — gneissic hornblende diorite
- Hon — gneissic metagabbro, minor diorite, anorthositic phases

PALEOHELIKIAN

- pHKg — KILLARNEY SUITE granite, granodiorite
- pHqfp — foliated, locally albitized quartz-feldspar porphyry associated with KILLARNEY SUITE
- pHqd — trondhjemite, quartz diorite

APHEBIAN AND/OR HELIKIAN

- Pgn — migmatitic granitoid orthogneiss; may include equivalents of pHKg
- Pb — gabbro, metagabbro
- Pan — anorthosite gneiss

APHEBIAN
NEOAPHEBIAN

- Aub — ultramafic and mafic intrusions
- Agp — SUDBURY IGNEOUS COMPLEX (Anb, Abh, Agp) granophyre
- Abh — norite, gabbro, quartz gabbro
- Anb — sublayer gabbro
- nAca — clastic rock, carbonatite of the SPANISH RIVER COMPLEX

MESOAPHEBIAN
WHITEWATER GROUP

- AW-C — CHELMSFORD FORMATION
- AW-O — ONWATIN FORMATION
- AW-Obx — ONAPING FORMATION

PALEOAPHEBIAN

- Ab — tholeiitic gabbro, metagabbro of the NIPISSING GABBRO
- Aqm — granite, quartz monzonite of the CREIGHTON AND MURRAY PLUTONS

HURON SUPERGROUP

- AC-GB — GORDON LAKE AND BAR RIVER FORMATION
- AC-L — LORRAIN FORMATION
- AC-G — GOWGANDA FORMATION

QUIRKE LAKE GROUP

- ACL — BRUCE, ESPANOLA AND SERPENT FORMATIONS

HOUGH LAKE GROUP

- AHL — RAMSAY LAKE, PECORS AND MISSISSAGI FORMATIONS

ELLIOT LAKE GROUP

- AEL — MATINENDA AND McKIM FORMATIONS
- Ava — mafic and felsic volcanic rocks, weakly of the THESSALON, SALMAY LAKE, ELSIE MOUNTAIN, STOBIE AND COPPER CLIFF FORMATIONS

PALEOAPHEBIAN

- Aa — gabbro, anorthosite
- Aan — gneissic anorthosite, minor gabbroic and ultramafic phases

PALEOAPHEBIAN (?)

- q — quartzite (HURON SUPERGROUP ?)

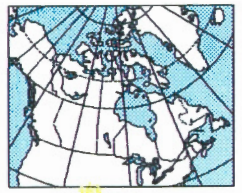
ARCHEAN AND/OR PROTEROZOIC
ARCHEAN AND/OR APHEBIAN AND/OR HELIKIAN

- n — quartzofeldspathic, biotite and amphibolite gneiss, migmatite in part; probable supracrustal rocks, locally with associated metaplutonic rocks

ARCHEAN
(relative ages uncertain)

- Xg — granite, pegmatite, minor quartz syenite, monzonite, granodiorite
- Xqd — tonalite, trondhjemite, quartz diorite
- Xgx — xenolithic and agmatitic granitic rocks; variable mixtures of Xg and Xqd with Xvb, Xva, Xnm
- Xqdn — tonalite, granodiorite and quartz diorite orthogneiss, commonly with xenoliths, chiefly Xnm, and intrusions of Xg
- Xng — xenolithic and layered granodiorite to diorite orthogneiss and associated migmatitic rocks
- Xngh — granulite facies xenolithic and layered granodioritic to dioritic orthogneiss
- Xnm — diorite, gabbroic and amphibolitic orthogneiss and associated migmatitic rocks
- Xif — iron formation, mainly oxide facies with lesser sulphide with carbonate facies
- Xn-b — biotite gneiss, partly migmatitic, locally enclosing amphibolite lenses and blocks; probable protolith: AW
- Xw — turbiditic wacke, siltstone, pelite, conglomerate; interbedded with volcanic rocks
- Xva — felsic, intermediate volcanic rocks; tholeiitic, calc-alkalic flows, pyroclastics, subvolcanic intrusions with interbedded volcanogenic sediments
- Xvb — mafic, intermediate volcanic rocks; tholeiitic, calc-alkalic flows, pyroclastics, subvolcanic intrusions with interbedded volcanogenic sediments

Geological boundary (defined, assumed) ......
Foliation trend ....
Fault, displacement unknown (defined, assumed) ....
Normal fault, solid circle on hanging wall (defined) ....
Strike-slip fault (defined, assumed) ....
Thrust fault, teeth on hanging wall (defined, assumed) ....



Geology derived from Card KD, Sanford BV, Davidson A, 1992
Lake Superior-Sudbury, Ontario, NL-16/17-G, Scale 1:1 000 000

Source of bedrock geology extracted from Geological Atlas, Map NL-16/17-G, Sheet 1 of 6

Geological digital cartography by the Geological Survey of Canada

EXPERIMENTAL MAP

GEOLOGY

SUDBURY

ONTARIO

Scale 1:250 000 - Échelle 1/250 000

Kilometres 5 0 5 10 15 20 Kilomètres

Transverse Mercator Projection
CM 81°, Scale Factor 1
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Projection transverse de Mercator
M.C. 81°, facteur d'échelle 1
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Any revisions or additional geological information known to the user would be welcomed by the Geological Survey of Canada

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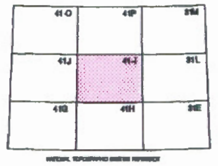
Copies of the topographical edition of this map may be obtained from the Canada Map Office, Department of Energy, Mines and Resources, Ottawa, Ontario, K1A 0E9



Canada

EXPERIMENTAL MAP
GEOLOGY
SUDBURY
ONTARIO

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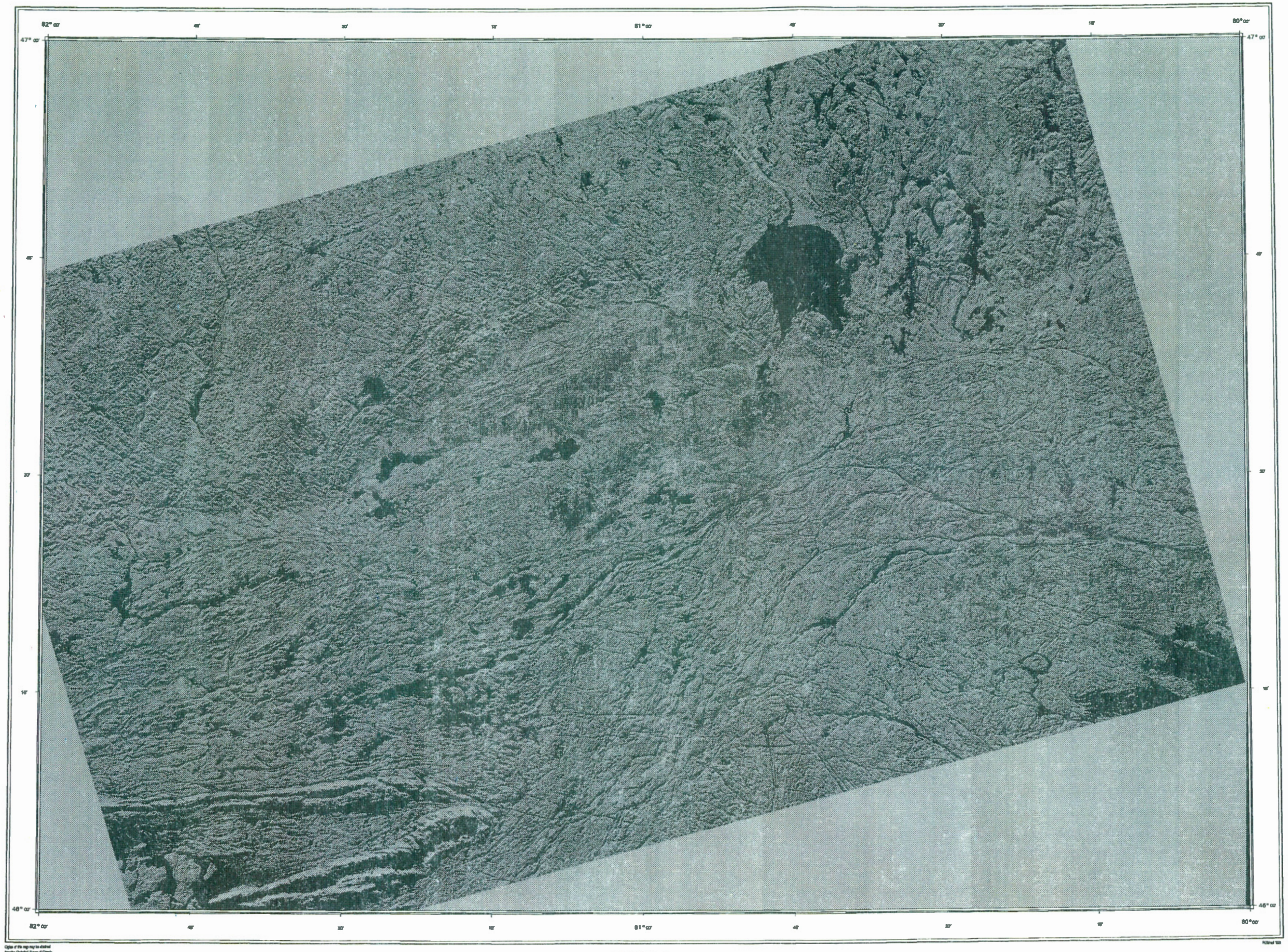

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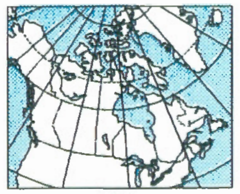

EXPERIMENTAL MAP

AIRBORNE SYNTHETIC APREATURE RADAR (SAR)

SUDBURY

ONTARIO

Source of airborne synthetic aperture radar (SAR) from Canada Centre for Remote Sensing (CCRS)

Geological digital cartography by the Geological Survey of Canada

Scale 1:250 000 - Échelle 1/250 000

Kilometres 5 0 5 10 15 20 Kilomètres

Transverse Mercator Projection
CM 81° Scale Factor

Projection transverse de Mercator
M.C. 81°, facteur d'échelle 1

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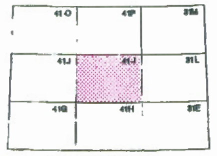

Canada

EXPERIMENTAL MAP
AIRBORNE SYNTHETIC APREATURE RADAR (SAR)
SUDBURY
ONTARIO

Energy, Mines and Resources Canada
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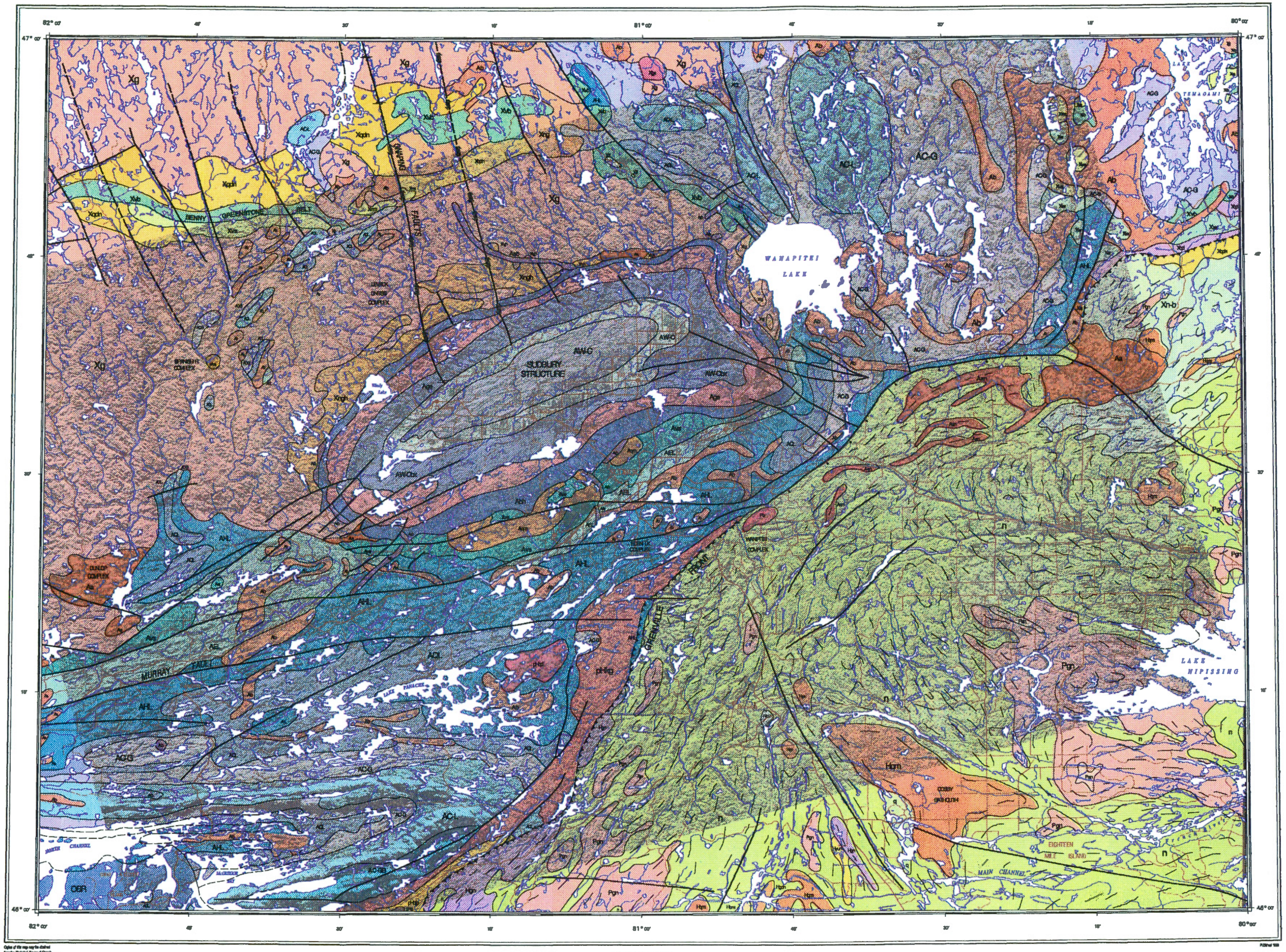
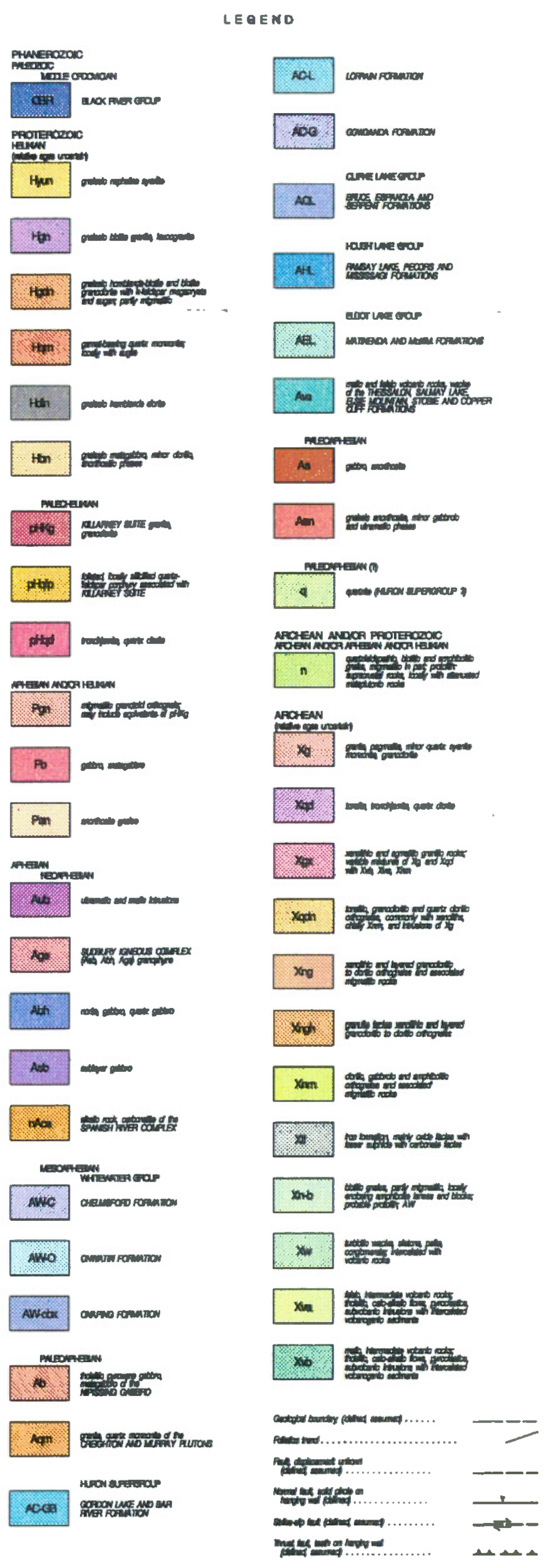
INTERA





EXPERIMENTAL MAP

AIRBORNE SYNTHETIC APREATURE RADAR (SAR) / GEOLOGY

SUDBURY

ONTARIO

Scale 1:250 000 - Échelle 1/250 000

Kilometres 5 0 5 10 15 20 Kilomètres

Transverse Mercator Projection
CM 81°, Scale Factor 1
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Projection transverse de Mercator
M.C. 81°, facteur d'échelle 1
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Source of bedrock geology extracted from Geological Atlas, Map NL-16/17-G, Sheet 1 of 6

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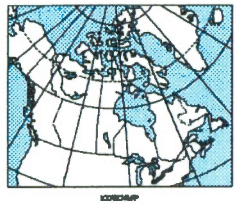

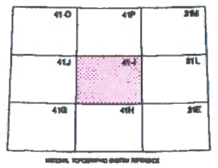

Experiments In Combining Geology Maps With Terrain Relief Data

The topographical relief of a region is of direct interest to the field geologist. The manner in which structural features such as folds, faults, foliations, lineations and joints are expressed via topographical relief, has bearing on the way a geologist will map an area or interpret an existing geology map. The Non-Renewable Resource Group of the Canada Centre of Remote Sensing, the Geoscience Information and Communications Division of the Geological Survey of Canada and Intera Information Technologies have collaborated on producing experimental geology maps which combine topographic relief with existing 1:250 000 scale geology maps using a combination of Image Analysis and Computer-Assisted Cartographic techniques. The source of relief information is Airborne Synthetic Aperture Radar (SAR) Data. The algorithm used to combine the two data types is based upon an Intensity-Hue-Saturation (IHS) colour transform. Final products are optimized for both hardcopy and digital output products. Various processing steps involved in producing the maps along with recommendations of future enhancements are discussed.

EXPERIMENTAL MAP
AIRBORNE SYNTHETIC APREATURE RADAR (SAR) / GEOLOGY
SUDBURY
ONTARIO

Canada

AEROMAG/DEM/GEOLOGY

Reed Lake - File Lake

Lucas, S., D. Viljoen and J. Broome

The Snow Lake area is host to numerous Cu-Zn deposits, including several that are being actively mined, and has historically had a history of gold mining. The challenge in mineral exploration in the Snow Lake area today, after decades of intense study is to utilize new concepts and technologies in concert with detailed geologic mapping. This mapping project employs image analysis and GIS technology to facilitate both visualization of numerous geological data sets and analysis of data attributes or derived attributes. However the geographic area examined in this study and represented in the four image products encompass a significant part of the eastern Flin Flon-Snow Lake area and thus presents a more regional perspective on the interrelation of geologic and remotely sensed data sets.

There are four maps in the series designed to show the merits of digitally combining data sets. In this case the map of bedrock geology was combined with aeromagnetic data to assist in the visualization of the bedrock architecture. This was further enhanced by providing a perspective view to the combined imagery.

The first map illustrates the geology of the area. This map was produced by compiling and digitizing existing geologic maps and incorporating new data from computer based field studies. The second map is a shaded relief map of total field magnetics. The picture is analogous to the sun setting on a mountain range with the height of the mountain being proportional to the magnetic flux intensity. The insert in the corner illustrates the simulated illumination direction for a light source which in this case was with an azimuth of 315^{o} and an altitude of 45^{o}. The red lines on the figure represent vector outlines of lithologic contacts from the geologic map. The thick red line near the bottom of the image represents the limit of the exposed Precambrian rocks of the Canadian Shield.. The third map is an **IHS** image combining geology and aeromagnetic data. The hue and saturation were derived from the geology map and the intensity was derived from the magnetic data. This was done to maintain the color integrity of the geology map and use the intensity of the magnetic data to provide structural information. The fourth figure provides a perspective to the imagery by putting the viewpoint above the surface and to the south of the map.

The complexity of the geologic structure in the eastern Flin Flon-Snow Lake Belt and especially in the area north of Snow Lake is highlighted in the obliquely viewed, 3-D image of the total field aeromagnetic data. One of the difficulties in geologic mapping and structural analysis has been the ability to trace important lithotectonic units or structures through poorly exposed or unexposed areas. The derived aeromagnetic images and the multi-component images with geologic units draped on the 3-D aeromagnetic base, indicate that the volcanic belt and sedimentary basin units are continuous from Snow Lake to the west towards File Lake and appear to be concentric around the orthogneissic cored domes to the north. These images are of a positive utility to the geologist because of the relative consistency of magnetic susceptibility or magnetic "texture" within individual geologic units or map scale assemblages.

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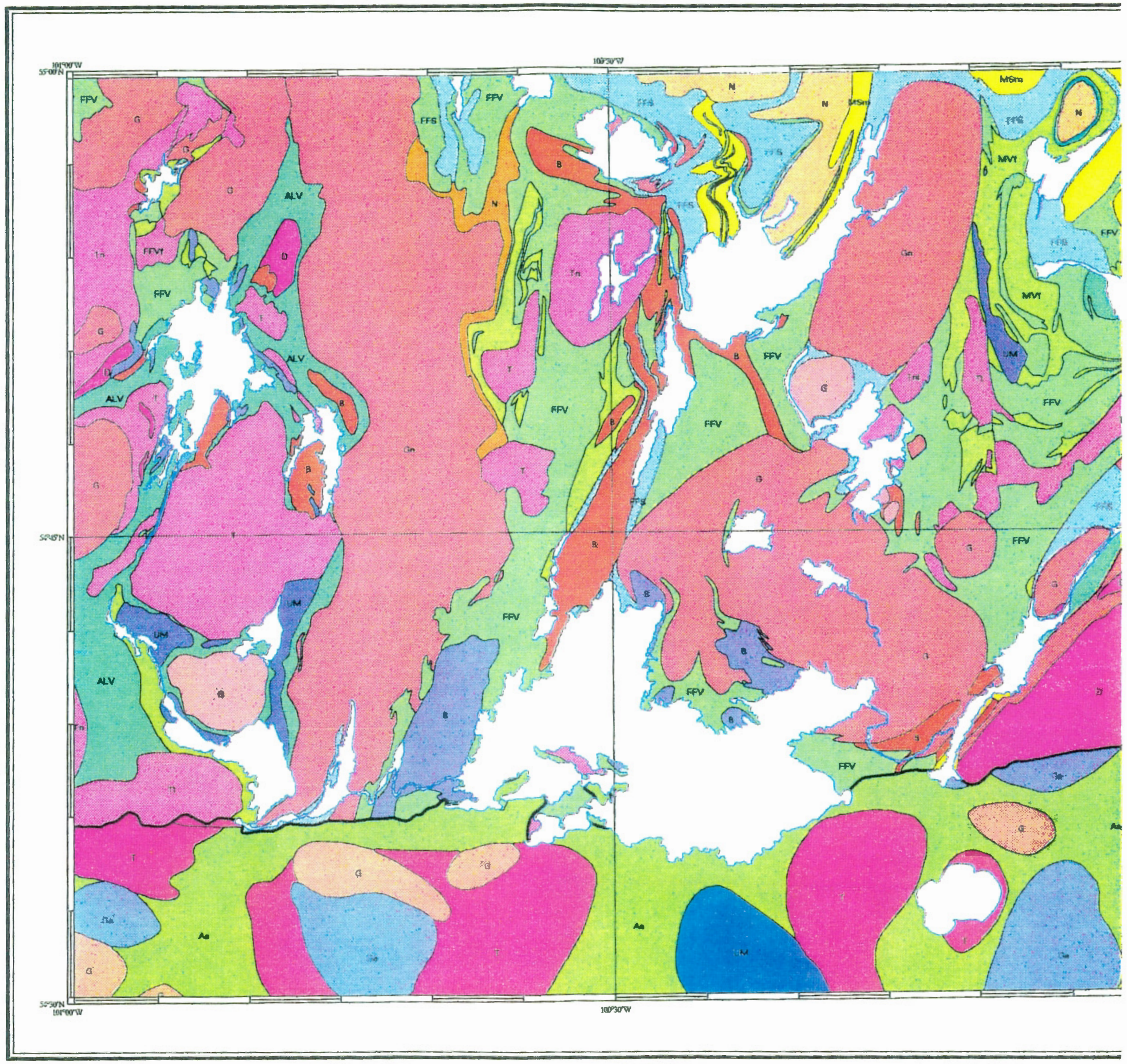
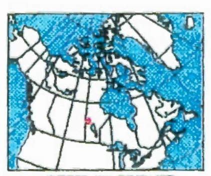




EXPERIMENTAL MAP

EXPOSED AND SUB-PALEOZOIC GEOLOGY AND SHADED MAGNETICS

REED LAKE - FILE LAKE

FLIN FLON - SNOW LAKE BELT, MANITOBA

Scale 1:125 000 - Échelle 1/125 000

Kilometres 2 0 2 4 6 8 10 Kilomètres

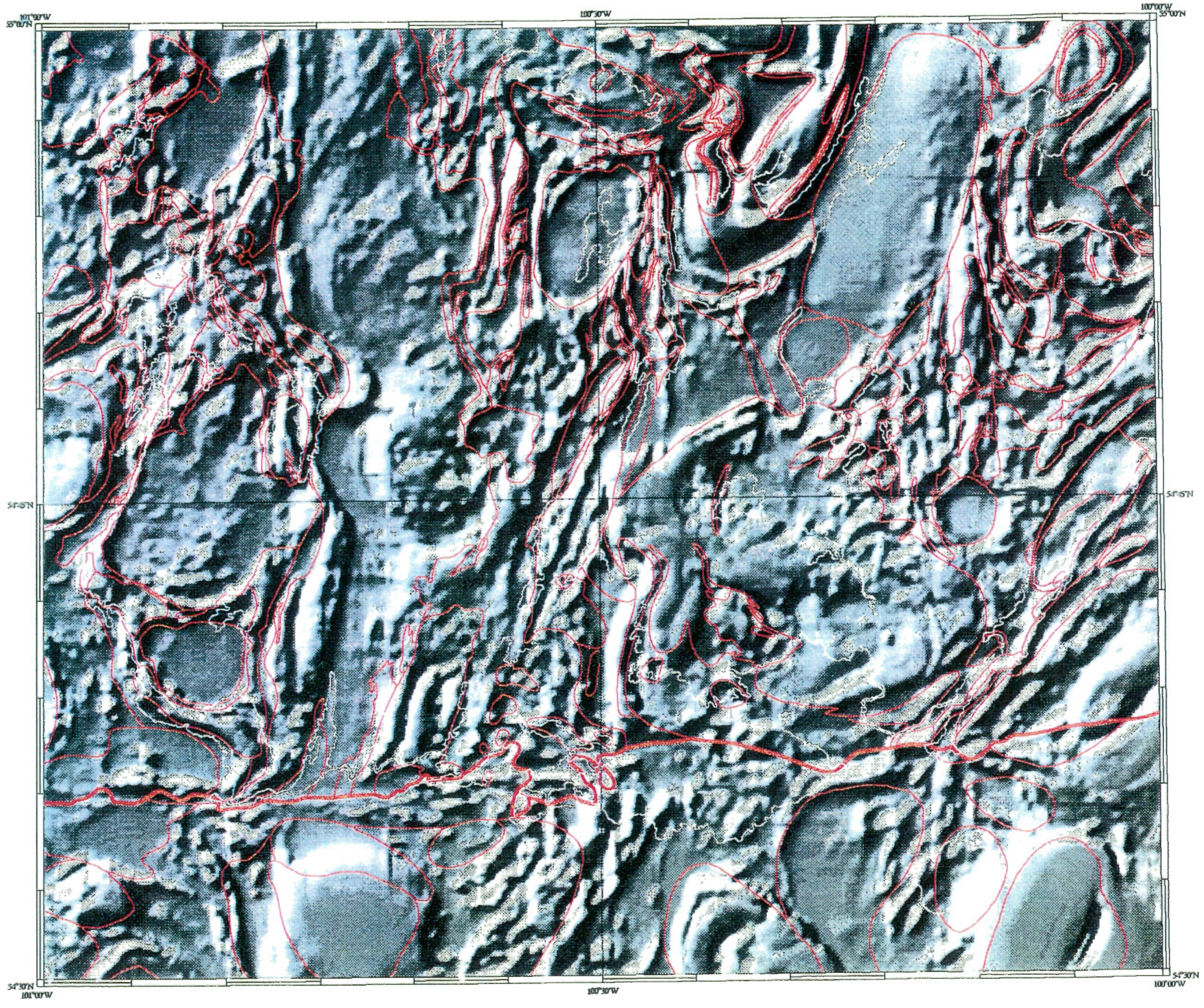
Original digital geology compilation by [illegible]

Data integration concept and digital cartography by [illegible]

Project coordinators [illegible]

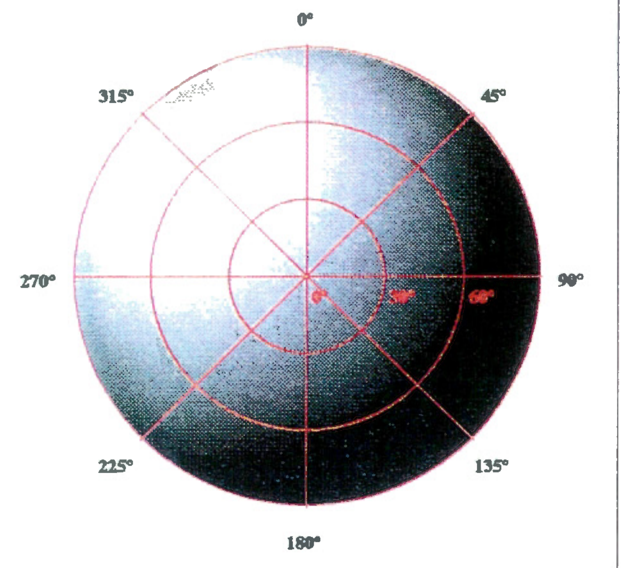
Energy, Mines and Resources, Canada   Énergie, Mines et Ressources, Canada

INTERA



LEGEND

Local surface illumination
Light source at Azimuth=315°, Altitude=45°

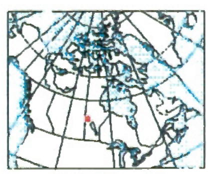


This map is shaded relief map of the total field aeromagnetics. It is analogous to the sun setting on a mountain range. In this case, the height of the mountains is proportional to the magnetic flux intensity.

Aeromagnetic surveys are flown with a sensor towed in a housing ("bird") at some distance from the aircraft to minimize magnetic effects of the aircraft. The sensor measures magnetic flux and is sufficiently sensitive to detect variations due to magnetic properties of rocks at and below the Earth's surface. The plane flies along equally spaced flight lines and takes measurements at regular intervals along each line. The result is a grid of points that can be interpolated into a continous image of total field magnetics.

The red lines are geological contacts between different lithological units. There is a thick line about one fifth up the map that represents the limit of the exposed precambrian rocks of the Canadian Shield. The geology mapped in this area was created by digitizing existing hardcopy geological maps, and incorporating new data from computer-based field systems. South of this line the Shield is overlain by much younger rock that is of little mineralogical value. The precambrian geology in this area is inferred from borehole and geophysical data.

This product provides for direct visualization of the relationship between geology and geophysics helping geologists and geophysicists to better understand the lithological architecture and litho-tectonic history of the area.



EXPERIMENTAL MAP

EXPOSED AND SUB-PALEOZOIC GEOLOGY AND SHADED MAGNETICS

REED LAKE - FILE LAKE

FLIN FLON - SNOW LAKE BELT, MANITOBA

Scale 1:125 000 - Échelle 1/125 000

Kilometres 2 0 2 4 6 8 10 Kilomètres

The geological data was extracted from the NATMAP Shield Margin Project's geoscientific database and represents the northeast quadrant of a 1:50,000 scale GSC Open File map compiled by [illegible] (GSC) and [illegible].
The geophysical data was preprocessed and provided by [illegible] of the Geophysical Data Center (GSC).

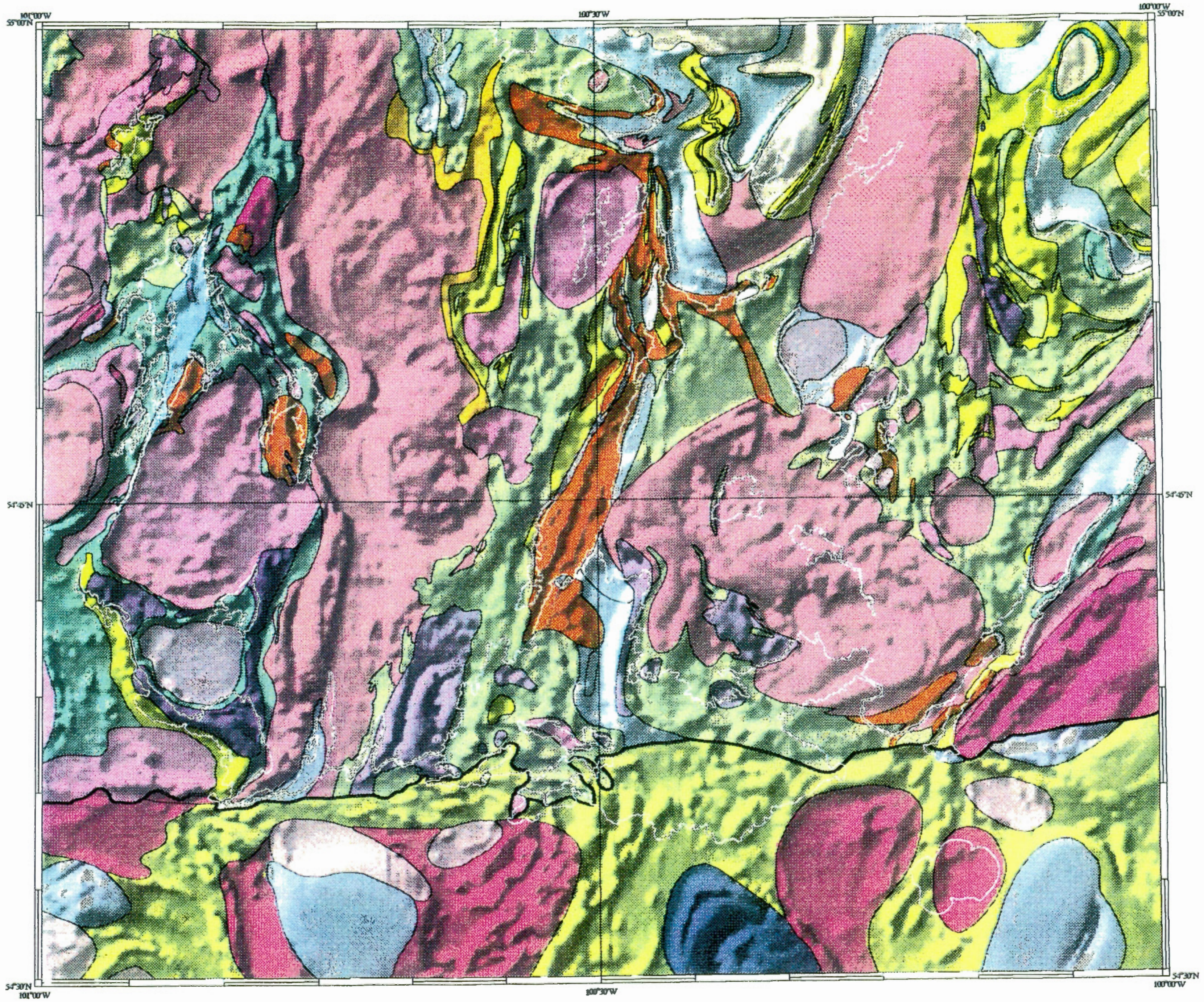
Digital cartography by [illegible] (GSC) and anyone else who wishes to lay claim to this masterpiece.

Project coordinators [illegible] (GSC), [illegible] (Intera), [illegible] (GSC) and [illegible] (GSC).

Canada

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

INTERA



LEGEND

EXPOSED PRECAMBIAN ROCKS

Plutonic rocks

- G — *Granite, massive*
- T — *Tonalite-granodiorite*
- G — *Granodiorite-granite; Gn - gneissic granodiorite*
- D — *Diorite +/ biotite, quartz diorite, gabbro*
- B — *Gabbro-quartz diorite*
- N — *Granfield gneiss*

Mafic and Ultramafic Intrusions

- B — *Gabbro-norite; layered gabbro, leucogabbro, anorthosite*
- UM — *Metadiorite, olivine gabbro peridotite*

Missi Group

- MVf — *Felsic gneiss of probable volcanic derivation*
- MS — *Sandstone, pebbly sandstone, polymictic conglomerate; MSm - metasandstone, quartzo-feldspathic gneiss, locally hornblende +/-biotite rich; quartz-rich gneiss +/-sillimanite*

Amisk Group - *Flin Flon Assemblage*

- FFV — *Pillowed mafic flows, volcaniclastic rock and related intrusions with arc tholeiite affinity*
- FFVf — *Rhyolite flows and volcaniclastic rocks, locally felsic intrusions*
- FFC — *Volcanic conglomerate*
- FFS — *Sediments (undivided); graywacke, siltstone, shale, quartz-plagioclase gneiss, metagreywacke, garnetiferous biotite gneiss +/-staurolite +/-sillimanite*

- Athapapuskow Lake Assemblage

- ALV — *Mafic volcanic rocks to MORB affinity and related mafic and ultramafic intrusive rocks*

- Mistik Lake Assemblage

- MLF — *Felsic intrusive rocks; tonalite, granodiorite, quartz diorite, rhyolite, pegmatite, aplite*

- Metamorphic Rocks and Tectonics

- W — *Biotite-garnet gneiss, metagreywacke +/-sillimanite*

Plutonic Rocks BURIED PRECAMBIAN (sub-Paleozoic)

- G — *Granite-granodiorite: massive to foliated, locally porphyritic biotite +/-hornblende monzogranite to granodiorite*
- T — *Tonalite-granodiorite-quartz diorite; foliated to gneissic hornblende-biotite tonalite, granodiorite and quartz diorite*

Mafic and Ultramafic Intrusions

- Gа — *Gabbro-diorite; mafic quartz diorite*
- UM — *Pyroxenite-metagabbro/diorite-peridotite(?); minor hornblendite and serpentine*

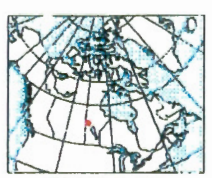
Supracrustal rocks

- Ae — *Metamorphic rocks derived from from volcanic, volcaniclastic and sedimentary units of the Amisk Group*

This map is hue-saturation-value colour composite image of geology and geophysics. The hue and saturation components of the colour are derived from the geology and the value from the geophysics (shaded total field magnetics).

There is a thick line about one fifth up the map that represents the limit of the exposed precambrian rocks of the Canadian Shield. The geology mapped in this area was created by digitizing existing hardcopy geological maps, and incorporating new data from computer-based field systems. South of this line the Shield is overlain by much younger rock that is of little mineralogical value. The precambrian geology in this area is inferred from borehole and geophysical data.

This product provides for direct visualization of the relationship between geology and geophysics helping geologists and geophysicists to better understand the lithological architechture and litho-tectonic history of the area.



EXPERIMENTAL MAP

EXPOSED AND SUB-PALEOZOIC GEOLOGY AND SHADED MAGNETICS

REED LAKE - FILE LAKE

FLIN FLON - SNOW LAKE BELT, MANITOBA

Scale 1:125 000 - Échelle 1/125 000

Kilometres 2 0 2 4 6 8 10 Kilomètres

The geological data was extracted from the NATMAP Shield Margin Project's geoscientific database and represents the northeast quadrant of a 250,000 scale GSC Open File Map 2391 (Sheet 3) compiled by S. Lucas (GSC) and W. Weber (MEM).

Original digital geology compilation by Mike Gignac (GSC), Les Chackowsky (MEM)

The geophysical data was preprocessed and provided by Warner Miles of the Geophysical Data Centre (GSC).

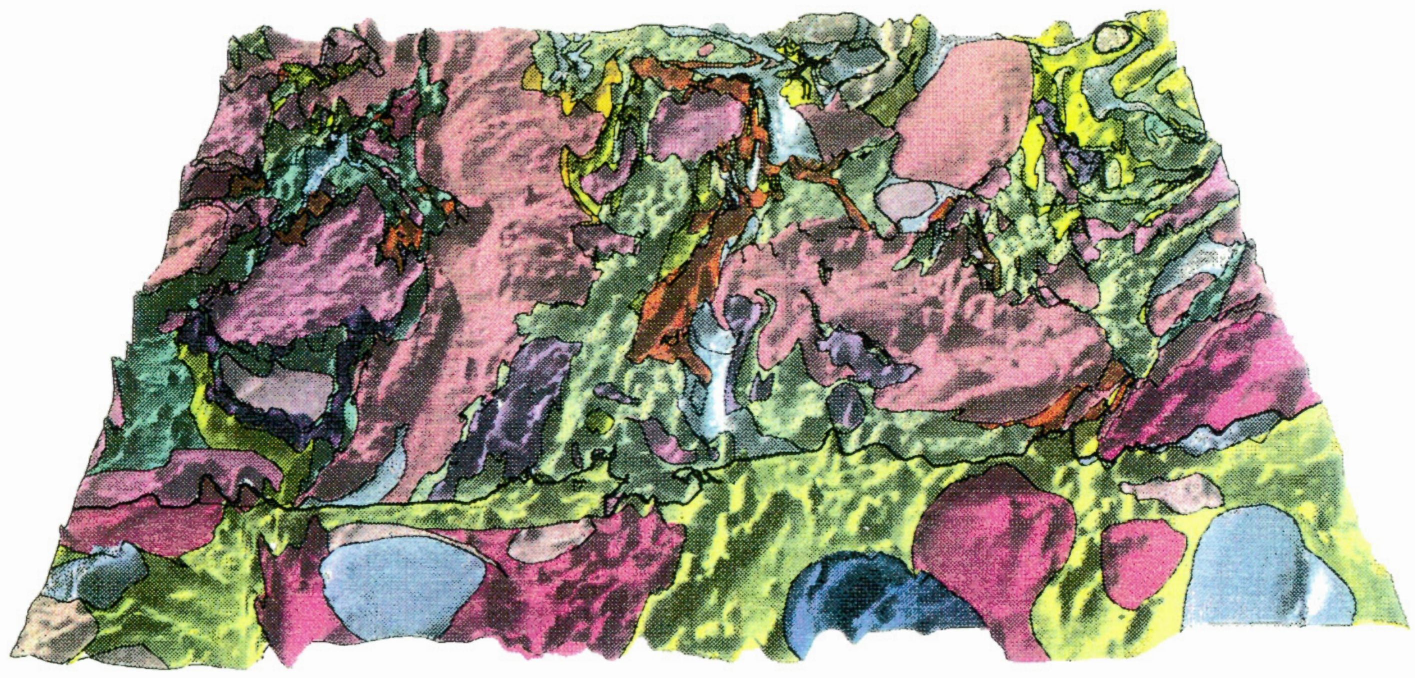
Data integration concept and digital cartography by David Viljoen (GSC).

Project coordinators Andy Rencz (GSC), Heather Press (Intera), Jeff Harris (GSC) and John Glynn (GSC).

Canada

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

INTERA



LEGEND

EXPOSED PRECAMBRIAN ROCKS

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Mafic and Ultramafic Intrusions

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Mafic and Ultramafic Intrusions

- Gb — *Gabbro-diorite; mafic quartz diorite*
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Supracrustal rocks

- As — *Metamorphic rocks derived from from volcanic, volcaniclastic and sedimentary units of the Amisk Group*

This map is hue-saturation-value colour composite image of geology and geophysics. The hue and saturation components of the colour are derived from the geology and the value from the geophysics (shaded total field magnetics).

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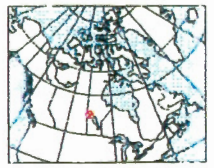
This product provides for direct visualization of the relationship between geology and geophysics helping geologists and geophysicists to better understand the lithological architechture and litho-tectonic history of the area.



EXPERIMENTAL MAP

EXPOSED AND SUB-PALEOZOIC GEOLOGY AND SHADED MAGNETICS

REED LAKE - FILE LAKE

FLIN FLON - SNOW LAKE BELT, MANITOBA

Scale 1:125 000 - Échelle 1/125 000

The geological data was extracted from the NATMAP Shield Margin Project's geoscientific database and represents the northeast quadrant of a 250,000 scale GSC Open File map compiled by Steve Lucas (GSC) and W(J) Weber (MEM). The geophysical data was preprocessed and provided by Walter Miles at the Geophysical Data Centre (GSC).

Project coordinators Andy Rencz (GSC), Heather Press (Intera), Jeff Harris (GSC)

Canada

GEOCHEMISTRY/REMOTE SENSING

Labrador

P. Friske, J. Harris

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National Geochemical Reconnaissance (NGR) surveys in Labrador commenced in 1976 and by 1988 the entire landmass had been covered. In total sediment and coincident water samples were collected from 19,030 lakes and 1380 streams, at an average sample density of approximately 1 every 13 km^2 (Friske and Hornbrook, 1991). These reconnaissance surveys were funded through a series of Mineral Development Agreements between the Governments of Canada and Newfoundland and Labrador.

The Nipishish Lake area was initially surveyed in 1983, as part of a much larger reconnaissance program (Hornbrook et al., 1984). Initially data for Zn, Cu, Pb, Ni, Co, Ag, Mn, Mo, As, Fe, Hg, LOI, U, F, V and Cd in sediment and U, pH and F in water were released. The accompanying maps are based on this data set. Also available for this area are: data for approximately 20 additional elements (including Au, Sb, La, Eu, Cr, Ba and others) generated by a re analysis program that included the archived 1983 sediment samples (Friske et al., 1993) and results of a detailed infill lake survey undertaken in 1992, that covers most of the southern and western part of the area (Friske et al., 1993a).

This set contains a series of three maps that combine lake geochemical data with remotely sensed data (LANDSAT TM and ERS1 Radar data). The first map is a red-green-blue (**RGB**) color display that combines copper, zinc and lead. The geochemical data were collected from approximately 400 sample points across the map. These were transformed into a continuous surface map using an interpolation routine available within the ARC/INFO software package. Proportional mixes of the three primary colors (red, green and blue) reflect the relative proportions of the three elements . The bright colors reflect higher concentrations of the three elements. Thus areas relatively high in copper, zinc and lead are displayed in bright red, green and blue hues, respectively. Areas relatively high in both copper and zinc are displayed in yellow (red plus green), areas high in copper and lead appear in a magenta/purple hue (red plus blue) and areas high in lead and zinc appear cyan (green plus blue). Areas relatively high in all elements will appear white (red plus green plus blue). The second map illustrates a combination of radar data (C- Band from ERS1) and the geochemical map. The data were combined using the **IHS** color transform. In this case the hue and saturation were derived from the geochemical map and the intensity was derived from the radar image. This was done to retain the color information from the geochemical data and attempt to enhance the structural and surficial geology features with the radar data. Similarly the third map illustrates a combination of geochemical data and LANDSAT TM data. The LANDSAT data were used to enhance structural and surficial information. The LANDSAT data were also used to provide a geographical backdrop for visualizing the geochemical data.

The geochemical map (3b) displays a number of anomalous areas. The most striking occur near the center of the map, where coincident Cu, Pb and Zn (white areas) and Cu and Zn (yellow areas) coincide with volcanic rocks of the Bruce River and Moran Lake Groups. Both are host to significant base metal occurrences. Base metals also occur to the northeast in the Copper Pond region over which there is a strong Cu response (red hues). A number of strong Pb anomalies (blue hues) are also shown that tend to be associated with areas of granitoid rocks (e.g. Otter Lake-Walker Lake granite, southwestern corner; Oscar Lake granite, northeaster corner).

It is noteworthy that some of these features are lost in the combined LANDSAT TM and geochemistry image (e.g. base metal anomalies in the Moran Lake area). This is related to replacement of the geochemical data by remotely sensed data in areas of high correlation in all three channels. Image 3c (radar and geochemistry) illustrates a solution to the problem by arithmetically combining the calculated intensity of the geochemical data with the remotely sensed data.

In the study area combining the geochemical data with the remotely sensed data using the IHS transform adds little additional information, other than providing a detailed base map. However this approach would likely be significantly more useful when used with elements such as Sb, Se and As which are pathfinder elements for Au and show a strong spatial association with lineaments (c.f. Davenport and McConnell, 1988).

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Lake sediment and water geochemical infill survey data, Province of Newfoundland (Labrador- NTS 13K/6, 13K/7, 13K/10 and 13K/15), Geological Survey of Canada Open File 2650, 90 p.

Hornbrook, E.H.W., Lund N.G. and Lynch J.J. 1984.
Geochemical lake sediment and water surveys, Labrador- 13K) maps and data, Geological Survey of Canada, Open File 997, p. 66.

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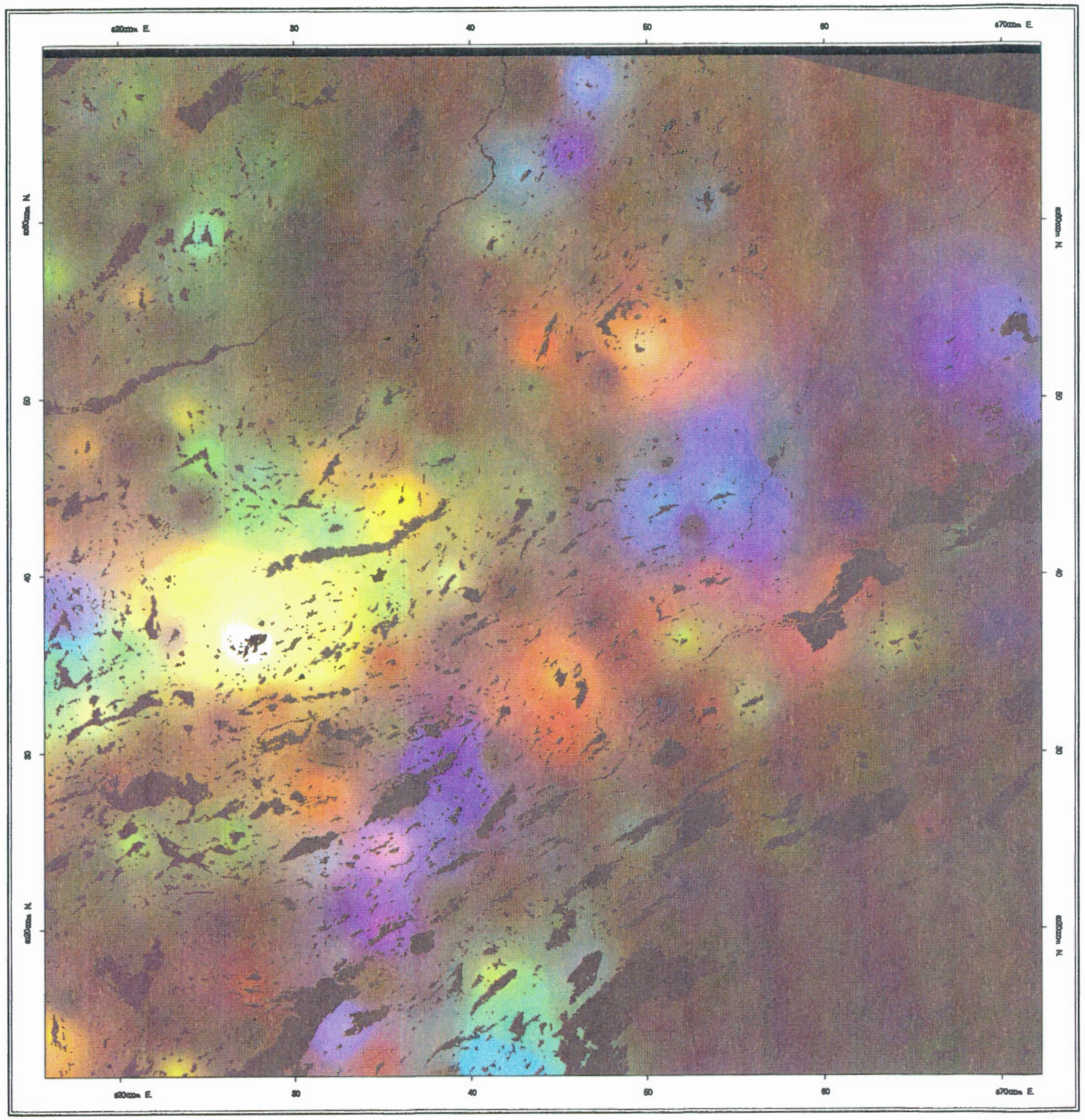
INTERA



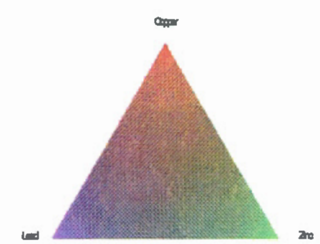
This map is a red-green-blue (RGB) colour composite (ternary) display of lake geochemical data collected over the Nipishish Lake district in Labrador, Newfoundland.

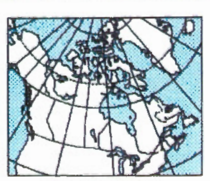
The map area is centred on the border between the Grenville and Nain Stuctural Provinces. The Grenville Province, occupying the southern portion of the map area, comprises Helikian paragneisses while the central portion of the map area comprises Helikian volcanic rocks of the Nain Province. Helikian anorthosites and Archean granitic gneisses are the major lithologies in the northern part of the map area.

The geochemical data were collected from sample points (approximately 400) across the map area. Continuous surface maps of copper, zinc and lead were generated using an interpolation algorithm available on the ARC/INFO GIS. The copper, zinc and lead data are displayed through red, green and blue colours as shown in the RGB triangle. Proportional mixes of the three primary colours (red, green, blue) reflect the relative concentrations of the three elements. The brighter colours reflect higher relative concentrations of each element. Thus, areas relatively high in copper, zinc and lead are displayed in bright red, green and blue hues, respectively. Areas relatively high in both copper and zinc are displayed in yellow (red + green), high in copper and lead in magenta/purple (red + blue) and high in lead and zinc in cyan (green + blue). Areas relatively high in all elements are white (red + green + blue).

Several anomalies can be seen, many of which occur within the volcanic and sedimentary rocks of the Nain province in the central portion of the map. An area relatively high in all elements occurs within this zone.

The volcanic rocks in the central portion of the map area contain a number of copper occurrences of economic interest.





EXPERIMENTAL MAP

LAKE GEOCHEMICAL COMPOSITE IMAGE

NIPISHISH LAKE

LABRADOR, NEWFOUNDLAND

Scale 1:125 000 - Échelle 1/125 000

Universal Transverse Mercator Projection / Projection transverse universelle de Mercator

The geochemical data were provided by the Geological Survey of Canada and are published in GSC Open File Report 1636.

Digital cartography by Jeff Harris (GSC), Paul Hazell (GSC), Gary Labelle (GSC) and Vic Dohar (GSC).

Project coordinators Andy Rencz (GSC), Heather Press (Intera), Jeff Harris (GSC) and John Glynn (GSC).

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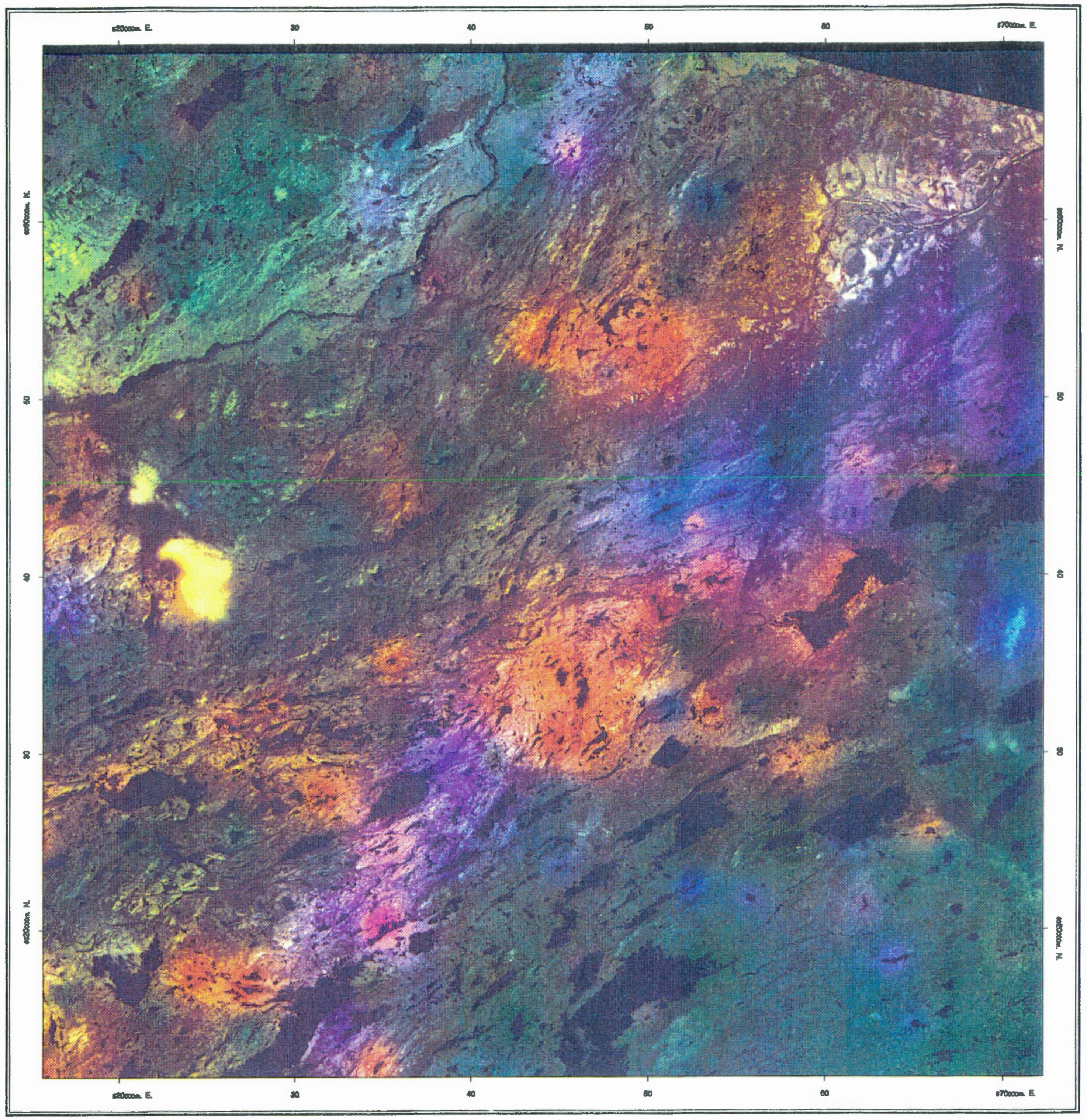
INTERA



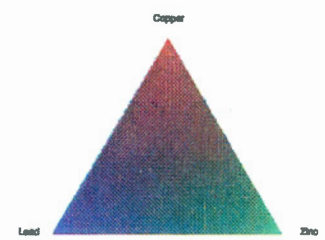
This map combines LANDSAT TM and lake geochemical data over the Nipishish Lake district in Labrador, Newfoundland.

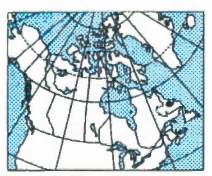
The map area is centred on the border between the Grenville and Nain Structural Provinces. The Grenville Province, occupying the southern portion of the map area, comprises Helikian paragneisses while the central portion of the map area comprises Helikian volcanic rocks of the Nain Province. Helikian anorthosites and Archean granitic gneisses are the major lithologies in the northern part of the map area

The data were combined using the intensity-hue-saturation (IHS) colour space transformation. Image intensity is modulated by the TM image while hue and saturation are modulated by the geochemical data. In this particular map the data has been combined in such a way to de-emphasize areas of high correlation in all three elements (copper, zinc, lead). Therefore, some of the available geochemical information has been surpressed and as result copper anomalies are emphasized.

The TM data provides information on surficial and structural features within the map area. The southeast and northeast areas comprise featureless low-lying wetlands. East-west trending structures within the volcano-sedimentary can be observed in the central portion of the map area.

Areas of anomolous geochemical concentrations can be directly compared to topographic and structural feaures seen on the TM data.





LOCATION MAP - LOCALISATION DE LA CARTE

EXPERIMENTAL MAP

LANDSAT TM AND LAKE GEOCHEMICAL COMPOSITE IMAGE

NIPISHISH LAKE

LABRADOR, NEWFOUNDLAND

Scale 1:125 000 - Échelle 1/125 000

Kilometres 2 0 2 4 6 8 10 Kilomètres

Universal Transverse Mercator Projection — Projection transverse universelle de Mercator

The geochemical data were provided by the Geological Survey of Canada and are published in GSC Open File Report [illegible]. The LANDSAT data was provided by RADARSAT INTERNATIONAL.

Digital cartography by Jeff Harris (GSC), [illegible] (GSC), Guy Labelle (GSC) and Vic Dohar (GSC).

Project coordinators Andy Rencz (GSC), Heather Press (Intera), Jeff Harris (GSC) and John Glynn (GSC).

Canada

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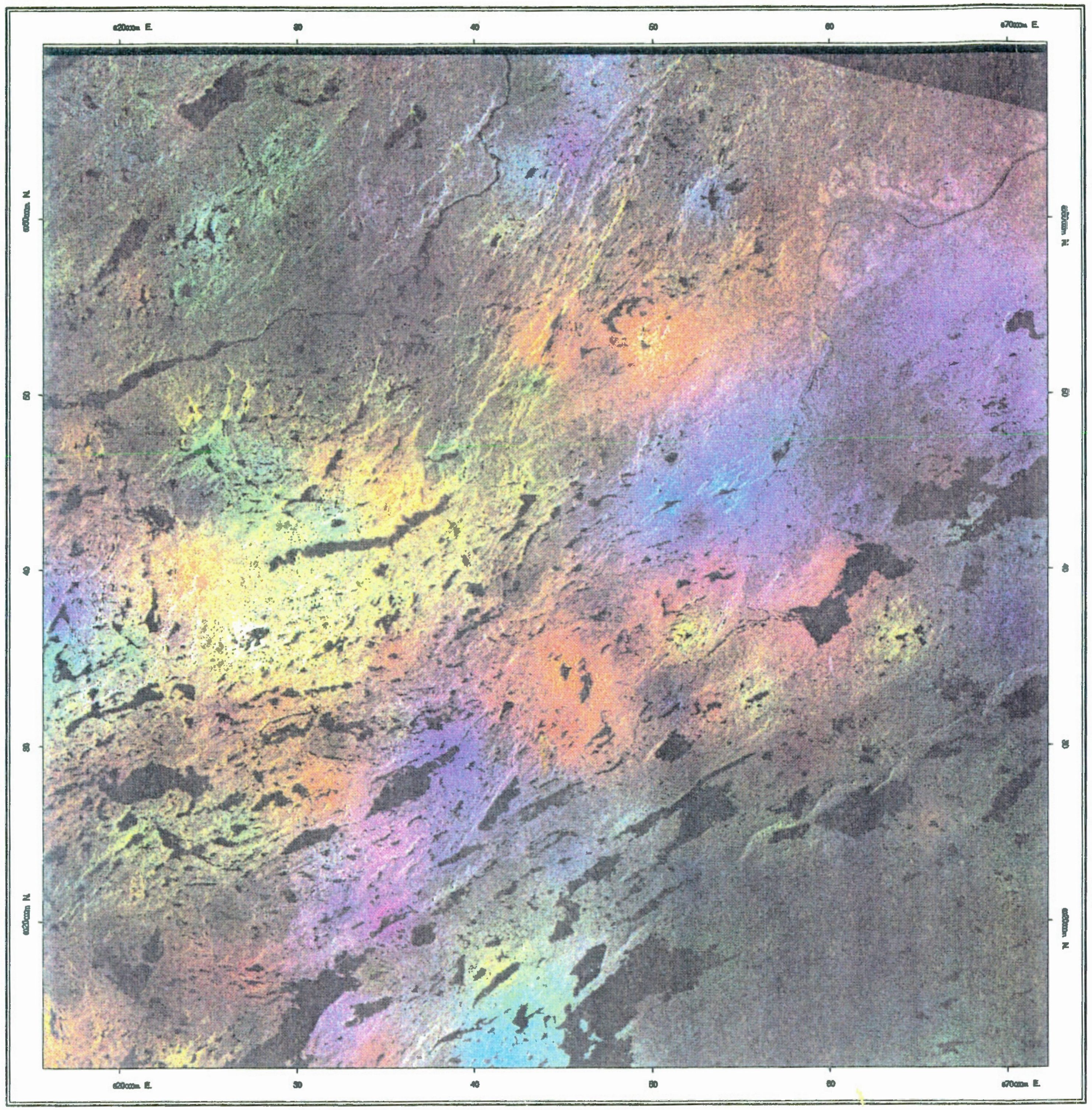
INTERA



This map combines ERS-1 SAR and lake geochemical data over the Nipishish Lake district in Labrador, Newfoundland.

The map area is centred on the border between the Grenville and Nain Stuctural Provinces. The Grenville Province, occupying the southern portion of the map area, comprises Helikian paragneisses while the central portion of the map area comprises Helikian volcanic rocks of the Nain Province. Helikian anorthosites and Archean granitic gneisses are the major lithologies in the northern part of the map area.

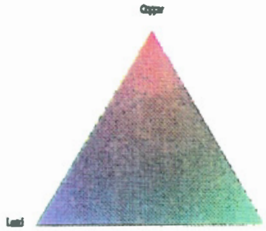
The satellite SAR image, which is characterized by approximately 30m spatial resolution (6 looks), was registered to a UTM base by identifying a series of ground control points (GCPs). A polynomial transform was used to warp ('rubber sheet') the data to the UTM co-ordinate grid.

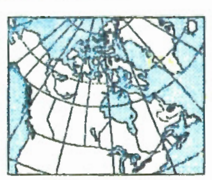
The data were combined using the intensity-hue-saturation (IHS) colour space transformation. In order to retain all the geochemical information, image intensity is modulated by a combination of the original intensity calculated from the geochemical data and the SAR data. Image hue and saturation are modulated by the geochemical data.

The copper, zinc and lead data are displayed through red, green and blue colours as shown in the RGB triangle. Proportional mixes of the three primary colours (red, green, blue) reflect the relative concentrations of the three element. The brighter colours reflect higher relative concentrations of each element. Thus, areas relatively high in copper, zinc and lead are displayed in bright red, green and blue hues, respectively. Areas relatively high in both copper and zinc are displayed in yellow (red + green), high in copper and lead in magenta/purple (red + blue) and high in lead and zinc in cyan (green + blue). Areas relatively high in all elements are white (red + green + blue).

The SAR data provides information on surficial and structural features within the map area. The SAR, because of its side-viewing geometry, preferentially enhances topographic features that trend roughly parallel to the azimuth track of the satellite. In this particular image the satellite track trends approximately northeast to southwest. As a result topographic features trending in this direction are enhanced and are expressed as bright linear features on the image. A northeast trending linear feature (esker) in the southeast part of the map is especially prevalent.

Areas of anomolous geochemical concentrations can be directly compared to topographic and structural feaures seen on the SAR data.





EXPERIMENTAL MAP

ERS-1 SAR AND LAKE GEOCHEMICAL COMPOSITE IMAGE

NIPISHISH LAKE

LABRADOR, NEWFOUNDLAND

Scale 1:125 000 - Échelle 1/125 000

Kilometres 2 0 2 4 6 8 10 Kilomètres

The geochemical data were provided by the Geological Survey of Canada and is published in GSC Open File Report [illegible]. The ERS-1 SAR data was provided by the Canada Centre for Remote Sensing (CCRS) as part of the Radar Development Program (RDDP).

Digital cartography by Jeff Harris (GSC), [illegible] (GSC), Gary [illegible] (GSC) and [illegible] (GSC).

Project coordinators Andy Rencz (GSC), Heather [illegible] (Intera), Jeff Harris (GSC) and John [illegible] (GSC).

Canada

RADIOMETRICS/ORTHOPHOTOGRAPHY
Chalk River

R.L. Grasty, J.E. Glynn, P. Huppé and J. Chyrula

On December 18th, 1981, an airborne gamma-ray spectrometer survey was carried out by the Geological Survey of Canada in the vicinity of the Chalk River nuclear reactor. The purpose of the survey was to map ground radiation levels due to the gas, argon-41 originating from the reactor. Argon-41 had been detected previously during a routine airborne geophysical survey.

The map of the argon plume was combined with a digital orthophoto.. In this image hue was derived from the argon map and the intensity and saturation were derived from the orthophoto. An orthophoto is a photograph in which geometric distortions related to terrain variations and the camera have been removed. Input into the orthoimage were four overlapping air photographs (1/50000 scale). The photographs were scanned at a very high resolution using an Optronix C1400Sp drum scanner. Rectification of the photograph to a map base required the incorporation of a digital elevation model. The final orthoimage was produced at a nominal scale of 1:10000 scale with a pixel size of 1.0 by 1.0 metres.

The airborne measurements were made using a 256 channel gamma-ray spectrometer with 50 L of NaI(Tl) detectors flown at a mean terrain clearance of 123 meters (400 feet) and a speed of 190 km/hr. The gamma-ray spectrum, covering an energy range from approximately 300 to 3000 keV, was recorded once every second. During the survey, the wind was blowing approximately west to east. Nine parallel flight lines, 1.4 km apart, were oriented in the northwest - southeast direction, downwind of the reactor. The flight lines were chosen as a compromise between intercepting the plume at right angles to the wind direction and remaining outside a military zone in the south-west of the surveyed area.

In analyzing the airborne data, the three standard energy windows were used to measure the gamma-rays emitted by the three naturally occurring radioactive elements, potassium, uranium and thorium. An additional fourth window was used to monitor argon-41 which emits gamma-radiation at 1290 keV and has a half life of approximately 2 hours. The count rates in the argon-41 window were first corrected for background radiation originating from cosmic radiation, decay products of radon gas in the atmosphere and the radioactivity of the aircraft and its equipment. Corrections were then applied for spectral scattering of natural gamma-rays into the argon window.

The argon-41 plume map shows the calculated ground radiation levels in standard radiation units of nanograys per hour (nGy/hr) which were calculated from the corrected argon window count rates assuming a uniform distribution of the gas in the atmosphere. The plume shows a decrease in radiation levels in the downwind direction primarily due to the dispersion of the plume. Variations in the plume generally reflect the topography of the area with the radiation levels increasing in the valleys. The maximum ground radiation levels were approximately 170 nGy/hr compared to typical values between 20 and 30 nGy/hr due to naturally occurring potassium, uranium and thorium.

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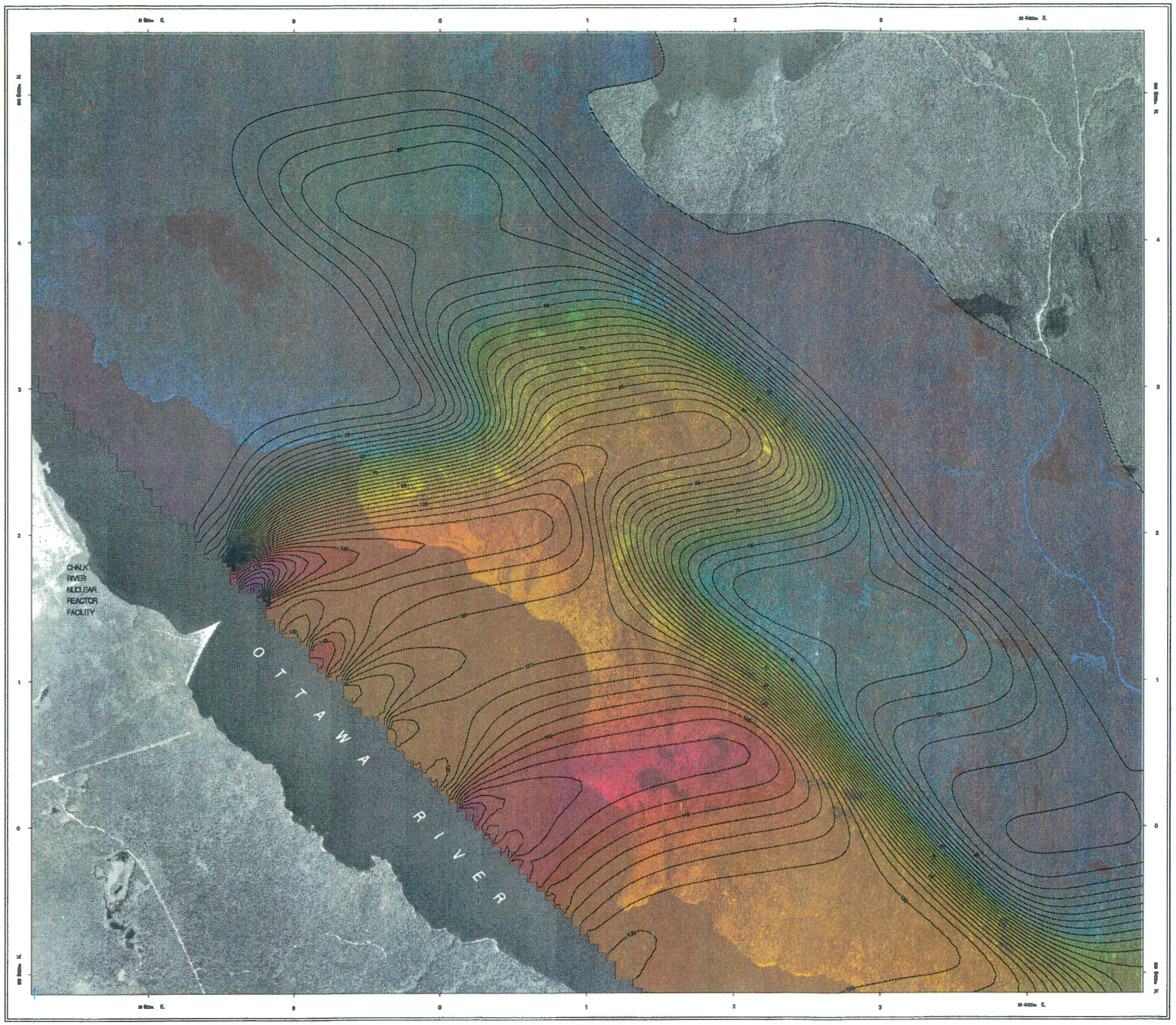
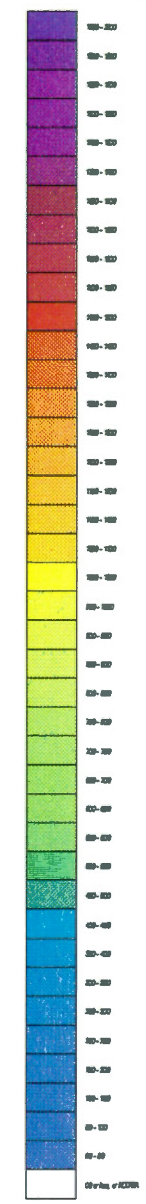
GEOLOGICAL SURVEY OF CANADA — COMMISSION GÉOLOGIQUE DU CANADA

INTERA



LEGEND

Calculated ground level dose rates (nGy / hr)



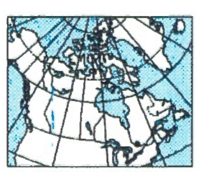
Mapping an Argon Plume from a Nuclear Reactor using a Digital Ortho-photograph Base

This map displays, in shaded contour intervals, an argon-41 plume from the Chalk River Nuclear Reactor Facility along the Ottawa River northwest of Ottawa. The image base data was produced by Intera Technologies Ltd. using digital orthophotography processed from scanned aerial photography which was obtained from the Surveys, Mapping and Remote Sensing Sector (SMRS). The gridded argon radiometric data was obtained from the Airborne Geophysics Section of the Geological Survey of Canada.

An orthophotograph is a photograph which has been digitally altered to remove the distortions due to tilt of the camera and to elevation variations in the terrain. The result is a photograph which is planimetrically correct and so may be registered in a standard geographic projection. Personnel at Intera Information Technologies Ltd. used standard SMRS pairs of aerial photographs and their own equipment to produce the 3 metre resolution digital base image displayed in the map. This base map was then enhanced by standard image processing techniques to increase the contrast in the image. The digital file was then imported into the Arc/Info geographic information system.

In the summer of 1992, the Geological Survey of Canada flew a gamma ray survey over the region downwind of the Chalk River Nuclear Reactor Facility. The GSC then processed the data to produce a 100 metre resolution grid of ground level dose rates (nGy / hr) due to radioactive argon-41 originating from the nuclear facility. This grid was registered in the same transverse mercator projection as the digital ortho-image and the gridded digital file was also imported into Arc/Info.

The gridded file of ground level dose rates was then interpolated and resampled to the same resolution and geographic limits as the ortho-image. The resampled grid of dose rates was then remapped to equal dose rates intervals and a colour lookup table was used to shade the resulting contour intervals. The hues from the dose rates grid were then combined with intensities from the ortho-image grid to produce the map.



EXPERIMENTAL MAP

ARGON-41 PLUME

CHALK RIVER

ONTARIO

Scale 1:12 000 - Échelle 1/12 000

Canada

SURFICIAL GEOLOGY/DIGITAL ELEVATION

Melville Peninsula

L. Dredge, C. Bowie, A. Rencz

The map of the surficial geology of the Melville Peninsula covers parts of four 1/250000 map sheets in the District of Franklin, Northwest Territories. The images in this study illustrate a part of the digital data set for that area. As on standard quaternary geologic maps the image illustrates the distribution of glacial materials, the main units being a set of marine deposits on the eastern part of the area, and calcareous and granitic till together with Precambrian outcrop, over the rest of the area.

There are three maps in the series to illustrate the effect of combining a map of surficial geology with ancillary data. In this case elevation data was combined with the surficial map to highlight topographic relationships with the geology . The first map illustrates a part of the surficial geology map produced by Dredge and Nixon (1993). The second image is an arithmetic combination of surficial geology and elevation. Hue was derived from the geology map whereas the intensity and saturation were derived from the elevation data. The map was further enhanced by "burning" in hydrographic information (lakes and rivers) that were derived from LANDSAT TM data. The elevation data were prepared from vectors of contour data extracted from 1/250,000 topographic map sheets. The contour data were purchased from the Surveys, Mapping and Remote Sensing Sector of EMR. The final image is a perspective view of the surficial geology draped over a shaded relief map of the digital elevation data.

The elevation-enhanced map provides several advantages over conventional geologic maps.

1. The addition of lakes clearly shows the glacial grain and rock structure in the landscape, an aspect obscured by conventional maps.

2. The relation between topography and the distribution of marine deposits is more clearly shown. For example the marine units occupy lowland areas and penetrate the deepest river valleys. Also apparent is a distinct limit of till against the escarpment that separates Precambrian rock from Paleozoic strata and marine deposits. This represents a wave-wash limit, an elevation-landscape element used to determine crustal response to glacial loading. The perspective view also clearly shows the relation between elevation and the distribution of marine deposits. Due to the coarseness on the image, however the limit of wave-washing is less apparent on the map view.

3. The relation between till and topography is also more apparent than on maps showing geology alone, with granitic till being confined to irregular uplands, and the carbonate drift to more regular, lower terrain.

Although the interpretation of ice flow dynamics may be an important potential product of elevation-enhanced images, the relationship between topography, ice flow style and ice flow direction is not apparent on this image. Subsequent maps with map symbols and plotted at a smaller scale may enhance this aspect.

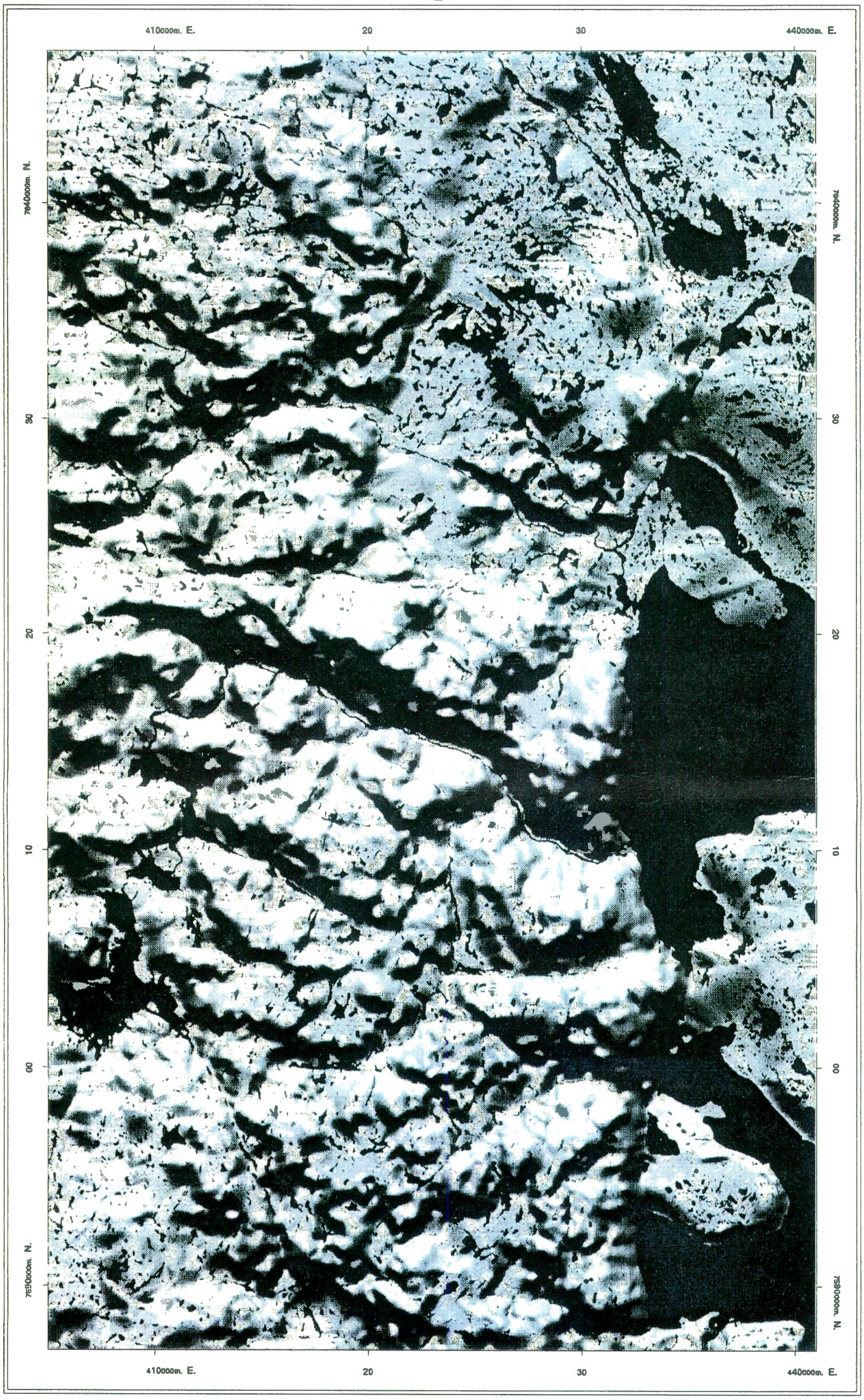
REFERENCES

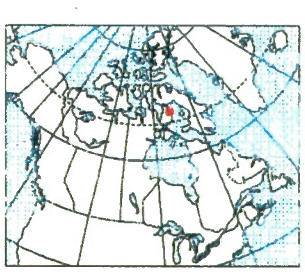
Dredge, L.A. and F.M. Nixon. 1993.
Surficial geology, northern Melville Peninsula, District of Franklin, Northwest Territories, Geological Survey of Canada Map 1782A, Scale 1/200000.

Energy, Mines and Resources, Canada — Energie, Mines et Ressources, Canada

GEOLOGICAL SURVEY OF CANADA — COMMISSION GÉOLOGIQUE DU CANADA

INTERA




LOCATION MAP - LOCALISATION DE LA CARTE

EXPERIMENTAL MAP

SHADED RELIEF IMAGE

MELVILLE PENINSULA

NORTH WEST TERRITORIES

Scale 1:125 000 - Échelle 1/125 000

Kilometres 2 0 2 4 6 8 10 Kilometres

Universal Transverse Mercator Projection — Projection transverse universelle de Mercator

The digital elevation data was extracted from contours from NTS Map Sheet 47A, Hall Lake.

Digital cartography by Cameron Bowie and Vic Dohar (GSC).

Project coordinators Andy Rencz (GSC), Heather Press (Intera), Jeff Harris (GSC) and John Glynn (GSC).

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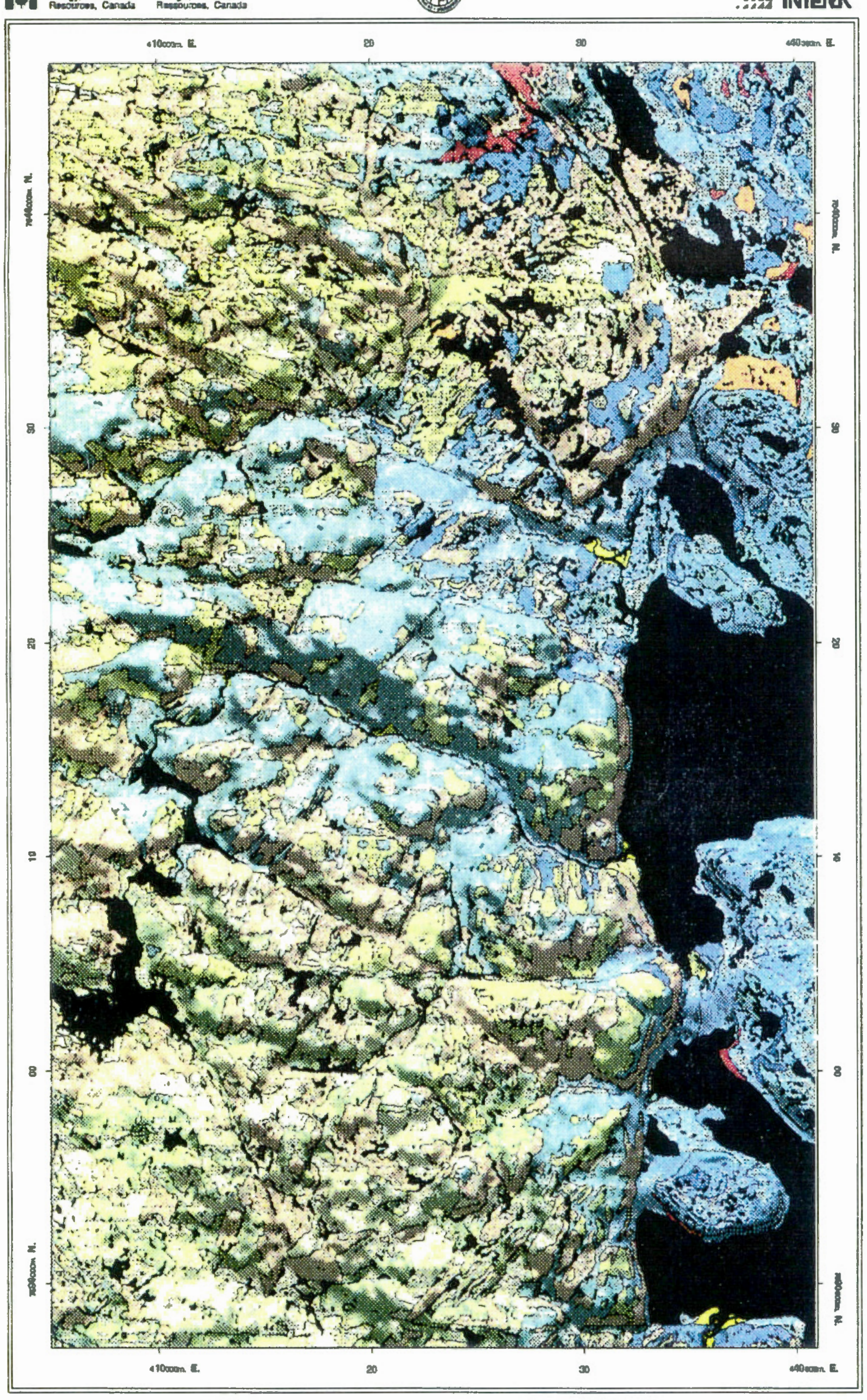
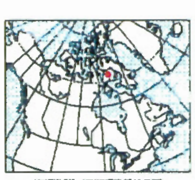


LEGEND

- alluvial sand and gravel
- marine littoral sediments
- marine deltaic sediments
- marine offshore/sublittoral sediments
- glaciomarine sediments
- glaciolacustrine sediments
- glaciofluvial outwash
- carbonate till blanket
- granitic till blanket
- carbonate till veneer
- granitic till veneer
- till blanket
- thin till veneer
- felsenmeer
- Paleozoic carbonate
- Archean bedrock
- marine offshore veneer



EXPERIMENTAL MAP

SHADED RELIEF SURFICIAL GEOLOGY IMAGE

MELVILLE PENINSULA

NORTH WEST TERRITORIES

Scale 1:125 000 - Échelle 1/125 000

The digital elevation data was extracted from contours from NTS Map Sheet 47A, Hall Lake.

Digital cartography by Cameron Bowie and Vic Dohar (GSC).

Project coordinators Andy Rencz (GSC), Heather Press (Intera), Jeff Harris (GSC) and John Glynn (GSC).

Map Evaluation

The image illustrates the surficial geology of the Melville Peninsula, Northwest Territories, superimposed on a shaded elevation model derived from contours on a 1/250000 NTS map sheet. In addition a lake imprint was produced LANDSAT Thematic Mapper image. As on standard geologic maps the image illustrates the distribution of glacial mate the main units being a set of marine deposits on the eastern part of the area, and calcareous and granitic till together with Precambrian outcrop, over the rest of the area.

1. The elevation-enhanced map provides several advantages over the conventional geologic maps.

2. The addition of lakes clearly shows the glacial grain and rock structure in the landscape, an aspect obscured by conventional maps. The relation between topography and the distribution of marine deposits is more clearly shown. m units occupy lowland areas and penetrate the deepest river valleys. Also apparent is a distinct limit of till against t escarpment that separates Precambrian rock from Paleozoic strata and marine deposits. This represents a wave-wash an elevation-landscape element used to determine crustal response to glacial loading.

3. The relation between till and topography is also more apparent, with granitic till being confined to irregular uplands, and the carbonate drift to more regular, lower terrain. Although the interpretation of ice flow dynamics may b an important potential product of elevation-enhanced images, the relationship between topography, ice flow style and ice flow direction is not apparent on this image. Subsequent maps with map symbols may enhance this aspect.

Canada

GAMMA RAY/AIRBORNE RADAR
Port Coldwell

Ford, K.L., D. Graham, and J.R. Harris

These images represent some of the results from a co-operative project between the Geological Survey of Canada and the Canada Center for Remote Sensing. Airborne gamma ray spectrometric (GSC) and airborne radar (CCRS) data were collected in the summer of 1990. The purpose of this project is to demonstrate the utility of these digital data to regional geological mapping and mineral exploration using image analysis and geographic information systems.

The study area is centered on the Port Coldwell alkalic complex on the north shore of Lake Superior, 275 km east of Thunder Bay. The complex intrudes an east-west trending sequence of Archean metavolcanic, metasedimentary and granitic rocks within the Abitibi-Wawa Subprovince of the Superior structural province. The complex, the largest alkalic intrusion in North America (580 km^2), is composed of a variety of felsic syenitic and gabbroic rocks subdivided into three intrusive centers which were emplaced by cauldron subsidence associated with major faults (Mitchell and Platt, 1977,1978; Walker et al, 1992).

There are three images in the set to demonstrate the effectiveness of combining airborne radiometric data with airborne radar data. The first image illustrates a red-green-blue color composite of three channels of radiometric data-equivalent uranium, equivalent thorium and % potassium. The ternary map provides a means for simultaneously plotting the three radiometric channels in color. Proportional mixes of the three primary colors (red, green and blue) reflect the relative concentrations of the three "elements", eU, eTh and %K, respectively. Pure colors represent relatively high levels of one element whereas other colors are the result of mixtures of elements. In this example the red areas represent areas relatively high in uranium . Cyan is the result of relatively high levels of potassium and thorium (blue plus green). The white areas reflect areas with relatively high concentrations of all elements (red plus blue plus green). The second image illustrates airborne synthetic aperture data (provided by Radar Development Program of the Canada Center for Remote Sensing). Because of the side-viewing geometry of the sensor topographic features with a north-east trend are accentuated. The final image is an **IHS** combination with the radiometric data providing the hue and saturation and the radar controlling the intensity.

Recent geological mapping of the Port Coldwell alkalic complex has used the airborne radar and gamma ray spectrometric data presented in combined and enhanced images, as an integral part of the project. The airborne radar data presents topographic and structural features of the complex and the surrounding Archean rock in a single image defining relationships between various block faulted rock types with differing physical expressions which were not previously observed. Topographic features coincident with the contact between the complex and the surrounding Archean rocks are evident, particularly along the northern and eastern boundaries. Walker (pers com) has indicated that faults which appear to control the petrogenesis of each of the centers and different intrusive events within each center are also evident as are faults which control the occurrence of known Cu-PGE mineralization.

Where radioelement concentrations vary in response to lithological variations and/or metasomatic and hydrothermal alteration, the airborne gamma ray spectrometric data are an excellent predictive tool for mapping surficial and bedrock geology. The ability of gamma ray spectrometry to subdivide apparently homogenous intrusives may increase the understanding of the petrogenetic history of the complex by outlining subtle petrological and sometimes cryptic compositional zonation that might not otherwise be recognized. Strong radioelement variations are evident within each of the intrusive centers of the Port Coldwell alkalic complex. Some of these variations correspond directly with mapped lithological units while others either cross geological contacts or appear to subdivide particular units. Subtle radioelement variations evident within particular lithologies may correspond to weak petrographic and/or compositional zonations. By combining a detailed topographic base with the gamma ray spectrometric data, the composite images allow direct correlation of topographical/structural features with the lithological/compositional information evident in the gamma ray spectrometric data.

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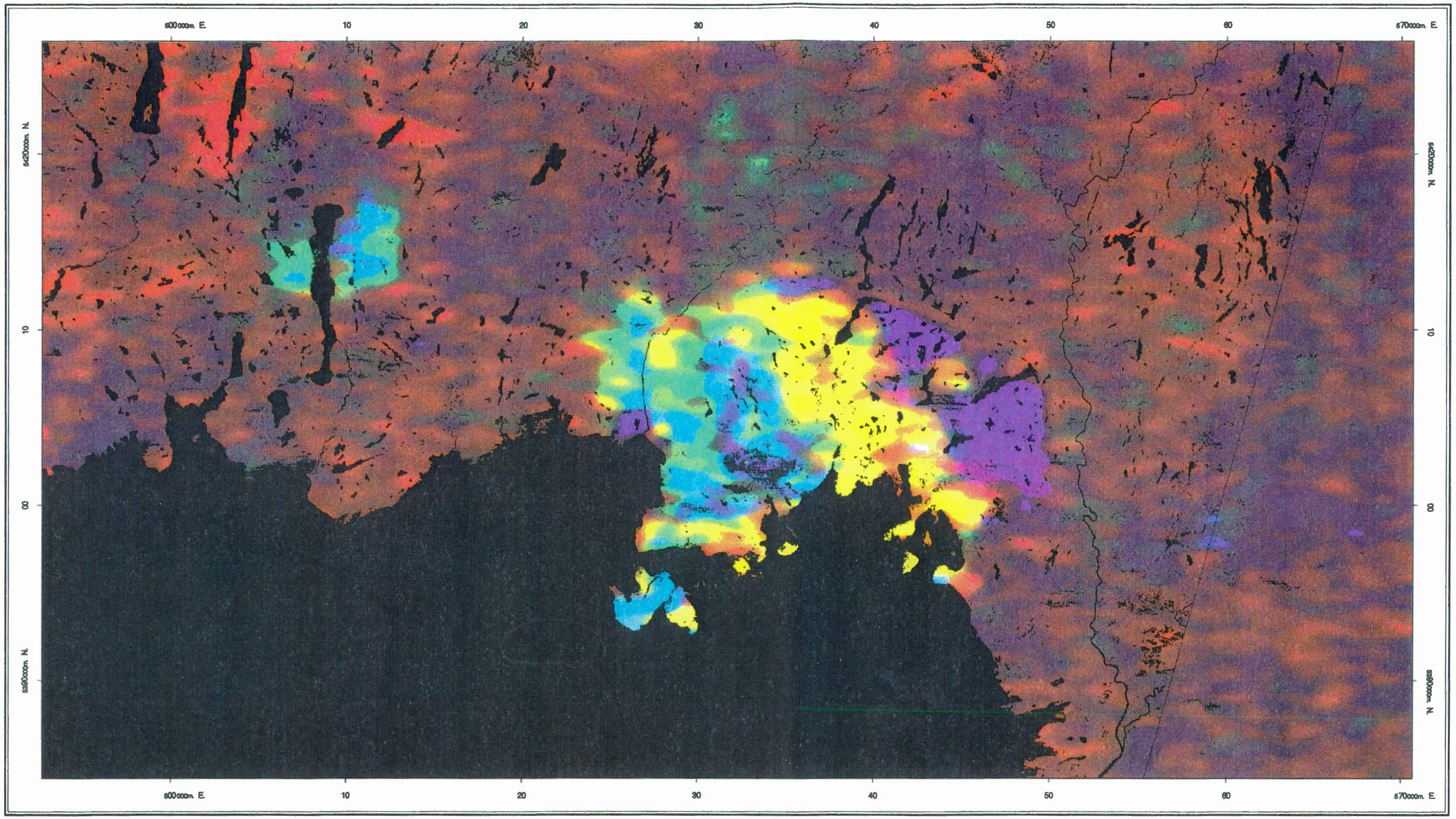
Mitchell, R.H. and Platt, R.G. 1977.
Field guide to aspects of the Coldwell alkaline complex; 23rd Annual Meeting, Institute on Lake Superior Geology, 34 p.

Mitchell, R.H. and Platt, R.G. 1978.
Mafic mineralogy of ferroaugite syenite from the Coldwell Alkaline Complex, Ontario, Canada. Journal of Petrology, V. 19, pp. 627-651.

Walker, E.C., R.H. Sutcliffe, C.S.J. Shaw, G. T. Shore and R.S. Penczak. 1992.
Geology of the Port Coldwell Alkalic Complex; *IN*: Summary of Field Work and Other Activities 1992, Ontario Geological Survey, Miscellaneous Paper 160, pp. 108-119.

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

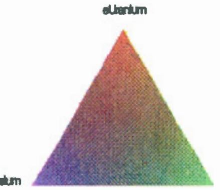
INTERA

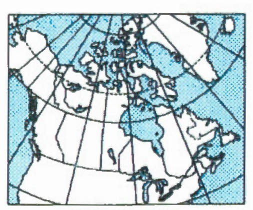


A red-green-blue (RGB) colour composite display of 3 channel gamma ray spectrometer data is shown in this map.

The gamma ray data were flown with a line spacing of 1 km and sample spacing of 200 meters. The data were levelled and interpolated to a 125m grid and then resampled to 30m and registered to a UTM grid. The data comprising equivalent uranium and thorium (eU, eTh) and percent potassium (%K) were decorrelated using a decorrelation algorithm available on the PCI image analysis system. Decorrelation of the data improves the colour range and contrast of the colour composite image. The eU, eTh and %K data are displayed in red, green and blue colours, respectively, as shown in the RGB triangle.

The airborne gamma ray data is an excellent tool for mapping both surficial and bedrock geology where radioelement concentrations vary in response to lithological variations and/or metasomatic and hydrothermal alteration. Three distinct zones within the Coldwell complex can be seen on the gamma ray data. Some of the variations in the radioelement response correspond directly with known lithological variations while others cross geological contacts. Subtle radioelement variations are also evident within particular lithologies and may correspond to weak petrographic and/or compositional zonations.





EXPERIMENTAL MAP

GAMMA RAY SPECTROMETER COMPOSITE IMAGE

PORT COLDWELL COMPLEX

ONTARIO

Scale 1:125 000 - Échelle 1/125 000

Kilometres 2 0 2 4 6 8 10 Kilomètres

Universal Transverse Mercator Projection   Projection transverse universelle de Mercator

The gamma ray spectrometer data was provided by the Geological Survey of Canada and is available in GSC Open File Report [illegible] (Hemlo-Marathon Area, Ontario, 19[illegible]).

Digital cartography by Jeff Harris (GSC), Paul Huppé (GSC), Gary Labelle (GSC) and Vic Dohar (GSC).

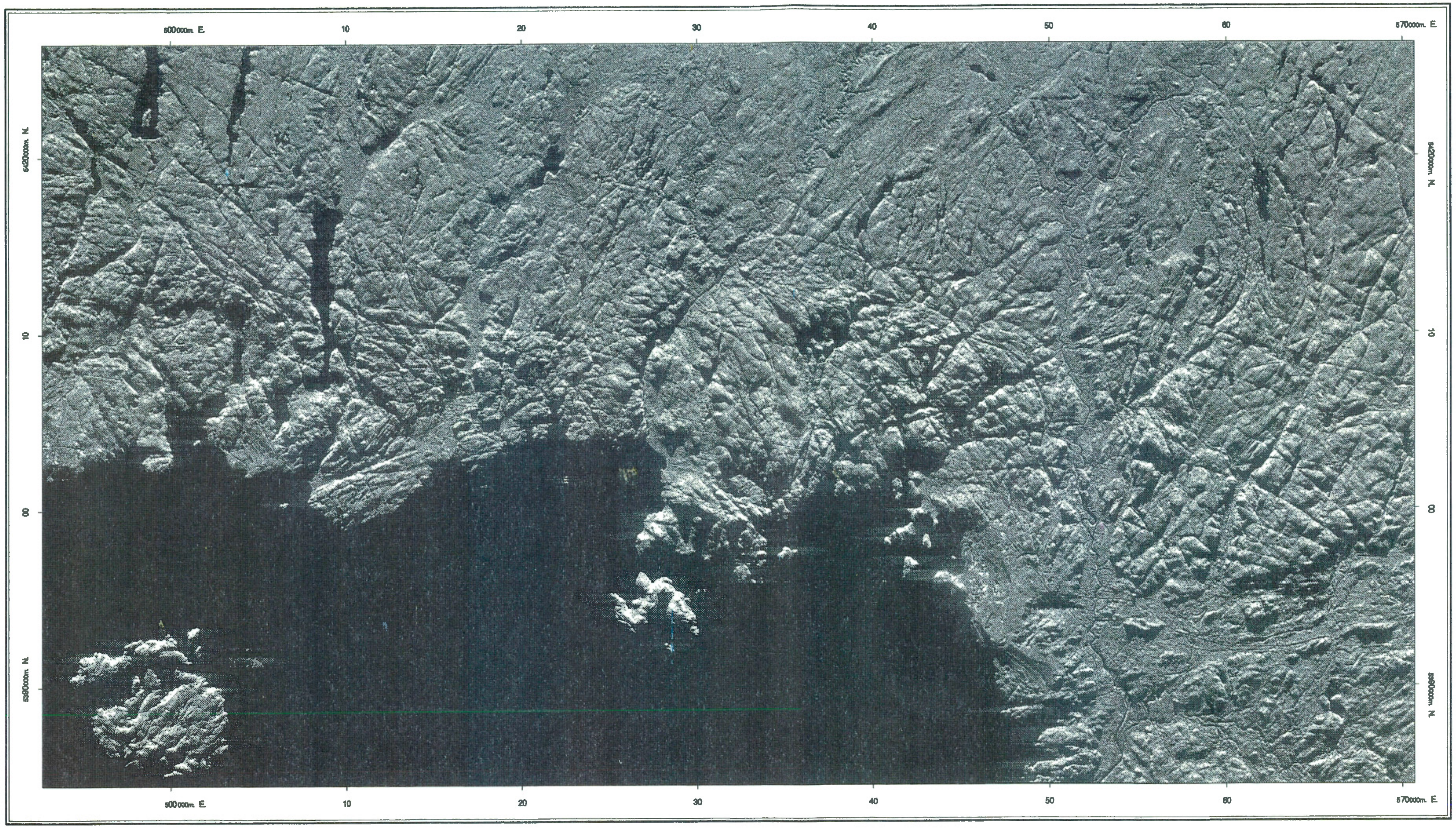
Project coordinators Andy Rencz (GSC), Heather Press (Intera), Jeff Harris (GSC) and John Glynn (GSC).

Canada

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

Geological Survey of Canada   Commission géologique du Canada

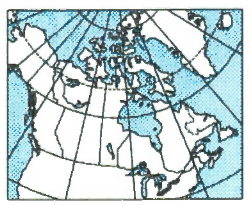
INTERA



An airborne synthetic aperture radar (SAR) image of the Port Coldwell alkali complex located on the shore of lake Superior, Ontario, is shown in this map.

The image, characterized by an original spatial resolution of approximately 12m, has been resampled to 30m and registered to a UTM co-ordinate base by identifying a series of ground control points (GCPs). A polynomial transform was used to correct the image geometry to the UTM co-ordinate space.

The SAR, because of its side-viewing geometry, provides a view of the terrain in which topographic patterns are enhanced. Numerous topographical and structural features of the Coldwell complex and surrounding Archean rocks can be readily observed and mapped. Topographical features (probable faults) that correspond to the contact between the complex and the surrounding rocks are evident, particularly along its northern and eastern border. Some of these faults may have controlled emplacement and petrogenisis of each of the apparent intrusive centres within the complex. Known Cu-PGE mineralization are associated with some of these faults.



EXPERIMENTAL MAP

AIRBORNE SAR DATA

PORT COLDWELL COMPLEX

ONTARIO

Scale 1:125 000 - Échelle 1/125 000

Kilometres 2 0 2 4 6 8 10 Kilomètres

Universal Transverse Mercator Projection   Projection transverse universelle de Mercator

The SAR data was provided by the Canada Centre for Remote Sensing (CCRS) as part of the Radar Development Program (RDDP).

Digital cartography by Jeff Harris (GSC), Paul Hupé (GSC), Gary Labelle (GSC) and Vic Dohar (GSC).

Project coordinators Andy Rencz (GSC), Heather Pease (Intera), Jeff Harris (GSC) and John Glynn (GSC).

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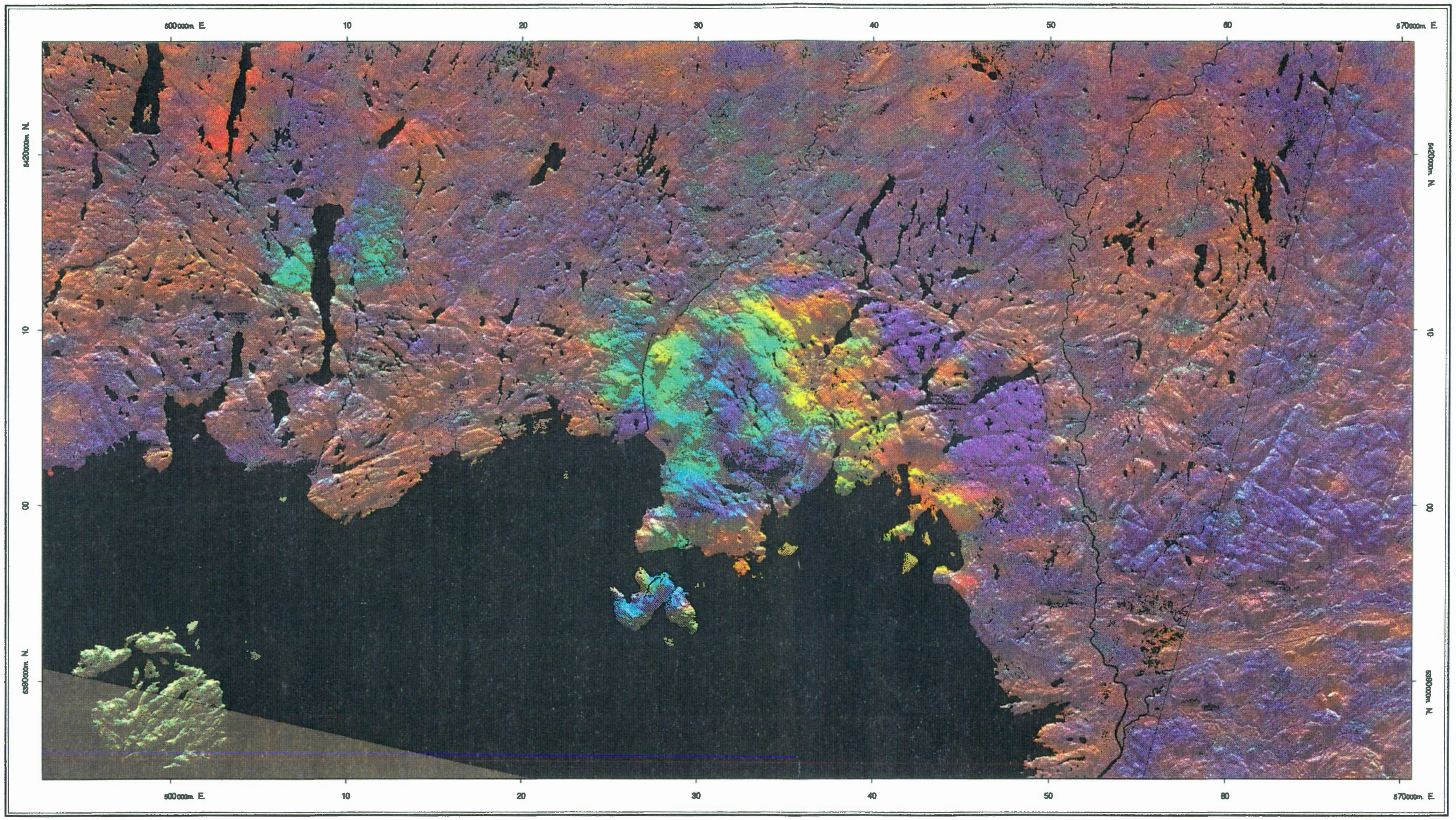
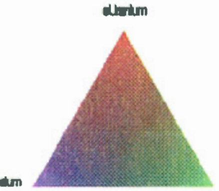
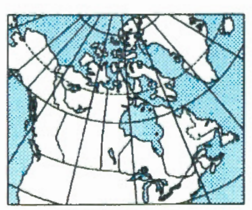
INTERA



This map is a combination of an airborne SAR image and 3 channel gamma ray spectrometer data. The eU, eTh and %K gamma ray data are displayed in red, green and blue colours, respectively, as shown in the RGB triangle. The data were combined using the intensity-hue-saturation (IHS) colour space transformation. Image intensity is modulated by the radar while hue and saturation is modulated by the gamma ray data.

This map, in addition to providing a detailed topographic and cartographic base for the gamma ray data, also facilitates the direct comparison of topographic/structural features, provided by the SAR data, with lithological/compositional information evident in the gamma ray spectrometer data. Possible cause and effect relationships between the two data sets can be derived from this map.





EXPERIMENTAL MAP

IHS TRANSFORMED GAMMA RAY SPECTROMETER / RADAR IMAGE

PORT COLDWELL COMPLEX

ONTARIO

Scale 1:125 000 - Échelle 1/125 000

Universal Transverse Mercator Projection | Projection transverse universelle de Mercator

The gamma ray spectrometer data was provided by the Geological Survey of Canada and is available in GSC Open File Report [illegible] (Hemlo-Marathon Area, Ontario, [illegible]).

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Canada

CONCLUDING REMARKS

The images produced in this volume illustrate examples of integrated maps containing several geoscientific map products. In these combined images there was one primary map, such as bedrock geology, that provided the color component and an ancillary data set that was used to modify the colors and thereby accentuate the information content on the primary map. The primary map was a thematic map whereas the ancillary data were continuous gray tone images. For this type of combination the Intensity-Hue-Saturation color transformation is very effective. The model permits the color intensity to be modified by an ancillary set of data yet maintains the basic color of the original map. These images can then be enhanced to produce map-like images that satisfy cartographic requirements such as scale, legend, and annotation. Currently this is seen as a two step process in which the user produces an "integrated image product" -to satisfy his information requirements- and the cartographer produces an "integrated map product" to satisfy cartographic specifications.

The utility of these products has not been totally explored; however it is critical that the researcher carefully select an ancillary data set that enhances features of the primary map. For example, in the current image set, the information content provided in the geology map of Sudbury could be enhanced by adding radar data because it accentuated some of the structural features that the map was trying to portray. Similarly the surficial geology of the Melville Peninsula could be better perceived by overlaying the geologic map on top of a "photograph" of the area. In this way the visual communication of information on the images could be enhanced by the addition of the ancillary data set. On the other hand the addition of the remotely sensed data to the geochemical data was most useful in providing a geographic context to the image. Perhaps in this case an integration of surficial geology with the geochemistry data, would have been b better.

Technological advances have permitted the production of integrated image and map products to be practically feasible. The products can enhance the transfer of visual information if the types of integrated data are compatible. However the basic integration process must be driven by a geological goal as opposed to technological objectives.

ACKNOWLEDGMENTS

This project has relied on a combined effort from many individuals. In addition to the names noted throughout the publication the following individuals have made significant contributions: Vic Dohar, Mario Méthot, Rick Allard, Jo-Anne Dohar, Rob Burns, Ben Chagnon, Mike Sigouin and Dave Graham. In addition we acknowledge the **I**ndustrial **P**artners **P**rogram for providing the majority of the funding. The **IPP** was a joint project funded by the Geological Survey of Canada and INTERA Technologies Limited. The Japan Science Technology Fund as part of a Geological Survey of Canada and Geological Survey of Japan also provided funding for projects used in this publication. The cover page, illustrating different perspectives of the surficial geology of part of Melville Peninsula was provided through the joint GSC-GSJ project.