Ontario Geological Survey
Miscellaneous Paper 119

Summary of Field Work 1984

Ontario Geological Survey

edited by
John Wood, Owen L. White,
R.B. Barlow and A.C. Colvine

1984

Ontario

Ministry of Natural Resources

Hon. Alan W. Pope
Minister

John R. Sloan
Deputy Minister

Printed in Ontario, Canada
ISSN (Series) 0704-2752
ISSN (Sub-series) 0225-5278

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Johns, G.W.
1984: Kakagi Lake – Rowan Lake Regional Geology; p.25-32 *in* Summary of Field Work, 1984, Ontario Geological Survey, edited by John Wood, Owen L. White, R.B. Barlow, and A.C. Colvine, Ontario Geological Survey, Miscellaneous Paper 119, 309p.

Scientific Editor: Z.L. Mandziuk
1000-84-CSG

Foreword

During 1984, the Ontario Geological Survey carried out a large number of independent geological, geophysical, geochemical, geochronological, and mineral deposits studies. In addition, studies were undertaken in cooperation with the Ministry of Natural Resources regional geological staff, personnel from a number of universities, and several private consulting firms. Interdisciplinary geoscience programs were also commenced in the Opapimiskan Lake and Black River- Matheson areas and are summarized in the section at the end of this report. Project involvement by the various participants is summarized in the section chiefs' summaries of activities and in the individual reports.

Separate funding for a number of regional stimulation projects was provided by the Ontario Ministry of Northern Affairs, the Government of Canada, and the Ontario Ministry of Natural Resources; and for the Hydrocarbon Energy Resources Program (HERP) by the Ontario Ministry of Treasury and Economics under the Board of Industrial Leadership and Development (BILD) Program. Funding acknowledgments are given in the individual summaries.

The locations of the areas investigated are compiled on 2 maps of the province at the beginning of this report. Preliminary results of field work and other research are outlined in this summary, which contains reports prepared by leaders and principal investigators for each of the projects. In these reports, some emphasis has been placed on the economic mineral resources aspects of the different investigations. The aim of the Ontario Geological Survey is that the information provided will help in the mineral resources evaluations of these areas, and so will be a valuable aid to mineral exploration and resource planning in Ontario.

Coloured maps and final detailed reports covering most of the field projects are being prepared for publication. In the interim, uncoloured preliminary geoscience maps with comprehensive marginal notes will be released for distribution, mainly during the winter of 1984-1985. Notices of the releases will be mailed to all persons or organizations on the Mineral Resources Group notification list, and will be published in the technical journals and other media.

V.G. Milne
Director
Ontario Geological Survey

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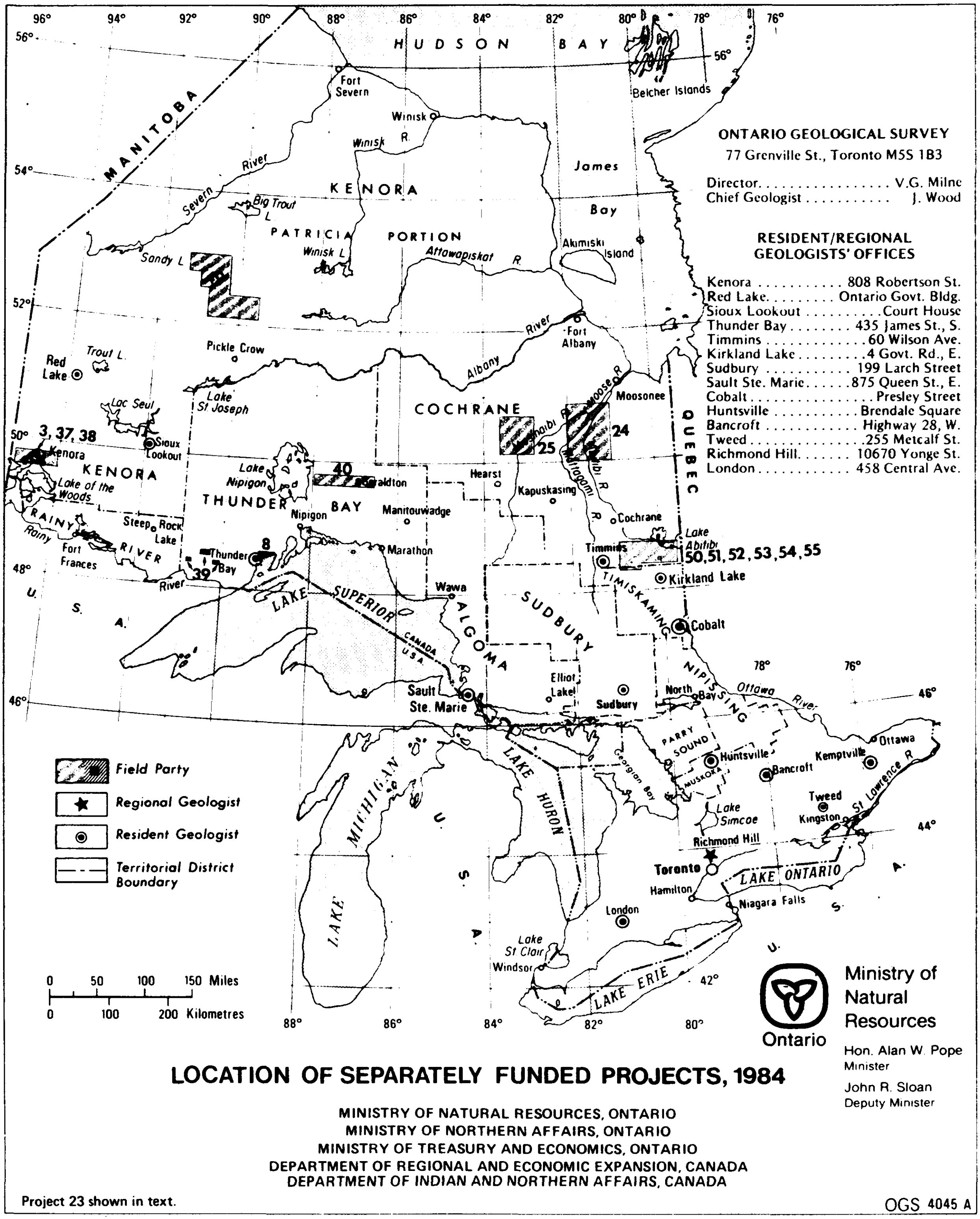


Location of Separately Funded Projects by the Ontario Geological Survey, 1984.

CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS.

CONVERSION FROM SI TO IMPERIAL			CONVERSION FROM IMPERIAL TO SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
			CAPACITY		
1 l	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy)/ton (short)	1 ounce (troy)/ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ton (short)	1 pennyweights/ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note. Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in cooperation with the Coal Association of Canada.

PRECAMBRIAN GEOLOGY PROGRAMS

Summary of Activities 1984, Precambrian Geology Section

John Wood

Chief Geologist and Section Chief, Precambrian Geology Section, Ontario Geological Survey, Toronto.

During the summer of 1984 the Precambrian Geology Section undertook 18 field projects. There are 2 primary objectives of the field program: the first is to provide an ongoing and up-to-date geological database on the Precambrian bedrock of the Ontario landmass for mineral resources exploration and assessment; the second is to stimulate and guide mineral resources exploration. Of these projects 11 involve detailed mapping, 2 provide regional geological syntheses, 1 was a reconnaissance mapping project, and 4 were special projects.

Detailed mapping at a scale of 1:15 840 provides the fundamental building block for the Precambrian bedrock database. Most of the detailed mapping projects are part of long term programs within a specific area; some however, such as the geology of the Mulcahy Lake area (Sutcliffe, Project 5.), part of a program that will investigate the ultramafic and mafic intrusions in the Wabigoon Subprovince, are thematic. Reconnaissance projects are designed to provide an overview of large areas in order to more effectively focus on specific parts which may require detailed mapping. The projects providing regional syntheses are carried out in areas where detailed mapping has been in progress for a number of years, often the mapping of individual map sheets has been carried out by different geologists. The aim of the regional programs is to synthesize the geology and fill any gaps in the detailed mapping. The special projects are designed to provide insights and solutions to particular geological problems in the Canadian Shield; mapping may or may not be involved.

Of the 18 field projects, 2 were led by Ontario Ministry of Natural Resources regional staff, 2 by graduate students from universities, and the remainder by staff of the Precambrian Geology Section.

The Ontario Ministry of Northern Affairs supported and totally funded 3 of the detailed mapping projects; these are: (1) The Opapimiskan Lake interdisciplinary project (Breaks *et al.*, Project S49.); (2) The Bigstone Bay project (Ayer, Project S3.); and (3) the MacGregor Township project (Scott, Project S8.). The Black River-Matheson (BRIM) interdisciplinary program is funded equally by the Ontario Ministries of Northern Affairs and Natural Resources. The support and funds provided by the Ministry of Northern Affairs is gratefully acknowledged by the Ontario Geological Survey.

The summary on the Atikokan-Lakehead Compilation Project (Thurston, Project 6.) could not be included in the 1983 volume because it was carried out late in 1983. The summary on geological computer software development (Ambrose *et al.*, Project 18.) is intended to acquaint the reader with data reduction programs currently available from the Precambrian Geology Section.

RECONNAISSANCE MAPPING

Greg Stott and Henry Wallace (Project 1.), working in the central part of the Uchi Subprovince between Meen Lake and Kasagiminnis Lake and near Pashkokogan Lake, have come up with major and significant revisions to previously published maps of the area. They have identified 2 cycles of volcanism on a regional scale and redefined the extent of felsic to intermediate volcanic rocks. They have also defined 2 major ductile deformation (shear) zones. Based on current exploration for gold in the Wabigoon Subprovince, in the Red Lake area, and indeed in the Hemlo area, both of these shear zones represent empirical exploration targets. The northern zone deforms major ironstone units, and for those currently involved in exploration for gold in deformed ironstone this would represent an obvious target.

Late in 1983 Phil Thurston did reconnaissance mapping of that part of Quetico Provincial Park which belongs to the Abitibi Subprovince. He defines the lithology, stratigraphy, and structure of this area and suggests a correlation with the better known sequence in the United States (Thurston, Project 6.).

DETAILED MAPPING

Fred Breaks and Jim Bartlett, who are responsible for the Precambrian component of the Opapimiskan Lake interdisciplinary project (Project S49.) have, in a short field season, covered a large part of the North Caribou Lake Belt, and have defined within it a number of major stratigraphic units. The stratigraphy of the area appears to be complex, and the lithologies diverse. In addition to the rock types commonly found in most "greenstone" belts, this area includes komatiites, quartzarenites, and stromatolite(?)-bearing units. Within Superior Province, sedimentary units appear to be either of subaerial or deep water origin, however, 1 of the sequences in the North Caribou Lake Belt appears to be of shallow marine origin thereby representing a shelf environment; heretofore an elusive feature of Superior Province supracrustal sequences. Major deformation zones have also been identified as part of the structural analysis of the belt. There are some geologically favourable exploration targets in the area and these are discussed in the report.

John Ayer, working in the Bigstone Bay area (Project S3.), has outlined the stratigraphy and structure of an area with many past producing gold mines. Part of the structural interpretation is the recognition of a major fault zone. Two parts of the area are suggested for further work. In one of these, the Crow Duck Lake-Rush Bay Lineament, a ductile shear zone, there are several fault zones with which carbonatization and the ubiquitous presence of fuchsitic mica are associated.

Richard Sutcliffe, in the first year of an investigation of ultramafic and mafic intrusions in the Wabigoon Subprovince, mapped the Mulcahy Lake intrusion (Project 5.). The intrusion displays excellent exposures of cryptic and rhythmic layering and has well preserved primary mineralogy. This mafic intrusion has potential for the occurrence of platinum group elements as well as copper-nickel and vanadium mineralization. Deformation zones within the intrusion contain quartz veins and warrant investigation for gold.

Maurice Carter, working in Goldie and Horne Townships (Project 7.), has subdivided the Archean rocks into a Keewatin-type sequence and a Timiskaming-type sequence. Volcanic rocks of the Keewatin-type sequence comprise 1 complete mafic to felsic cycle and part of an incomplete second cycle. Ultramafic flowrocks were identified during field work. The Timiskaming-type rocks, which unconformably overlie the Keewatin-type, consist primarily of clastic metasedimentary rocks interlayered with red and grey trachyandesite. The area has potential for a number of commodities, however gold mineralization would appear to be of highest current priority. Gold occurs in a number of environments within the area, several of which have further exploration potential.

John Scott (Resource Geologist, Thunder Bay), working in MacGregor Township near Thunder Bay (Project S8.), has outlined the lithology, stratigraphy, and structure of an area that encompasses Archean and Early and Middle Proterozoic rocks. The Archean rocks include analogs to the Keewatin-type and Timiskaming-type that Carter outlines farther to the west. MacGregor Township is known for its old silver occurrences, which occur in veins within faults and shear zones. These veins have potential for the amethyst variety of quartz. Samples that have yielded gold assays have been taken from the township indicating that further such potential exists.

Giorgio Siragusa continued mapping in the White Lake area to the east of Hemlo (Project 10.). He also mapped a small area on the "nose" of supracrustal rocks to the east of the Cedar Lake pluton. The once continuous fold nose is considered to have been faulted, with the result that part of the supracrustal assemblage continues at least as far east as the western side of the Bremner River. He has considerably refined pre-existing maps of the area immediately to the west of White Lake. Some parts of the area appear to have excellent potential for gold mineralization; several localities are suggested for further exploration.

Ron Sage continued mapping in the Wawa area and covered a number of townships over the course of the summer (Project 11.). Coarse volcanic breccias near Trader Lake have potential for base metal sulphide mineralization. A sphalerite showing was located in Aguonie Township. Sage suggests that precious metal and base metal exploration programs should place very considerable emphasis on geology and geochemistry as well as geophysics.

Rob Johnstone and Norm Trowell mapped Beatty and Munro Townships and the western half of McCool Township (Project S50.), areas which are part of the Black River-Matheson program. These townships have been the site of some of the classical early work in Canada on komatiites and the area has a documented economic potential; as a result, the lithologies, stratigraphy, and structures outlined by Johnstone and Trowell should be of interest to a wide spectrum of the geological community.

Joanna Martins (Acting Resident Geologist, Sudbury) did detailed mapping in Snider Township (Project 14.), which is host to 3 producing nickel-copper mines in the Sudbury area. The township is underlain by a variety of rock types that include Huronian metavolcanic and metasedimentary rocks, the Creighton Granite, the Nipissing Diabase, the Whitewater Group, and various units of the Sudbury Igneous Complex, as well as younger dike rocks. In addition to outlining the lithology and structure of the area, the mapping has served to resolve some of the interrelationships between intrusive rock types.

Mike Easton and Martin Van Kranendonk did detailed mapping in the Digby-Lutterworth area (Project 16.); this is a continuation of the work done by Easton in 1983 in the Howland area. The mapping this year provides a basis on which to rationalize the complex geology of this particular area, which straddles 2 of the major terrains within the Grenville Province. The area has potential for: base metals including zinc and copper, uranium, molybdenite, tremolite, dolomitic and calcitic marble, as well as building stone.

Ted Bright mapped the Mellon Lake area (Project 17.), located close to Tweed. This area is underlain by a variety of rock types including the Flinton Group. The area has potential for zinc, uranium, and a variety of industrial minerals such as mica, kyanite, and sillimanite.

SYNOPTIC MAPPING

Glen Johns initiated integration and synthesis of the geology of the Gibi-Kakagi-Rowan Lakes area (Project 4.). The depositional environment of many of the metavolcanic formations is discussed and a volcanic facies model for the Berry River Formation is proposed. Most of the gold occurrences in the area would appear to be related to major zones of deformation. Several areas of high gold potential are outlined. Two areas of pyroclastic rocks are described which are considered to have potential for both base metals and gold.

Eric Grunsky completed field work for the Batchawana synoptic project (Project 12.). Part of this work was devoted towards modifying and refining a computer-based format for recording field data. A number of areas were examined during the field work; some of these are suggested for mineral exploration attention.

SPECIAL PROJECTS

Gary Beakhouse continued a project (Project 2.) started in 1983, the aim of which is to elucidate criteria whereby supracrustal rocks, particularly felsic volcanic rocks, can be identified within granitoid complexes and in high grade metamorphic terrains. A number of these were examined over the course of the summer. The most interesting is the Rice Bay area of Rainy Lake where rocks previously considered to be of metasedimentary origin appear to be at least in part metavolcanic. One area of alteration has given rise to the metamorphic assemblage of quartz, chlorite, garnet, anthophyllite, staurolite, and cordierite, an assemblage similar to those found in alteration zones associated with massive sulphide deposits.

Tom Muir, in the Hemlo area (Project 9.), initiated a study to produce a unified detailed overview of the geology of the deposit area. The report deals with a number of the stratigraphic and structural aspects of the immediate deposit area.

Eric Grunsky, in conjunction with the Batchawana synoptic project. has also been involved in geochronological, paleomagnetic, and lithogeochemical studies in the Batchawana area (Project 13.). The geochronological studies have gone a long way towards resolving the detailed age relationships, particularly of the granitic rocks. Geochemical analyses of dike rocks within the Batchawana area so far appears to have added little to the discrimination of dike swarms.

P. Brockmeyer and R. Lakomy of the University of Muenster studied an area at the western end of the Sudbury Igneous Complex (Project 15.). The aim of this work is to better understand the origin of the breccias and the footwall of the complex and the controls and variety of sulphide mineralization associated with the sublayer and the footwall breccia. Field relationships of the sublayer with the footwall breccia which usually underlies the sublayer, suggests that the footwall breccia is older than the sublayer, and also older than the norite of the main mass of the Sudbury Igneous Complex. A detailed study will be made of shock metamorphic features within the rocks.

Elizabeth Ambrose, Danny Wright, and Eric Grunsky present a package of general purpose computer programs for geological applications, which can be used on mini, micro, and mainframe computers (Project 18.). These are programs that are utilized by the Precambrian Geology Section and may be of interest to a wider audience.

The reports contained in this volume represent a first appraisal of raw geological field data, as do the preliminary maps which are in preparation for publication during the 1984-85 winter period. The reports and maps are designed as a means to rapidly diseminate "highlights" and to present general outlines of new information. Extended analysis of field data, in conjunction with detailed theoretical and laboratory research for publication of a final report and map, can be expected to result in changes to the field terminology, interpretations, and concepts expressed in this rapid release summary.

1. Regional Stratigraphy and Structure of the Central Uchi Subprovince: Meen Lake-Kasagiminnis Lake and Pashkokogan Lake Sections

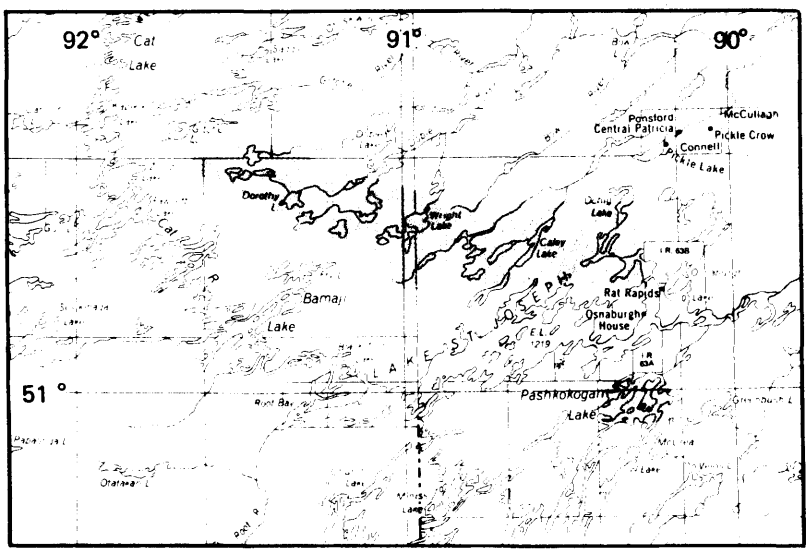
G.M. Stott[1] and Henry Wallace[2]

[1]Geologist, [2]Supervising Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto.

INTRODUCTION

This report outlines the results of the first part of a 2-year program to upgrade our knowledge of the regional stratigraphy and structure in the central part of the Uchi Subprovince. The main region to be described lies north of Lake St. Joseph, 30 to 85 km southwest to west of Pickle Lake. The results of preliminary work on Pashkokogan Lake are also included.

The project will continue in 1985 when the area to be surveyed will cover Pashkokogan Lake westward across Lake St. Joseph and northward towards Fry Lake.



LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

Approximately 430 km^2 were mapped in the Meen Lake-Kasagiminnis Lake area (Figure 1). The northwestern section from Meen Lake to Dobie River has been surveyed in detail recently (Stott and LaRocque 1983a, 1983b); the original interpretation of the regional structure in that area is revised here to conform with the data obtained in 1984.

This survey has resulted in some major revisions to previously published maps of the area and has outlined structural features of significance for gold exploration. Two cycles of volcanism have been identified in this belt, and the lateral extent of felsic to intermediate volcanic rocks has been enlarged. Two major dextral shear zones have been delineated along the northern and southern margins of the belt.

The bedrock exposure throughout most of this area is very poor inland from the lakes. Major drumlinoid ridges of fine sand trend northeastward and dominate the topographic character of the region. As a consequence, this survey is based on cross-sections through the belt along waterways and other bedrock "windows" between drumlinoid zones.

A field data recording system in which field notes and summaries were compiled using a battery operated NEC PC-8200 computer and stored on cassette tape was tested and revised during the field season. The benefits of this system are already evident in streamlining report production, and processing and displaying various categories of information, notably structural data.

MINERAL EXPLORATION

Past exploration in the map area has been limited to a few regional base-metal exploration programs and sporadic gold prospecting. However, considerable exploration activity has occurred in the last several years near Pickle Lake. Recent drilling and other exploration work on the nearby Dona Lake property of Dome Exploration (Canada) Limited has further stimulated the already keen interest in ironstone-hosted gold in this region. In addition, current exploration drilling for gold by Moss Re-

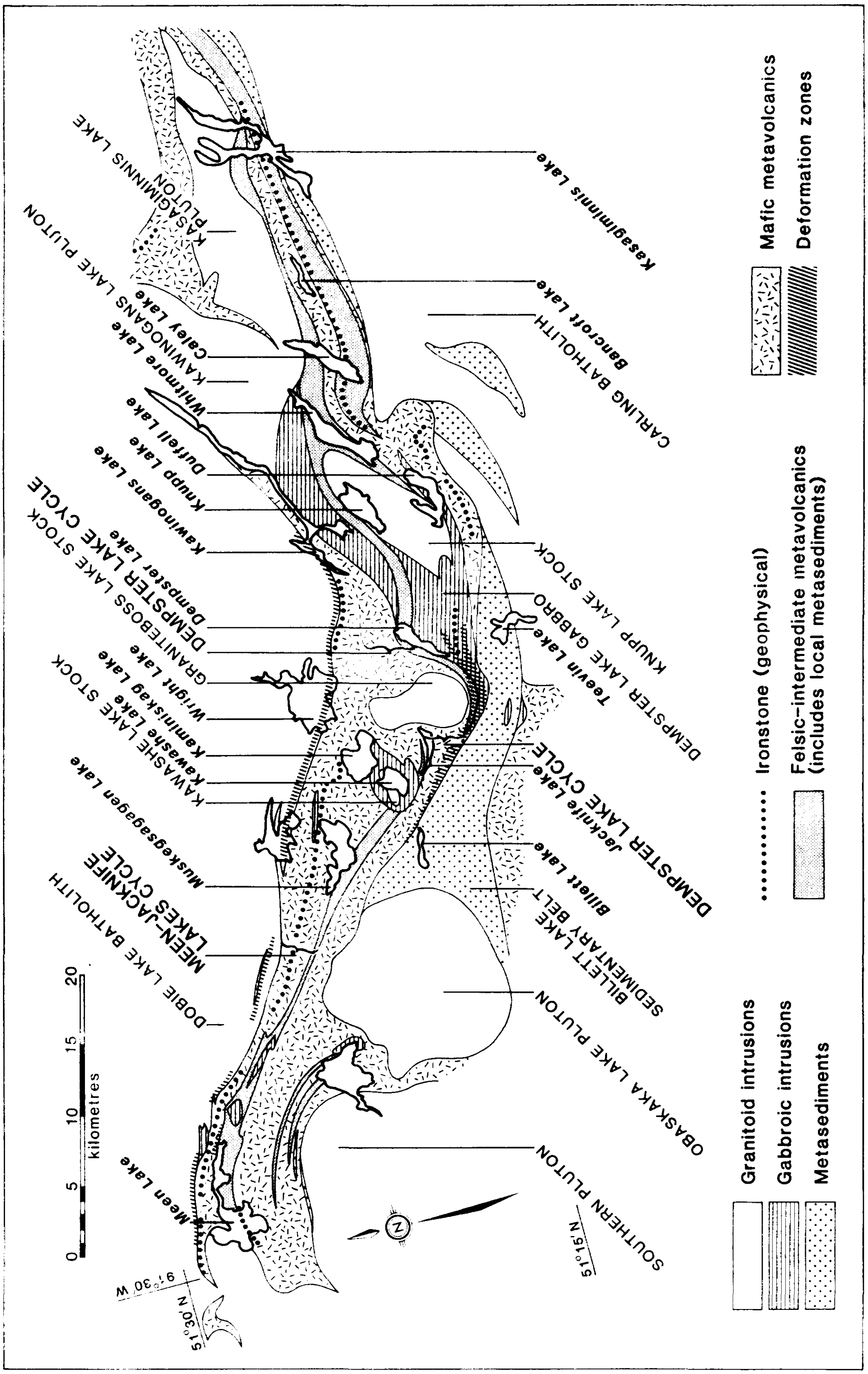


Figure 1. General geology of the Meen Lake-Kasagiminnis Lake area. (Project 1.)

sources Limited is focussing on a folded ironstone unit south of Bancroft Lake (locally referred to as Ben Lake).

The spring and summer of 1984 saw extensive staking and reconnaissance prospecting by several companies covering large parts of the survey area.

GENERAL GEOLOGY

MEEN LAKE–KASAGIMINNIS LAKE SECTION

Figure 1 outlines the major stratigraphic and intrusive components of the Archean supracrustal belt from Meen Lake to Kasagiminnis Lake.

The belt can be subdivided into 2 volcanic cycles. These cycles comprise massive to pillowed basalt capped by dacitic to locally rhyolitic pyroclastic rocks. On a regional scale, the stratigraphy youngs consistently to the south with local evidence of folding, notably on, and south of Meen Lake, and within the Billett Lake metasedimentary basin (Figure 1).

The older cycle is referred to here as the Meen-Jacknife Lakes cycle and occupies the northern 1/3 to 1/2 of the belt from Meen Lake eastward to at least south of Wright Lake. Its easternmost extent has not been defined but the stratigraphy swings northeastward and is probably obliquely transected by the Dobie Lake batholith.

This cycle is dominated by tholeiitic basalts with stratigraphically continuous marker units of magnetite-quartz ironstone, notably within the lowermost part of the cycle near the Dobie Lake batholith. Minor intermediate pyroclastic rocks occur northeast of Muskegsagagen Lake, and on and south of Kaminiskag Lake.

The top of the older cycle is marked by intermediate to felsic pyroclastic rocks with interlayered and overlying ironstone, clastic metasediments, and graphitic schist. The pyroclastic suite is now recognized to extend from Meen Lake to Jacknife Lake, where it appears to thin out. This assemblage of pyroclastic rocks is best observed on Meen Lake, locally south of Muskegsagagen Lake, and on Jacknife Lake.

A thick sequence of interbedded chemical and clastic metasedimentary rocks is prominently displayed along the north shore of Jacknife Lake, immediately overlying a calcite-bearing felsic lapilli tuff. The sequence includes ferriferous black chert, iron carbonate units, magnetitic, actinolitic, and locally pyritic ironstone, graphitic argillite, quartz-calcite arenite, and an oolitic carbonate bed. Some thin carbonate beds possess finely laminated fabrics similar to stromatolites but their presence remains to be confirmed.

Diamond-drill logs for holes drilled southeast of Meen Lake in this sequence of pyroclastic and sedimentary rocks were filed by Cominco Limited with the Assessment Files Research Office (Ontario Geological Survey, Toronto). These logs attest to the extensive development of sulphide facies ironstone, clastic metasediments, and pyritic and graphitic metasediments interbedded with the felsic to intermediate volcanics that cap this cycle.

Concentrations of coarse pyroclastic material occur on Meen Lake and south to southeast of Muskegsagagen Lake. Finer intermediate tuff beds characterize this stratigraphic package between these lakes and suggest that 2 volcanic centres may have been active at the close of this cycle. One centre is in the vicinity of Meen Lake (Stott 1982) and the other is in the vicinity of Muskegsagagen-Kawashe Lakes.

The overlying volcanic cycle is referred to here as the Dempster Lake cycle. Its lowermost section is best exposed on the south shore of Jacknife Lake, which lies along the contact between the 2 cycles. On the south shore, weakly deformed pillowed basalts with well defined cusps confirm a southward younging direction to the stratigraphy. These pillowed basalts become markedly distorted southwest of Jacknife Lake and develop a strong cleavage. This deformational fabric defines the boundary of a major deformation zone (shear zone) that is described later in this summary.

Cross-sections through the Dempster Lake cycle suggest that pillowed basalts containing iron carbonate amygdules are predominant south of Jacknife Lake and north of Dempster Lake. Massive to pillowed basalts typify the section south and east of the Graniteboss Lake stock.

The top of this cycle is marked by a suite of felsic to intermediate tuffs. These rocks extend beyond what is shown on previous maps (Sage *et al.* 1975); they extend from Kasagiminnis Lake, around the Knupp Lake stock, southwestward through Dempster Lake, and south of the Graniteboss Lake stock. The northwest extent of the felsic volcanics has not been determined due to the poor exposure around Billett Lake; however, felsic volcanics at the east end of Billett Lake may be correlative with this suite.

The uppermost suite on Dempster Lake is composed of fine-grained felsic to intermediate flows or ash-flow tuffs. On Whitmore Lake, where the stratigraphy appears to wrap partially around the Knupp Lake stock, there is a complex sequence of wackes, derived from the volcanic edifice and interbedded with some intermediate tuffs. Farther east, in the north part of Caley Lake, intermediate lapilli tuffs are prevalent. This suite appears to continue eastward beyond Kasagiminnis Lake and merge with a suite of more thinly bedded tuffs that trends westward to the south end of Caley Lake. Apparently a large antiformal zone of basalts extends from Caley Lake to Kasagiminnis Lake, flanked to the north and south by felsic to intermediate pyroclastic rocks and metasedimentary rocks.

Fine-grained, thinly bedded dacitic to andesitic tuff characterizes the sections on the south half of Caley Lake and south of Bancroft Lake. The tuffaceous rocks become interbedded with volcanic-derived clastic metasedimentary rocks close to the contact with a major sequence of metawackes.

The metawackes comprise a discontinuous unit along the southern margin of the belt and form large inclusions within the late tectonic Carling batholith. These metasedimentary rocks are interpreted to be remnants of the once more extensive Billett Lake sedimentary basin that stretched obliquely and unconformably across the Meen-Jacknife and Dempster Lakes volcanic cycles.

TABLE 1. THE SEQUENCE OF SUPRACRUSTAL AND TECTONIC EVENTS, MEEN LAKE- KASAGIMINNIS LAKE SECTION. (PROJECT 1.)

Late tectonic plutons with primary strain fabrics:
-Knupp Lake stock, Graniteboss Lake stock, Kawinogans Lake pluton, Kasagiminnis Lake pluton, Carling batholith, Southern pluton.
Conjugate shear bands:
-in the northern 1/3 of the greenstone belt.
Dextral deformation zones:
-on north and south margins of the belt.
Regional deformation and emplacement of the syntectonic Dobie Lake Batholith
Kawashe Lake stock:
-intruded the Kawashe gabbro.
Dempster Lake Gabbro:
-intruded the Billett Lake sedimentary belt.
-other discordant gabbro bodies probably emplaced at this stage.
Billett Lake Sedimentary Belt.
Unconformity:
-unconformity exists between the sedimentary belt and the Meen - Jacknife and Dempster Lakes cycles
Dempster Lake Volcanic cycle:
-includes Sky Lake quartz porphyry intrusion
Meen-Jacknife Lakes Volcanic cycles:
-includes Meen Lake quartz porphyry intrusion.

Large metasedimentary inclusions range across the northern half of the Carling batholith from highway 599 to Teevin Lake. Much of the region southeast and northwest of Billett Lake is covered by overburden, with the best exposures occurring in the vicinity of Billett Lake and west of Teevin Lake.

Apart from the proximally-derived conglomerates of Billett Lake, most of the sedimentary sequence appears to have been composed of wackes with minor interbeds of aluminous mudstone.

South of Billett Lake, an antiformal "window" of basalts which underlie the conglomerates is exposed. In addition, diamond-drill logs (Assessment Files Research Office, Ontario Geological Survey, Toronto) suggest that the sedimentary belt probably forms a relatively thin, folded mantle over the volcanic rocks southeast of Billett Lake.

The volcanic belt has been intruded by a number of early and late granitoid and gabbroic plutons as shown in Figure 1. These intrusions have been assigned to a relative sequence within the regional supracrustal and tectonic history (Table 1).

Several of the gabbroic masses intrude the enveloping volcanic rocks discordantly. The gabbro body on Dempster Lake contains a narrow anorthosite phase on its northwest margin. This large body discordantly intrudes rocks of the Dempster Lake cycle. Its margins tend to conform with the enveloping stratigraphy, but it contains mafic volcanic and other supracrustal inclusions. The body also intrudes the Billett Lake sedimentary belt and thereby is recognized as a late intrusion in the supracrustal history. The southern half of the body is characterized by high magnetic susceptibility, and is magnetite-rich near an unassimilated ironstone inclusion.

The portion of the gabbro body northeast of Dempster Lake on Kawinogans Lake is crossed by numerous northeast-trending shear zones that are related to the regional deformation. These zones are locally associated with pyritic gossan zones. The gabbro is generally concordant with the surrounding metavolcanic rocks.

Granitoid intrusions range widely in relative age. Two small stocks may represent subvolcanic intrusions in this belt. A quartz porphyry underlies the dacitic rocks on Meen Lake. This small intrusion is on the north side of the eastern arm of the lake. The small Sky Lake quartz porphyry stock lies just east of Caley Lake. It appears to underlie dacitic-andesitic tuffs near the top of the Dempster Lake cycle.

The Kawashe Lake stock is an early trondhjemitic body enveloped by the Kawashe gabbro. Intruding the gabbro is a set of quartz porphyry and fine-grained trondhjemitic sills apparently related to the stock. Some of the porphyry dikes are pyrite- and tourmaline-bearing.

Two intrusions were emplaced very late in the tectonic history of this region. The Graniteboss Lake and Knupp Lake stocks consist of quartz porphyritic, K-feldspar megacrystic granodiorite. They possess primary strain fabrics and postdate the regional deformation recorded in the surrounding supracrustal rocks. The Knupp Lake stock, as defined here, includes the formerly mapped Duffell Lake stock (Sage *et al.* 1975).

The regional deformation, particularly in the western half of the belt, is relatable to the emplacement of the large Dobie Lake batholith to the north. This batholith is a syntectonic body. In contrast, the Southern pluton, south of Meen Lake, and the Carling batholith are both late tectonic intrusions. These have imposed limited contact-strain aureoles that overprint the regional deformation in the "greenstone" belt. The Carling batholith appears to have been emplaced largely by magmatic stoping.

The Kasagiminnis Lake pluton and a pluton east of Kawinogans Lake are also interpreted to be late tectonic granodioritic intrusions with primary fabrics and limited contact-strain effects upon the surrounding volcanic rocks.

PASHKOKOGAN LAKE SECTION

A reconnaissance survey around Pashkokogan Lake (approximately 60 km south of Pickle Lake) was carried out by the second author (Henry Wallace) in order to examine large-scale stratigraphic and structural features previously identified by Goodwin(1965), and to assess the need for more detailed mapping in the area.

This section is notable in this region for its high proportion of felsic to intermediate metavolcanic rocks relative to mafic flows. Much of Pashkokogan Lake and the southern half of East Pashkokogan Lake are underlain by a variety of pyroclastic rocks, mostly monolithic tuffs, lapilli tuffs, and tuff-breccias of dacitic to andesitic composition. In some places these tuffaceous rocks are intercalated with chemical metasedimentary rocks such as chert and lean magnetitic iron formation, and with units of fine wacke-mudstone.

The felsic rocks, which generally strike east to east-northeast, appear to envelop a mafic sequence consisting of basaltic pillowed, massive, and fragmental units. The general pattern suggests an east-west trending fold, however the extent of this mafic sequence and its relationship with the more felsic rocks surrounding it are difficult to determine because of poor exposure and the paucity of reliable top indicators. Low to medium grade metamorphic recrystallization has obscured features such as graded bedding, and deformation has induced marked flattening and transposition of pillows in mafic flows. The few facing determinations made suggest that sequences in the northern part of Pashkokogan and East Pashkokogan Lakes young southward, but no unequivocal determinations could be made in the south.

Linear structural elements such as minor fold axes, rodding of pyroclasts, and mineral lineations are commonly well developed in the southern part of the area. These linear elements trend roughly east-west, plunge steeply to moderately, and form an undulating pattern in the plunge azimuths across the area from east to west. This pattern of opposing plunges at fairly regular intervals may indicate roughly north-south cross-folding of an earlier east-west syncline.

STRUCTURAL GEOLOGY

The most notable structural features outlined by the survey in the Meen Lake-Kasagiminnis Lake section are 2 major ductile deformation zones (shear zones) shown in Figure 1. Both zones trend to the northwest and both display a dextral (right handed) sense of shear. Movement in these zones was dominantly transcurrent and plunged southeastward.

One zone forms a mylonite band along the northern contact between the Dobie Lake batholith and the "greenstone" belt. The band is apparently discontinuous as shown in Figure 1. The mylonite zone extends from north of Meen Lake southeastwards and diminishes north of Knupp Lake at the belt contact. Spatially associated with this zone is a conjugate set of narrow shear bands widely observed in the northern half of the belt and within the immediately adjacent part of the Dobie Lake batholith. The bands are typically 5 to 15 cm wide. There is a consistent dextral sense of transcurrent movement in the northwest-trending shears and a sinistral sense in the northeast-trending shears. These shear bands are most prominent north of Muskegsagagen Lake and in the vicinity of Wright Lake. As one proceeds southwards across the belt, the bands diminish to form thin shear fractures and cracks with slickensided surfaces that record the same conjugate sense of movement. This change in conjugate shear mechanism southward may reflect change down the thermal gradient away from the Dobie Lake batholith.

The second major deformation zone is wider and lies to the south of Jacknife Lake. It appears to widen from northwest of Billett Lake towards the southeast, and crosses a major gabbro body north of Teevin Lake. The full extent of this deformation zone has not been defined. It ranges up to 1500 m wide and contains moderately to strongly deformed rocks that grade into discrete mylonite zones. Eastward, the deformation appears to diminish to form narrower zones north of Teevin Lake. Towards its margins, where the deformation decreases, the zone is recognized only by a characteristic southeasterly plunging mineral lineation which contrasts with the earlier, regional, northwesterly plunging extension lineations in the rocks outside the zone.

These 2 deformation zones appear to be late formed, integral elements in the regional deformation pattern across the westernmost half of the belt from Meen Lake to Graniteboss Lake stock.

Regional mineral lineation patterns were mapped in the Meen Lake area (Stott and LaRocque 1983a, 1983b) and this work was continued across the present survey area. The results show major progressive changes in lineation plunge azimuth along the length of the belt. The patterns are presently being studied for their relationships to the regional tectonic history, and as clues to the timing of deformation zones and granitoid intrusions.

The most complex structure in the belt occurs between Whitmore Lake and Kasagiminnis Lake. Here, the central axis of the belt appears to be an antiform flanked to the north and south by the uppermost suites of the Dempster Lake volcanic cycle. In the vicinity of Bancroft Lake there is some evidence, from folds and progressive changes in lineation azimuth along strike, of a doubly-plunging antiform.

In the Meen Lake area, previously interpreted fold patterns in the belt have been reinterpreted. The stratigraphy is now interpreted to be younging southward with only local folding—a syncline on the southern part of Meen Lake and tight folding along the southern margin of the belt. At present, regional stratigraphic correlations of the metasedimentary and felsic to intermediate metavolcanic rocks just north of the Southern pluton remain problematical.

ECONOMIC GEOLOGY AND SUGGESTIONS FOR EXPLORATION

There are few records of mineralization in this belt. Due to the poor exposure and the limited geological data base available, relatively little exploration has been done in this area in the past. As a consequence, this supracrustal belt is, within Ontario, one of the few remaining moderately accessible areas of high mineral potential that has not been exhaustively explored.

The present reconnaissance survey has identified 2 major dextral shear zones. The northernmost mylonite zone is largely constrained to the margin of the belt but it may be associated with shear bands within the belt. In addition, a conjugate set of shear bands is prominently developed in the northern third of the belt, notably in the Meen Lake-Wright Lake section. Since major ironstone units are concentrated along the northern length of this belt, the overprint of shear bands in the vicinity of ironstone units provides an obvious target for explorationists seeking auriferous vein concentrations associated with deformed ironstone. Quartz veins were widely observed within these shear bands. Folding of ironstone, notably exemplified by a unit north of Kaminiskag Lake, may also prove to be a factor controlling gold mineralization.

The other major deformation zone, south of Jacknife Lake, transects part of the felsic to intermediate volcanic rocks of the Dempster Lake cycle in the area south of the Graniteboss stock. This has produced a wide zone of mylonitic schist in the felsic volcanics and a local abundance of folded quartz-filled fractures which should be examined.

Quartz, and quartz-carbonate±tourmaline veins are widely observed across this belt. The veins are parallel to the regional foliation and occur along narrow shear zones. Quartz-tourmaline veins are most notable on Jacknife Lake, Kaminiskag Lake, and in the vicinity of Dempster and Bancroft Lakes.

Carbonatization was only observed in outcrops of mafic volcanic rocks near the south side of Muskegsagagen Lake, further west on the Obaskaka River, and within the felsic volcanic rocks on the north shore of Jacknife Lake.

Owing to the relatively high grade of metamorphism prevalent in this belt, syntectonic carbonatization may not be a significant exploration factor. Instead, sulphide-bearing silicification associated with ironstone, such as that found south of Bancroft Lake, may be considered to have high gold potential.

Gold prospectors should, in view of the relatively poor exposure in this belt, focus their exploration for gold on the ironstones and the major shear zones along the northern and southern margins of the belt. Shear zones such as these are now actively being explored in the Red Lake belt, and within and on the margins of the Wabigoon Subprovince.

Base-metal prospectors should note the major revisions to the regional stratigraphy in the Meen Lake-Kasagiminnis Lake belt. Of particular note is the observation that this belt contains a greater proportion of felsic to intermediate metavolcanic rocks than has been previously reported. The best evidence of diverse lithologies typical of vent and proximal volcanic facies is observed on Meen Lake and in the Muskegsagagen-Jacknife Lakes section. There is similar evidence on the northern end of Caley Lake.

In the Pashkokogan Lake area, sulphide-bearing chert and lean magnetite-quartz ironstone units exposed in a few places around northern Pashkokogan Lake, and sulphide-bearing quartz-tourmaline veins found in the southern part of East Pashkokogan Lake, should be tested for gold.

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2. Reconnaissance Investigations of Granitoid and Medium to High Grade Metasedimentary Terrains: Volcanic Components and Mineral Potential

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INTRODUCTION

The purpose of this project is to study the characteristics of volcanic rocks metamorphosed to medium and high grades, and to determine their extent in areas of northwestern Ontario hitherto considered to have low potential for the discovery of economic mineral deposits. Geological environments in which such metavolcanic rocks and related mineral deposits could be present but unrecognized include granitoid complexes and paragneiss terrains. Neither of these environments have received much exploration attention in the past.

Previous work in the Winnipeg River belt has suggested that mafic metavolcanic rocks and chemical sedimentary rocks, which are comparatively easy to identify under upper amphibolite and granulite facies metamorphic conditions, are more abundant than previously recognized (Beakhouse *et al.* 1983). However, felsic metavolcanic rocks were not recognized in the Winnipeg River belt, so during the 1984 field season emphasis was placed on examining areas where these rocks might occur within granitoid complexes and paragneiss terrains. In order to address these objectives and problems the following reconnaissance studies were undertaken:

1. investigation of areas where "greenstone" belts terminate in a granitoid complex. Areas examined include Manitumieg-Wawapus Lakes, Redgut Bay of Rainy Lake, and Lake Despair.
2. investigation of areas previously mapped as paragneiss or amphibolite facies metasedimentary rocks including those at Northern Light Lake, Titmarsh Lake and Rice Bay of Rainy Lake.

MANITUMIEG-WAWAPUS LAKES AREAS METAVOLCANIC INCLUSIONS

Blackburn (1979) reports numerous metavolcanic inclusions up to 1 km^2 in surface exposure in the southern part of the Niven Lobe of the Atikwa batholith. He describes these inclusions as decreasing in abundance to the north and considers them to be blocks rafted away from the Manitou Lakes greenstone belt in which corresponding lithologies occur. Blackburn (1981) indicates a discontinuous septum of metavolcanic rocks between the Upper Manitou Lake greenstone belt and the southward projecting promontory of the Eagle Lake greenstone belt. The present survey located several more inclusions (all <0.1 km^2) but the general distribution of inclusions is as described by Blackburn (1979, 1981).

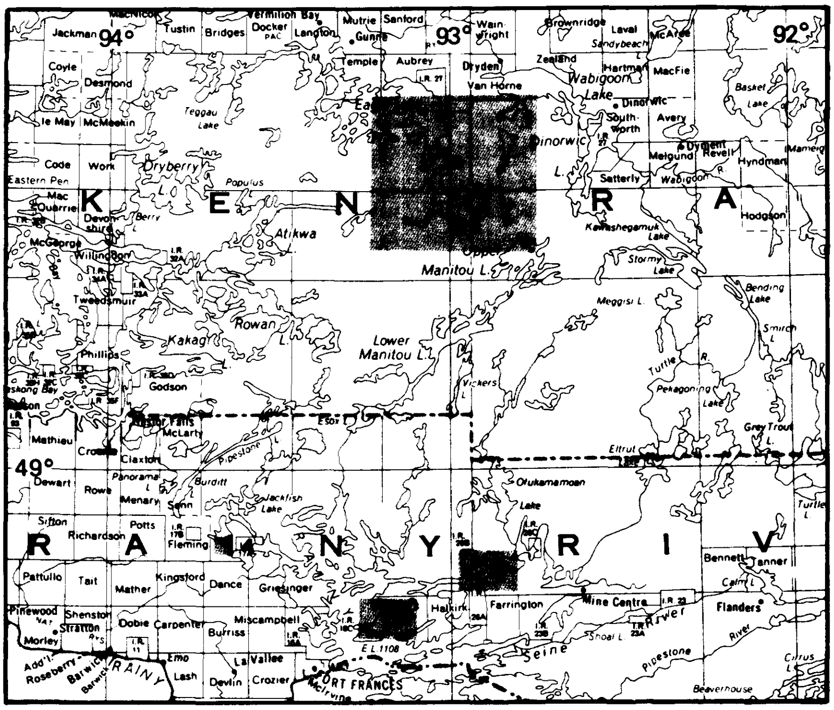
Two rock types predominate among the metavolcanic inclusions; mafic flow rocks, and intermediate to felsic fragmental rocks. The mafic flows include equigranular and feldspar-phyric, massive and pillowed varieties. The fragments in the intermediate to felsic rocks are predominantly dacitic although numerous textural variations are common. Fragments containing quartz phenocrysts are rare. Mafic fragments are present but not abundant although these are difficult to distinguish from the matrix. Primary textures and structures are well preserved (*see* Blackburn 1979, photographs).

Most of these inclusions are contained within a medium-grained, grey, nonfoliated, homogeneous, microcline megacryst-bearing, biotite granodiorite. The contacts between the inclusions and granodiorite are sharp with little evidence of reaction. The metavolcanic rocks show no evidence of having been partially melted and it is unlikely that any highly migmatized metavolcanic rocks are present in the areas between the readily recognizable inclusions.

REDGUT BAY (RAINY LAKE) METAVOLCANIC ROCKS

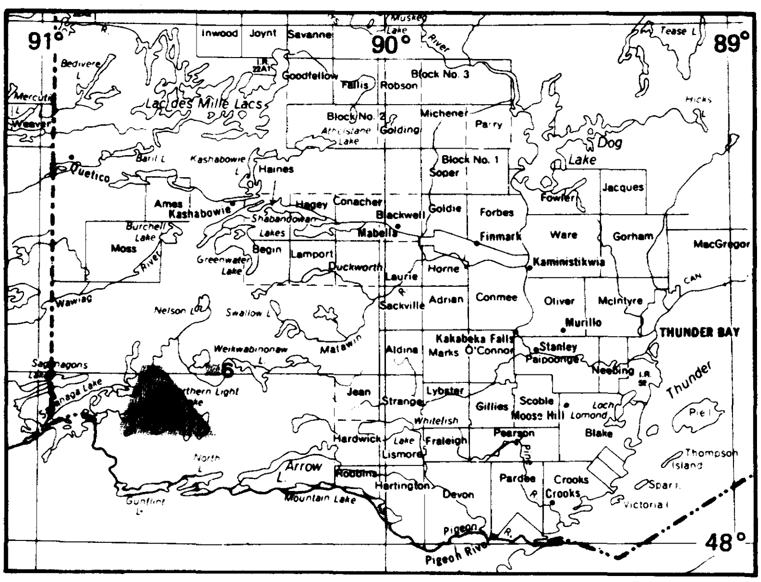
Previous geologic mapping has indicated the presence of metavolcanic migmatites in the vicinity of Redgut Bay of Rainy Lake but workers in adjacent and partially overlapping map areas have offered different interpretations for certain of the felsic migmatites (Wood *et al.* 1980; Blackburn 1973).

Observations made by the present survey suggest that the relatively mafic, hornblende-bearing migmatites are of mafic metavolcanic origin and that the more felsic, biotitic



LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

1 Niven Lobe area
2 Manitumieg - Wawapus Lakes area
3 Redgut Bay area
4 Lake Despair location
7 Rice Bay area



LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

5 Northern Light Lake area
6 Titmarsh Lake location

migmatites are metaplutonic rocks. The metavolcanic origin of the mafic units is evidenced by the presence of highly deformed pillow structures and distinctive alteration (epidote-rich) pods and zones that are interpreted to be related to seawater alteration. Ultramafic rocks identified within this association are not ultramafic flows but appear to be a melanosome phase arising from partial anatexis of rocks of basaltic composition.

The following observations suggest that the felsic migmatitic rocks are metaplutonic rather than metavolcanic:

1. **Although primary structures are recognizable in high grade mafic metavolcanic rocks and metasedimentary rocks, no primary metavolcanic structures are present in the felsic migmatites.**
2. **The composition of the rocks (predominantly tonalitic and granodioritic) is that of normal plutonic rocks. Felsic metavolcanic rocks commonly exhibit local distinctive, aluminous mineralogical assemblages due to secondary alteration (e.g. breakdown of volcanic glass, hydrothermal alteration).**
3. **Cross-cutting relationships amongst the various felsic phases demonstrates that much of the heterogeneity in the felsic units is due to intrusive processes and not original supracrustal heterogeneity.**

TERMINATION OF THE METAVOLCANIC BELT AT LAKE DESPAIR

Exposures of granitoid rocks off the end of the metavolcanic termination south of Lake Despair were examined

briefly to evaluate the possible presence of metavolcanic migmatites. Blackburn (1976) indicates a heterogeneous sequence of amphibolite facies mafic to felsic metavolcanic rocks terminating against granitoid rocks. A major fault (Northwest Bay Fault) appears to be, at least in part, responsible for the truncation.

Examination of outcrops in the granitoid complex reveals little evidence of a supracrustal component. Minor amphibolite inclusions are common but not abundant.

NORTHERN LIGHT GNEISS

The origin of the Northern Light gneiss is controversial having been interpreted as metavolcanic, metaplutonic, or metasedimentary (Grout 1929; Goldich *et al.* 1961, 1972; Harris 1968).

Selected exposures of the Northern Light gneiss outcropping on the shore of Northern Light Lake and along the forest access road east of the lake were briefly examined in 1984. These consist of moderately to extremely well banded, fine-grained, biotite tonalite and leucotonalite gneiss. Throughout much of the complex, amphibolite enclaves are small (usually <1 m in diameter) and not abundant (usually <1% of outcrop). Numerous larger amphibole enclaves (up to 1 km^2 in surface exposure) are interlayered with the gneiss and are interpreted to be of mafic metavolcanic origin. Some of the smaller enclaves have a similar origin but the possibility that some represent disrupted mafic dikes cannot be discounted. No rocks with distinctive mineralogy or structures that would suggest a felsic volcanic origin, such as observed in the Titmarsh Lake area (*see* below), were identified.

Diagnostic field evidence for either an intrusive or extrusive origin for the fine-grained tonalite gneiss is lacking in many outcrops. In the vicinity of the larger metavolcanic amphibolite enclaves the tonalites are intrusive into, and contain inclusions of, the mafic metavolcanic rocks. On the basis of this observation it is tentatively concluded that the Northern Light gneiss is a metaplutonic rock with inclusions of predominantly mafic metavolcanic rocks that represent a fragmentary continuation of the Saganagons greenstone belt.

An unusual tonalite unit occurring east of Titmarsh Lake was brought to the author's attention by John Percival (Geologist, Geological Survey of Canada, personal communication, 1984). This fine- to medium-grained tonalite is distinctive due to the abundance of white mica which constitutes between 5 and 30% of the rock. The white mica occurs throughout the rock but is most abundant in irregularly shaped, discontinuous, anastomosing zones. The unit exhibits some textural heterogeneity that could reflect an original fragmental texture. The unit contains no mafic inclusions and is in sharp contact with amphibolite of probable mafic volcanic origin. Distinctive mineralogy, textural heterogeneity, and association with mafic metavolcanic rocks suggests this unit is probably of felsic volcanic origin although, in the absence of detailed mapping, the possibility that it represents a greisen cannot be completely discounted.

RICE BAY AREA (RAINY LAKE)

The Rice Bay area of Rainy Lake is a classical geologic area wherein an overturned sequence of metavolcanic and metasedimentary rocks are deformed into a domical structure (Poulsen 1980). Metamorphic rocks interpreted to be of sedimentary origin occupy the core of the dome (Harris 1974). Howard Poulsen (Geologist, Geological Survey of Canada, personal communication, 1984) suggested that some of these rocks do not resemble the metasedimentary rocks with which they have been correlated.

A limited number of outcrops in the northwestern part of the metasedimentary unit of Harris (1974) were examined and the observations made suggest that some of these rocks are highly altered, amphibolite facies metavolcanic rocks. Brief descriptions of some of the outcrops examined are presented below.

Thin- to medium-bedded metawacke that resembles the Coutchiching metasedimentary rocks with which the entire core of the Rice Bay dome has been correlated outcrop on the northwestern shore of Rice Bay (Figure 1, location A). Of the several dozen outcrops examined only this outcrop is clearly of sedimentary origin.

The most readily identifiable metavolcanic rock encountered outcrops on a small island in the north channel of Rice Bay (Figure 1, location B). Here, a fine-grained, grey, buff weathering, highly garnetiferous rock contains pillow structures. The selvage edges differ mineralogically from the cores of the pillows primarily in the greater abundance of garnet (up to 50% in selvage versus 5

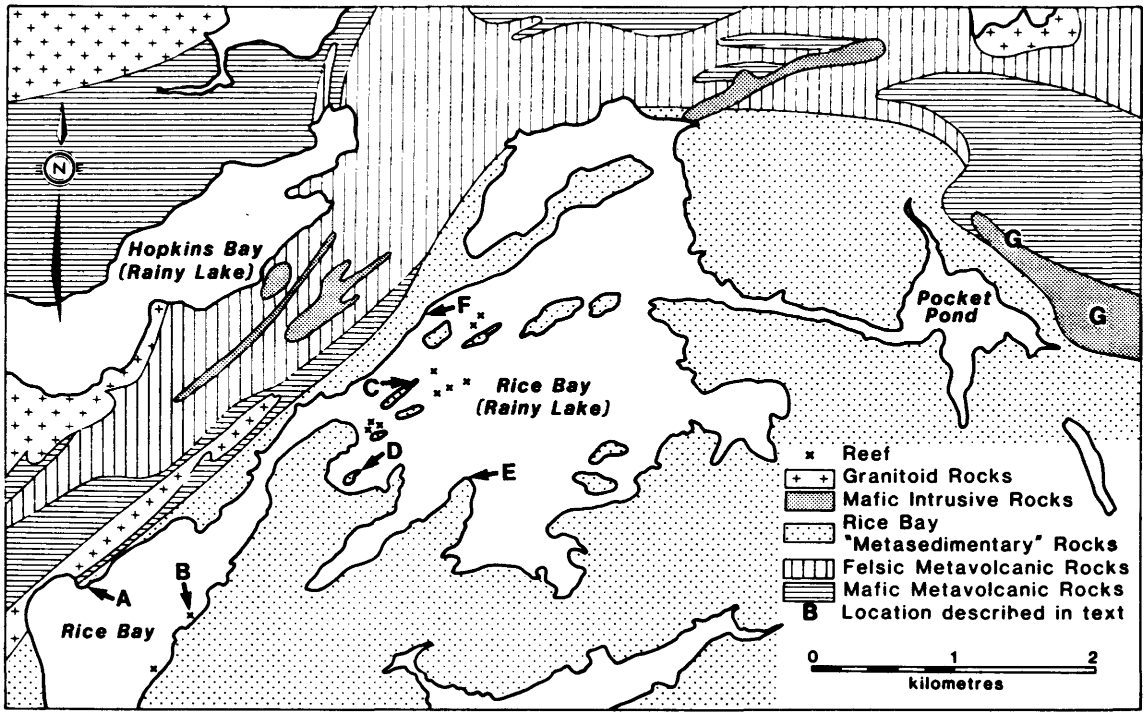


Figure 1. Geologic map of the northwest portion of the Rice Bay dome (*after* Harris 1974) illustrating the location of outcrops described in the text. (Project 2.)

to 15% in cores) and biotite. The pillows range in size up to 2 m in longest dimension and are flattened with length to width ratios ranging from 5:1 to 10:1. The garnets are red in colour with a greenish-black rim and are sometimes partially replaced by biotite. A plagioclase corona occurs around some of the garnets. This rock is interpreted to be a highly altered, pillowed flow that probably had an original basaltic composition.

The origin of many of the rocks examined is not obvious. Examples include a fine-grained, grey, well foliated biotite schist (Figure 1, location C). This unit contains pelitic anastomozing zones that, on the basis of their geometry, do not appear to be either relict layering or shear zones. This rock may be an intermediate tuffaceous rock. A fine-grained tonalite (Figure 1, location E) contains anastomosing chlorite±garnet alteration zones but diagnostic evidence in favour of either an extrusive or shallow intrusive origin is lacking.

The most interesting alteration encountered occurs in a fine- to medium-grained, greenish-grey, well foliated chlorite schist that contains minor, thin concordant zones of quartz-chlorite- garnet-anthophyllite-staurolite-(cordierite ?) schist (Figure 1, location D). Cordierite has not been recognized in the single thin section examined to date but large crystals replaced by chlorite with abundant quartz inclusions and, rarely, staurolite cores are interpreted to be altered cordierite. Feldspar is not present in the intensely altered rock. The abundance of aluminous mineral phases and absence of feldspar suggests that the latter may have been broken down by dealkalinization reactions with aluminum and silicon left behind to contribute to the new metamorphic mineral assemblage. Such chemical and mineralogical features are reported from alteration zones lying stratigraphically below volcanogenic massive sulphide deposits (Franklin and Thorpe 1982).

No significant base-metal occurrences are reported from the "biotite schist" that cores the Rice Bay dome. Harris (1974) reports a "20-foot wide band of garnet-biotite-amphibolite schist that contains up to 5% disseminated pyrrhotite, pyrite and up to 15% disseminated magnetite" from the northern shore of Rice Bay (Figure 1, location F). Zinc, copper, and molybdenum mineralization is reported in the Pocket Pond area (Figure 1, location G). The mineralization here is associated with iron formation within mafic and ultramafic flows near the contact with the Rice Bay dome "biotite schist" (Harris 1974; Poulsen 1984).

The observation and interpretations discussed above indicate that the core of the Rice Bay dome is lithologically complex. Metavolcanic rocks are present, and perhaps predominate in these units previously considered to be of sedimentary origin. Many of the rocks are intensely altered. Systematic detailed mapping is required to establish the origin and distribution of lithologic units.

SUMMARY AND RECOMMENDATIONS FOR MINERAL EXPLORATION

Where metavolcanic rocks are known to occur in granitoid complexes, they tend to have preserved relict structures and compositions that facilitate their identification. Metavolcanic rocks other than those recognized by earlier workers are not abundant in any of the granitoid complexes described in this report although intrusive rocks in the Atikwa batholith may be related to volcanism.

Of the areas selected for reconnaissance investigations, potentially extensive and previously undocumented metavolcanic rocks have only been identified in the Rice Bay area where they were formerly mapped as metasedimentary rocks. The lithologic associations and intense alteration of these rocks suggests they have considerable potential for base metal mineralization.

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S3. Geology of the Bigstone Bay Area, District of Kenora

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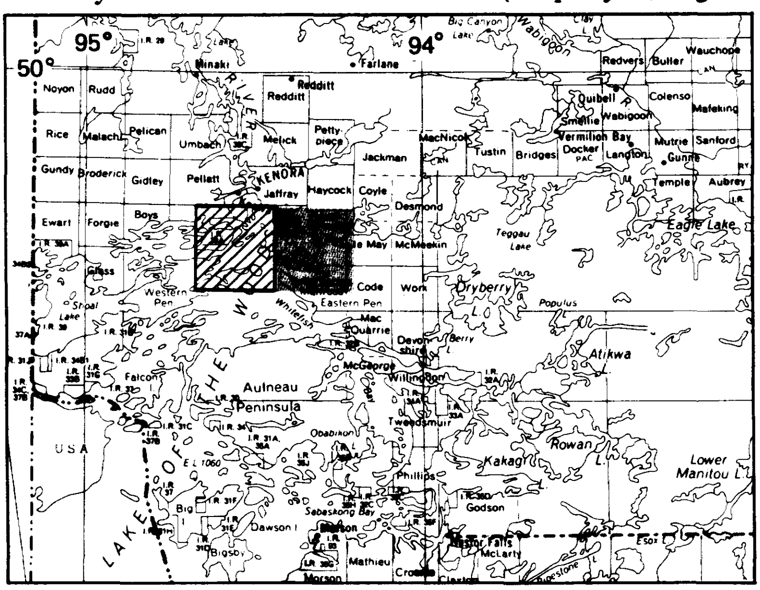
This Project was Funded by the Ontario Ministry of Northern Affairs (Bigstone Bay Survey).

INTRODUCTION

This is the first year of a 2-year project to map the northern part of the Lake of the Woods area at a scale of 1:15 840. Field work during the summer of 1984 was concentrated in the eastern half of the area. The area covered is bounded by Latitudes 49°34′N and 49°45′N, and Longitudes 94°13′42″W and 94°27′24″W. The city of Kenora is about 5 km west of the northwestern corner of the mapped area.

Most of the area is easily accessible by boat from Lake of the Woods. The northern and eastern parts are also accessible by paved provincial highways and gravel secondary roads. The area south of Longbow Lake is serviced by a new Ministry of Natural Resources Forest Access Road which extends from Highway 71 to just west of Hollow Lake.



LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

1984 Map Area

1985 Map Area

MINERAL EXPLORATION

Unless otherwise specified, the following information has been derived from the files of the Resident Geologist, Ontario Ministry of Natural Resources, Kenora (AFK). Locations and mineral deposits mentioned in the text can be found on Figure 1.

The Lake of the Woods area has been actively explored for gold since the 1850s (Beard and Garratt 1976). The earliest period of significant production was the 1880s to the early 1900s. In this period, production was recorded from the Sultana Mine from 1894 to 1906 (Property E, Figure 1; 15 977 ounces Au from 77 481 tons of ore, grading 0.21 ounce Au per ton), the Ophir Mine from 1893 to 1894, 1900, and 1911 (Property D; 1097 ounces Au from 6089 tons, grading 0.18 ounce Au per ton), the Gold Hill Mine from 1886 to 1893 (Property B; 1090 ounces Au from 220 tons, grading 4.95 ounces Au per ton), the Black Jack Prospect in 1893 (Property C; 50 tons milled ran 0.33 ounce Au per ton) and the Treasure Prospect in 1898 (Property G; 29 ounces Au from 34 tons, grading 0.85 ounce Au per ton) (Beard and Garratt 1976).

A second period of activity took place in the 1930s and 1940s at the Wendigo Mine (Property A). Production records indicate a total of 67 423 ounces Au, 14 762 ounces Ag and 1.9 million pounds Cu from 206 054 tons of ore (Beard and Garratt 1976).

From the 1950s to the mid-1970s, base-metal exploration gained precedence over gold exploration. From 1966 to 1968, the western end of the Eastern Peninsula was explored for copper, zinc, and nickel by Augmitto Explorations Limited, Copconda Mines Limited, Norlex Mines Limited, and Canadian Javelin Limited (Davies 1967). Work done during this period included geological mapping, ground geophysics (electromagnetic (EM) and magnetic), trenching, and diamond drilling.

In 1973, Dome Explorations Limited covered the area around the eastern end of Witch Bay with an airborne geophysical survey (EM and magnetic) that extended to the

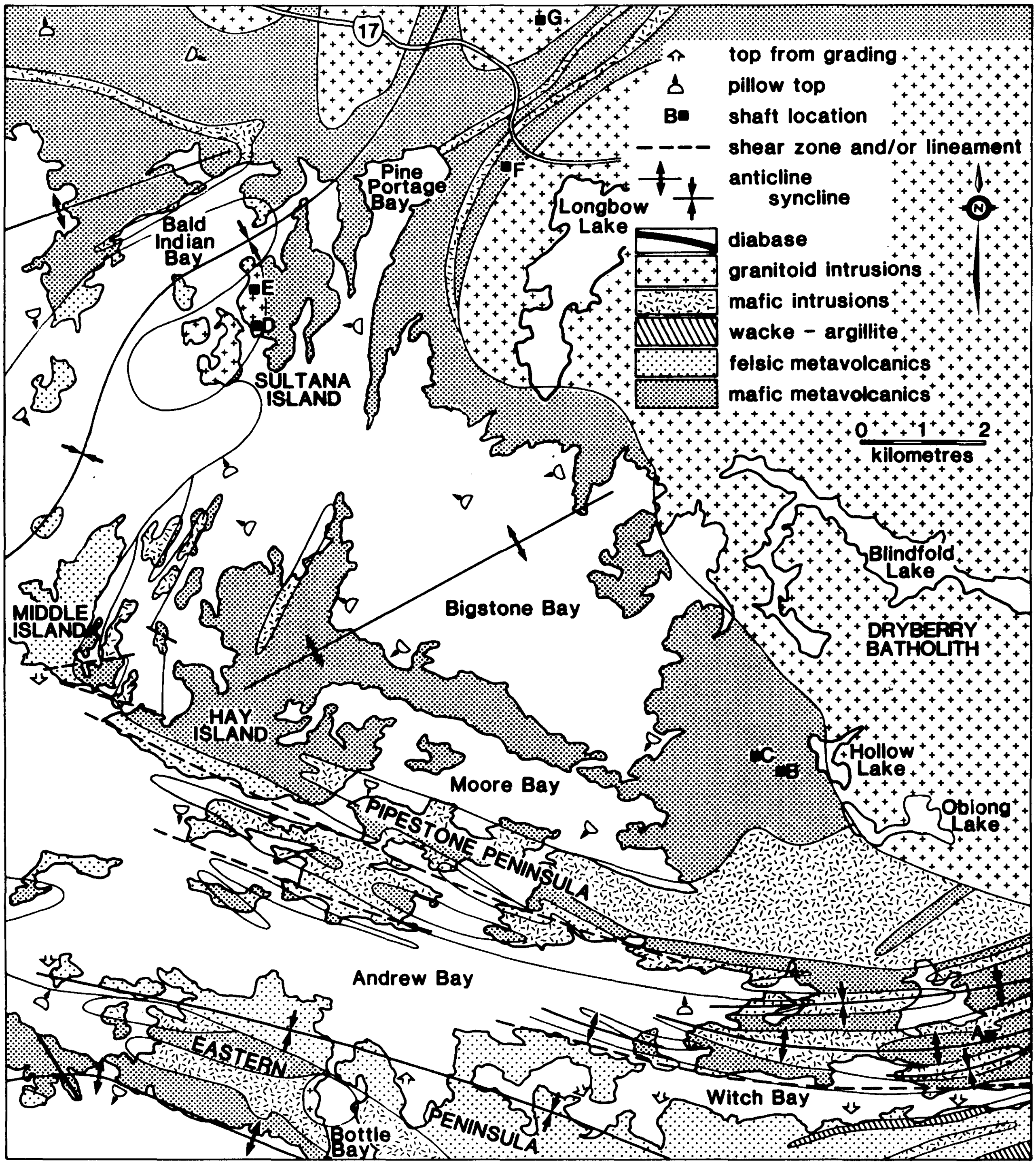


Figure 1. Generalized geology and property locations in the Bigstone Bay area. (Project S3.)

east and south of the map area. This program was followed by diamond drilling in 1973 and 1974.

From 1972 to 1974, Minaki Gold Mines Limited explored the area around the northern part of Sultana Island, first for gold and then for base metals. Their work consisted of ground geophysics (EM, magnetic, and induced polarization) and diamond drilling.

In the past 10 years, gold exploration has again regained predominance in the area. Most of the work has been concentrated in the vicinity of past producers and prospects. In the area northwest of the Pine Portage Prospect (Property F), Willow Lake Mines Limited conducted a geological survey (EM and magnetic) in 1975. From 1979 to present, President Mines Limited have been exploring in the vicinity of the Pine Portage Prospect. Their work has consisted of dewatering and resampling of the old shaft and workings, diamond drilling, and geophysics.

The former Wendigo Mine Property (Property A) was explored by Denison Mines Limited from 1981 to 1982. Their program included geological mapping, geochemistry, and geophysics. From 1982 to 1983, Bonzano Exploration Limited undertook a program to re-evaluate the old workings at the former Gold Hill Mine (Property B) and Black Jack Prospect (Property C). Their work consisted of cleaning, stripping, and sampling many of the old workings as well as geological mapping and a magnetometer survey.

During the 1984 field season, Bigstone Minerals Limited worked on 2 claim groups within the map area. Their program on an 11-claim group north of the old Wendigo Mine (Property A) included geological mapping and geophysics (VLF and magnetic). The second property is a 10-claim group on the eastern part of Hay Island, on which geological mapping was performed.

GENERAL GEOLOGY

Geological mapping of the Lake of the Woods area was first done by Lawson (1885). The project area was also covered in more detail by Suffel (1931). The southeastern portion of the map area is included as part of a more recent map by Davies (1967). Other recent mapping in the general area was done by Davies (1970), Johns (1982), King (1983), and Trowell (1980).

All rocks in the map area are of Archean age, with the exception of a northwest-trending diabase dike of Late Precambrian age.

The oldest rocks are a thick basal succession of pillowed to massive mafic metavolcanic flows. The thickest exposure of this lower mafic unit is in the Bigstone Bay-Hay Island area. Here the unit is a monoclinal sequence which is intruded by the Dryberry Batholith at its base and is overlain by felsic to intermediate metavolcanic rocks on Middle Island and the southwestern part of Hay Island.

Overlying the lower mafic unit is a diverse sequence of felsic to intermediate metavolcanic rocks which predominantly consist of pyroclastic flows and redeposited volcaniclastic rocks with minor flows (locally flow laminated and autobrecciated). Some minor horizons of mafic metavolcanic rock occur within this felsic unit. In general these mafic flows differ from those of the lower mafic unit in that they are highly amygdaloidal and contain abundant primary breccias (i.e. pillow breccias and hyaloclastites).

Two horizons of turbidites, consisting of interbedded wacke and argillite, occur within the felsic unit in the southeastern corner of the map area.

Intrusion of medium- to fine-grained mafic sills are most abundant in the upper part of the mafic unit and rarely within the felsic unit. Many of the sills in the upper portion of the mafic unit are highly differentiated, ranging from ultramafic at the base to leucogabbro at the top. Locally, rhythmic cumulate layering, 5 to 30 cm thick, can be observed in these sills. Other sills are of gabbroic composition and are undifferentiated.

Feldspar and quartz-feldspar porphyry dikes and sills intrude the felsic unit and to lesser extent, the upper portion of the mafic unit.

Several ages of granitoid intrusions are evident in the map area. The older intrusions are more mafic in composition. North of Pine Portage Bay, 2 lobes of medium- to fine-grained foliated tonalite to quartz diorite coalesce to the north into the Island Lake Diorite-Quartz Diorite (King 1983). Another body of similar age is the Sultana intrusion, a composite stock of medium-grained, equigranular quartz diorite with a northern core of pink alkali feldspar porphyritic granodiorite.

The later intrusions are more felsic and alkalic. The largest body is the Dryberry Batholith, which consists of medium-grained, equigranular, massive granite to granodiorite. Another small granite intrusion occurs to the west of the 2 lobes of the Island Lake intrusion. This stock consists of pink, medium-grained, alkali feldspar porphyritic granite (the Jones Road Quartz Monzonite, King 1983). Another late intrusion is a small, pink, medium-grained syenite body on the eastern peninsula.

The metamorphic grade rises from lower greenschist facies in the central portion of the supracrustal belt to upper greenschist or lower amphibolite facies adjacent to the granitoid plutons.

STRUCTURAL GEOLOGY

An early syncline is indicated by a reversal of tops in pillowed mafic and graded pyroclastic rocks in the Bald Indian Bay area. This northeasterly trending structure has resulted in the fold-closure termination of the felsic unit just north of Sultana Island.

Another early, but somewhat more complicated structure occurs in the Andrew Bay area. The structure here appears to be an east-southeasterly trending synclinorium with numerous associated parasitic anticlines and synclines. An anticline of similar age on the southern part of the Eastern Peninsula has resulted in the repetition of the felsic unit in the southwestern corner of the map.

A later antiformal structure trends southwesterly from the Dryberry Batholith to the southwestern part of Hay Island. This structure is largely responsible for the change in strike of rock units between the northern and southern parts of the map area. This structure is interpreted to be related to the diapiric rise of the Dryberry Batholith with the resultant draping of supracrustal rocks over and around the intrusion. Minor folds associated with this later structure are gently plunging, while those of the earlier structures tend to have steep plunges.

Throughout the map area, numerous shear zones have been identified. These are typically zones of strongly foliated to schistose rock often with associated carbonatization. In particular, the area north and east of Andrew Bay has numerous extensive east-southeasterly trending shear zones. This whole zone is proposed by the author to be an easterly extension of the Crow Duck Lake-Rush Bay Lineament from the western part of the Lake of the Woods (Blackburn 1981). This structure also appears to be responsible for the abrupt termination of the differentiated mafic sill at the southwestern tip of Hay Island.

ECONOMIC GEOLOGY

GOLD

The Mineral Deposits Section of the Ontario Geological Survey is currently involved in the second year of a 2-year project to study in detail the gold deposits of the Lake of the Woods area (Davies 1983, this volume).

Numerous gold occurrences are within the map area. In particular, there is a large concentration of occurrences adjacent to the contact of the Dryberry Batholith and Island Lake Quartz Diorite with the metavolcanic rocks. In general these occurrences can be characterized by thin discontinuous quartz and/or quartz-carbonate veins and veinlets in shear zones. The shears are zones of highly foliated or schistose, chloritized and/or carbonatized rock from several centimetres to many metres in thickness. The quartz veins occur with or without tourmaline and sulphides and many have reported visible gold (AFK). The sulphides reported are any or all of the following; pyrite, pyrrhotite, arsenopyrite, chalcopyrite, sphalerite, and galena. Gold mineralization tends to be irregularly distributed, is often closely associated with sulphides, but also occurs freely in the quartz and as gold tellurides.

The largest past producer was the Wendigo Mine (Property A). The geology consists of a large differentiated ultramafic to leucogabbro sill which has been repeated on the property by an isoclinal pair of anticlinal and synclinal folds. This unit is in contact with pillowed to massive aphyric and plagioclase porphyritic basalts. The gold mineralization occurs in 4 east-striking quartz veins in strongly foliated to schistose basalt. The main quartz vein consists of about 50% sulphides (pyrite, pyrrhotite, and chalcopyrite) and averages about 30 cm in thickness.

The Sultana Island deposits occur in the northern portion of a small composite stock which ranges in composition from quartz diorite in the south to an alkali feldspar porphyritic granodiorite core in the north. All the deposits occur on the western part of Sultana Island and are either close to, or at the contact between, quartz diorite and granodiorite. Two types of quartz veins are present. The first, typified by the former Sultana Mine vein, is a vein system averaging 6 to 9 m wide, reaching 18 m at its widest point. The system consists of interbanded laminae of quartz and chlorite schist, both containing disseminated sulphides and tourmaline. Reported sulphides include pyrite, pyrrhotite, chalcopyrite, galena, sphalerite, and molybdenite. The second type of quartz vein occurs in the Crown Reef vein. This is a fissure type quartz vein which strikes at a high angle to the first type of vein and consists primarily of quartz with minor disseminated pyrite and visible gold. The vein is very sinuous and varies in strike from 045° to 060° with a steep dip to northwest.

BASE METALS

The main exploration activity for base metals was in the late 1960s in the area on, and around, the western end of the Eastern Peninsula. Mineralization occurs as sulphide-rich zones in shears and fractures in thin felsic metavolcanic units within the mafic metavolcanic rocks just south of a large southeasterly trending mafic sill (Davies 1967). Sulphide-rich zones (20 to 50%) are up to 15 m thick and 600 m long. The best reported results from diamond drilling are 0.39% copper and 0.06% zinc over 8.5 feet (AFK).

INDUSTRIAL MINERALS

Talcose soapstone was observed at numerous localities north and east of Andrew Bay. At some of these locations talc-rich veins 5 to 10 cm thick occur within the soapstone. At another location, veins of fibrous asbestos up to 5 cm thick were observed cutting the soapstone. These soapstone occurrences tend to be located within ultramafic parts of differentiated sills which have been intersected by shear zones.

RECOMMENDATIONS TO THE PROSPECTOR

Potential exists for economic gold mineralization within the Bigstone Bay area. Much of the present exploration is concentrated around known occurrences adjacent to the contact of the Dryberry Batholith with the metavolcanic rocks. In light of this favourable contact, the mapping has disclosed changes in the contact which merit prospecting. In the northeastern part of the map area the contact has been extended 6 km east and continues an unknown distance northeast of the map area (Blackburn 1981).

Another area with potential for gold mineralization is the southwestern part of Hay Island. In this area several east-northeasterly trending fault zones have been observed with associated pervasive iron carbonatization of brecciated rock. Associated with these faults are zones of pervasive green mica (fuchsite?) alteration. These fault zones are interpreted to be splay faults produced by brittle deformation from the east-southeasterly trending Crow Duck Lake-Rush Bay Lineament, a ductile fault zone. Preliminary assay results have indicated only minor anomalous values in the carbonatized rock (up to 210 parts per billion gold) from this area. However, if zones of silicification and/or quartz veining could be uncovered, these would be areas of potential gold enrichment.

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4. Kakagi Lake-Rowan Lake Regional Geology

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INTRODUCTION

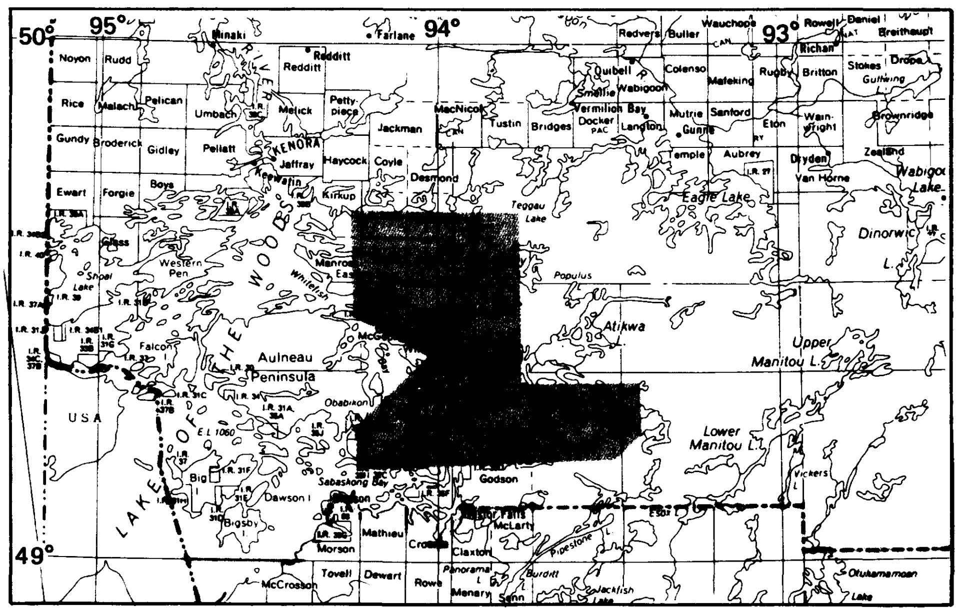
Field work during the summer of 1984 represents the first phase of a project designed to integrate existing geological data on the Gibi Lake-Kakagi Lake-Rowan Lake area, and to provide a regional synthesis of the geology. The study area, outlined on the location map, has been mapped previously: the Gibi Lake area in 1979 and 1980 (Trowell, in preparation); the Long Bay-Lobstick Bay area (Johns and Richey 1982; Johns and Davison 1983; and Johns, Good, and Davison 1984); the Cedartree Lake area (Davies and Morin 1976); the Rowan Lake area (Kaye 1973); the Kakagi Lake area (Kaye 1981) and the Schistose Lake area (Edwards 1980).

Highway 71, linking Highways 17 and 11, transects the area; the village of Sioux Narrows, 48 km southeast of Kenora, is located in the west central part. Gibi Lake is reached by private road from near Tower Lake on Highway 71. Dryberry Lake can be reached from the Highwind Lake road or a road extending east from Graphic Lake. The Berry River formation is accessible by both road and water (Long Bay and Lobstick Bay on Lake of the Woods). The northeastern portion of the Kakagi Lake group of pyroclastic rocks is exposed on Cedartree and Stephen Lakes, either of which are a single, short portage from the Dogpaw-Caviar-Flint Lakes system. The western and southern part of this group is accessible from Kakagi Lake.

During the 1984 field season, the western part of the area was examined. The metavolcanic sequence centered on Gibi Lake was examined; a volcanic facies model was developed for the Berry River formation; a shoreline reconnaissance of the Dryberry Batholith on Dryberry Lake was carried out; and the pyroclastic rocks of the Kakagi Lake group were briefly examined.

MINERAL EXPLORATION

Gold remains the metal of main interest in the Gibi-Kakagi Lakes area. Past exploration activity has been described by Johns (in preparation), Davies and Morin (1976), Edwards (1980), and in past annual volumes of "Report of Activities, Regional and Resident Geologists" published by the Ontario Geological Survey. Presently, exploration is very active along the Pipestone-Cameron Fault and



LOCATION MAP

Scale : 1 : 1 548 000 or 1 inch to 25 miles

the Wabigoon Fault (Figure 1). Silicified-carbonatized shear zones in the metavolcanic rocks along these faults are the most promising gold exploration targets.

The majority of the southern part of the area is staked. Nuinsco Resources Limited was active both on their Cameron Lake Deposit (Figure 1) and the Monte Cristo Occurrence on Rowan Lake. Falconbridge Limited is actively exploring north of Emm Bay on Kakagi Lake. Noranda Incorporated (formerly Noranda Mines Limited) is exploring the Fairservice claims northeast of Lobstick Bay. BP Resources Incorporated (formerly Selco Incorporated) has optioned the Thrasher Gold-Fluorite Occurrence on the north shore of Lobstick Bay from R. Fairservice and has commenced exploration. Dubenski Gold Mines Limited has completed stripping and commenced diamond drilling on the south shore of Flint Lake. The area north and northwest of Dogpaw Lake and north of Long Bay is open for staking.

GENERAL GEOLOGY

The study area is situated at the western end of the Wabigoon Subprovince between Lake of the Woods and the Savant Lake-Crow Lake area (*see* Location Map).

Trowell, Logothetis, and Caldwell (1980) subdivided the metavolcanic rocks in the Gibi Lake area into 2 groups: mafic flows of the Dogtooth Lake group, and the intermediate to felsic and mafic pyroclastic rocks of the Gibi Lake group. Although the contact is a major fault zone the author suggests that the Gibi Lake group is younger than the Dogtooth Lake group based on the hypothesis of Trowell, Blackburn, and Edwards (1980). The Gibi Lake group metavolcanic rocks underlie and are in fault contact with the wackes of the Warclub group metasedimentary rocks in the eastern part of the Gibi Lake area. In the western part fine-grained, well-bedded feldspathic arenites overlie the intermediate to felsic pyroclastic rocks of the Gibi Lake group. Near Gibi Lake some arenites were observed to grade vertically from fine-grained pyroclastic tuffs into epiclastic material, and thus they are believed to be part of the Gibi Lake group.

The intermediate and mafic pyroclastic rocks of the Gibi Lake group consist of interbedded feldspathic tuff, intermediate lapilli tuff, tuff breccia, pyroclastic breccia, coarse-grained hornblende crystal tuff/lapillistone, and mafic tuff breccia to pyroclastic breccia. Crossbedded base surge deposits were identified in both the hornblende crystal tuffs and intermediate feldspathic tuffs. The coarse pyroclastic deposits are predominantly homolithic, angular, and matrix supported. Presence of the base surge deposits indicates that the Gibi Lake pyroclastic rocks resulted from phreatomagmatic explosions and were deposited in a shallow water, proximal, volcanic environment (Macdonald 1972). Intimate interbedding of the intermediate and mafic pyroclastic rocks indicates either a zoned magma chamber tapped by different feeder systems or 2 separate adjacent magma chambers.

The Berry River formation, part of the Warclub group, (Johns *et al.* 1984) was examined to verify the facies model previously proposed by Easton and Johns, in press). Some revisions in the model have been made. The most complex facies is the proximal to distal depositional facies found throughout almost the complete length of the Berry River formation. This depositional facies unit varies from debris flows in the east, to doubly graded subaqueous pyroclastic flows and fall units in the central part of the area, to debris flows in the west. The debris flows are massive, indistinctly bedded, coarse to fine material in the east; and poorly bedded, coarse to fine material in the west. The subaqueous pyroclastic flows are doubly graded with coarse bases overlain by thickly laminated tuffs. The airfall units consist of thin-bedded tuffs and pumiceous lapilli tuff horizons. Thin horizons of wacke and reworked pyroclastic material are also within this facies. Interbedded with the proximal to distal depositional facies are massive quartz-feldspar and feldspar porphyries. These units have varied grain size, varied phenocryst/clast ratios, and horizons bearing lithic clasts. They are believed by the author to represent ash-flow tuffs. The eastern part of the Berry River formation is comprised of vent facies deposits of quartz-feldspar porphyry with blocks and rafts of pyroclastic material. Outward from the vent facies there occurs a proximal depositional facies consisting of coarse homolithic pyroclastic rocks with thin tuff interbeds of ground surge or cloud surge origin. Surge deposits suggest deposition by ash-flow mechanism (Sparks *et al.* 1973). This proximal facies is exposed along the north shore of Lobstick Bay and within Long Bay on Lake of the Woods. Minor amounts of redeposited distal

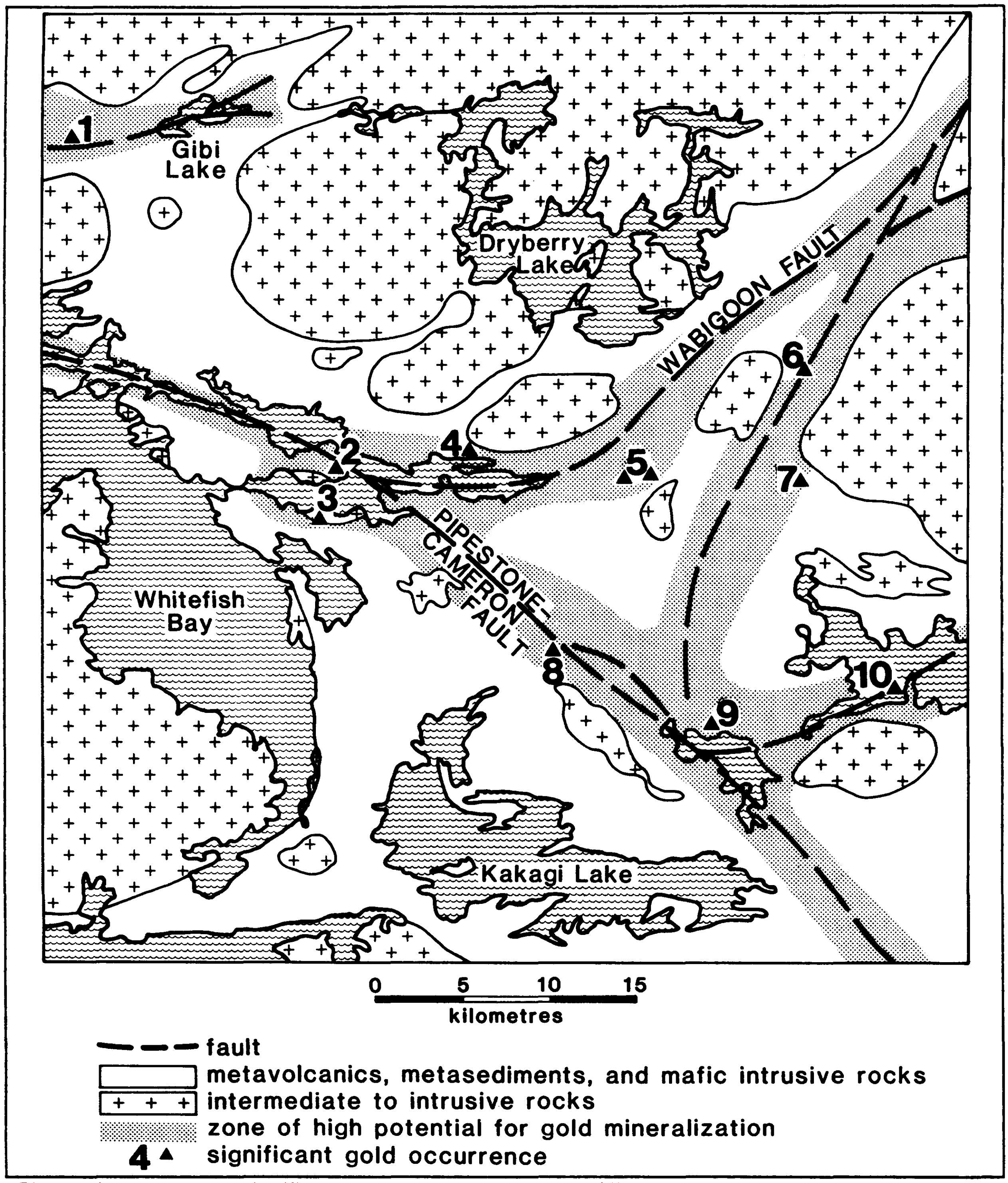


Figure 1. Location of significant gold occurrences in the Gibi Lake-Kakagi Lake area as listed in Table 1. (Project 4.)

pyroclastic material occur along the margins of the Berry River formation.

The Kakagi Lake group of pyroclastic rocks (Edwards 1979) lie to the west of the Pipestone-Cameron Fault and overlie the Snake Bay formation on the west, and the Katimiagamak Lake formation on the south. While hot, the pyroclastic rocks were intruded by cosanguinous ultramafic to mafic sills (Ridler 1966). These intrusive rocks have been dated by U/Pb methods at 2724.8 Ma (Davis and Edwards 1982).

Edwards (1979) has subdivided the Kakagi Lake group into 4 formations. The Emm Bay formation overlies the Snake Bay formation and underlies the Cedartree Lake formation. Within Emm Bay and Peninsula Bay of Kakagi Lake, and in the western part of Cedartree Lake, the Emm Bay formation consists of interbedded, heterolithic, matrix-supported lapilli tuff to pyroclastic breccia debris flows, and homolithic, matrix-supported, primary deposition, lapilli tuff to pyroclastic breccia pyroclastic flows. Interbedded with these clastic deposits are minor intermediate flows and autoclastic breccia. To the north, on Cedartree Lake, debris flows with more rounded clasts and better sorted matrix material are found. A fine to coarse breccia with a hornblende, feldspar-phyric, crystalline matrix is found along the eastern shore of Emm Bay and western shore of Peninsula Bay. At the eastern shore of Peninsula Bay some of the tuff described by Davies and Morin (1976) was identified as a fine-grained feldspar porphyry intrusive by the present survey.

The Cedartree Lake formation overlies the Emm Bay formation and is truncated by the Pipestone-Cameron Fault. The lower or western part of this formation is fine feldspar tuff with interbedded coarse pyroclastic rocks. A unit of thick to thin-bedded arenites, wackes, and cherts with interbedded fine pyroclastic rocks strikes north through the eastern part of Cedartree Lake. The sediments are reworked volcanic detritus containing graded beds, flame structures, and soft sediment deformation structures. A lapilli tuff ashflow has been recognized within this sedimentary horizon. In the Stephen Lake area, the Cedartree Lake formation consists of very fine-grained tuff, cherty tuff, reworked tuff, arenaceous siltstone, and chert containing an abundant variety of sedimentary structures and textures. At the north end of Stephen Lake, near the portage into Flint Lake, 2 thin (<60 cm) semi-welded pumiceous tuff units occur. The darker pumice fragments are not completely flattened and exhibit swallow tail terminations. One of these units exhibits an 8 cm thick, trough crossbedded ground surge base, and a subtly laminated pumice ash top overlain by a bed of reverse-graded feldspar ash to coarser pumice tuff. The Cedartree Lake formation is considered to represent a shallow water, distal, volcanic environment (*cf.* Williams and McBirney 1979). Within this sequence a poorly sorted, angular, matrix-supported, heterolithic, coarse, pyroclastic unit, previously identified as an ignimbrite (Davies and Morin 1976), contains no essential clasts and may be the result of a phreatic explosion (*cf.* MacDonald 1972). The upper portion of this breccia is very rusty and is also an electromagnetic conductor. Davis and Edwards (1982) have determined a 2711.1 Ma age for this formation using U/Pb methods on a tuff from Pictograph Point, Stephen Lake.

The South Kakagi Lake formation overlies the Katimiagamak formation east of Blacky Bay on Kakagi Lake. The South Kakagi Lake formation is composed of tuffs, reworked tuffs, cherty tuffs, wackes, and arenites intruded by hornblende porphyry and feldspar porphyry sills. These medium- to thick-bedded rocks contain many primary sedimentary structures and many of the graded tuffs have cherty tops. Based on lithologic similarity, Edwards (1979) postulated a correlation between this formation and the Cedartree Lake formation.

The East Kakagi Lake formation is north of the South Kakagi Lake formation and the stratigraphic relationship between them is in doubt. Edwards (1979) proposed that the East Kakagi Lake formation overlies the South Kakagi Lake formation with a gradational contact. This survey shows numerous opposing top determinations in this area, casting doubt on Edwards' hypothesis. The East Kakagi Lake formation is a pyroclastic unit with homolithic to heterolithic tuff to pyroclastic breccia debris flows and pyroclastic flows. No obvious bedding is seen within the thick massive beds. Many previously unnoted feldspar porphyry and hornblende porphyry dikes and sills are intrusive into the pyroclastic rocks, some with amygdaloidal margins indicating near-surface intrusion. This formation may be related to the Emm Bay formation.

Although the margin of the Dryberry Batholith is complex (Johns and Richey 1982; Johns, Good, and Davison 1984) the core is relatively simple. A shoreline reconnaissance of Dryberry Lake indicates that the core is a massive magnetite-bearing biotite granodiorite grading north into quartz monzonite and granite. Intrusive relationships indicate that more than one phase of this massive material can be delineated. Pink granitic pegmatite veins and pods are associated with the massive finer grained phases.

STRUCTURAL GEOLOGY

The general structural geology of the area is outlined on previously published maps (Johns and Richey 1982; Johns and Davison 1983; Johns, Good, and Davison 1984; Edwards 1980; Davies and Morin 1976; Kaye 1973,1981). The important structures to note are the large regional fault zones (Figure 1).

In the Gibi Lake area, a fault zone trends east-northeasterly through Gibi Lake and splays into several faults west of Highway 71. It can be traced westerly through Witch Bay into Lake of the Woods (Bill Bond, geologist, Kidd Creek Mines Limited, Toronto, personal communication, 1984).

The Pipestone-Cameron Fault is a major structural and topographic feature trending southeast. A large shear zone splays from this fault northeasterly through the southern part of Rowan Lake (Howard Poulsen, geologist, Geological Survey of Canada, Ottawa, personal communication, 1984). The Pipestone-Cameron Fault merges with the Manitou Straits Fault east of the area.

The Wabigoon Fault merges with the Pipestone-Cameron Fault in the Long Bay-Regina Bay-Lobstick Bay (Lake of the Woods) area. Strong shearing, carbonatization, and silicification is associated with this zone between the Kishquabik Lake and Hope Lake stocks.

ECONOMIC GEOLOGY

Significant gold occurrences (Table 1) are related to the regional fault zones found within the present synoptic area (Hunter and Curtis 1983). At Nuinsco Resources Limited's Cameron Lake Deposit (No. 9, Figure 1), gold is concentrated in silicified pyritiferous pods within carbonatized shear zones, and the surrounding carbonatized rocks contain lesser gold values (David Melling, graduate student, Carleton University, Ottawa, personal communication, 1984). The shear zone associated with this deposit is a splay from the Pipestone-Cameron Fault and lies north of the main fault zone. The Caswell Williams Prospect, currently being explored by Dubenski Gold Mines Limited, is on the south shore of Flint Lake within the Pipestone-Cameron Fault zone (No. 8, Figure 1). Gold is associated with lenses of pyrite mineralization and silicification in a sericite schist (Davies and Morin 1976).

A gold-fluorite prospect on the north shore of Lobstick Bay (Johns, Good, and Davison 1984) occurs on a sericitic shear zone trending 110° (No.4, Figure 1). This fluorite-bearing shear zone can be traced for 2.5 km (R. Fairservice, prospector, Kenora, personal communication, 1984). A highly altered quartz porphyry northwest of Hope Lake is cut by quartz veins and is associated with many new gold occurrences (No.5, Figure 1). As well, gold is associated with quartz-carbonate shear zones around Mushkasu Lake (R. Fairservice, prospector, Kenora, personal communication, 1984). Both the porphyry and the quartz-carbonate shear zones are in the mafic Populus volcanics (Trowell, Blackburn, and Edwards 1980) that have been affected by the Wabigoon Fault.

Areas of high mineral potential within the present synoptic area are: (1) The Wabigoon Fault Zone and the area where it merges with the Pipestone-Cameron Fault; (2) the Pipestone-Cameron Fault through its entire length and breadth; and (3) the fault zone within the Gibi Lake-Witch Bay area (*see* Figure 1).

The top of the phreatic breccia noted at Stephen Lake contains a gossan and an electromagnetic conductor (Davies and Morin 1976). The presence of the gossan and conductor indicates post-eruptive hydrothermal activity and accordingly this zone has a high potential for both base metals and gold.

Pyroclastic rocks of the Kakagi Lake group north of Chase Point and east of Blacky Bay contain many previously unnoted intrusions of feldspar porphyry and fine-grained diorite. These indicate a center of high magmatic activity and thus have higher potential for base metal and gold mineralization.

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TABLE 1: SIGNIFICANT GOLD OCCURRENCES IN THE GIBI LAKE-KAKAGI LAKE AREA. LOCATIONS ARE OUTLINED ON FIGURE 1. (PROJECT 4.)

	NAME	HOST ROCK	MINERALIZATION	GRADE	PRODUCTION	ASSOCIATED MINERALIZATION
1.	Wendigo Mine*	Sheared basalt Ultramafic/mafic sills	Au in quartz veins	0.33 oz Au/ton	67 423 oz Au and 14 762 oz Ag from 206 054 tons	Half vein material is sulphide mineralization
2.	Gaudry Occurrence*	Sheared mafic metavolcanic rocks	Au in silicified zones	0.15 oz Au/3 ft 0.47 oz Au/3 ft	N/A	Py
3.	Regina Mine*	Basic metavolcanic rocks intruded by tonalite Lentinular veins near and normal to contact	Au in quartz veins	0.15 to 0.38 oz Au/ton	over 8000 oz Au and 1460 oz Ag from 36 828 tons	N/A
4.	Thrasher Occurrence*	Intermediate to felsic tuff	Au, fluorite in quartz veins in sericite schist	0.02 to 2.68 oz Au/ton	N/A	N/A
5.	Fairservice Occurrence	Mafic metavolcanic rocks	Au in silicified-carbonatized shear zones	0.35 to 0.5 oz Au/ton	N/A	N/A
6.	Violet Mine* (Empire Mine)	Sheared metavolcanic rocks	Au in quartz veins	0.5 oz Au/ton	150 oz Au from 300 tons	Py, Po, Cpy

TABLE 1. CONTINUED (PROJECT 4.)

	NAME	HOST ROCK	MINERALIZATION	GRADE	PRODUCTION	ASSOCIATED MINERALIZATION
7.	Maybrun Mine*	Fine-grained basalt	Au in fine-grained basalt	open pit: 0.05 oz Au/ton Bay Zone: 0.201 oz Au/ton Pot Hole Zone: 0.139 oz Au/ton	Cu-Au concentrate produced at rate of 300 t.p.d.	Cpy, Py, Po
8.	Dubenski Occurrence	Intermediate to felsic tuff	Au, Ag-Py in shear zone	0.15 to 1.4 Au oz/ton	N/A	Py
9.	Nuinsco Cameron Lake Deposit	Schistose mafic metavolcanic rocks	Au in quartz in silicified-carbonatized zones	0.02 to 0.15 oz Au/ton	N/A	N/A
10.	Monte Cristo* Prospect	Schistose mafic metavolcanic rocks with porphyry dikes and sheared acid metavolcanic rocks	Au associated with carbonates and trace sulphides	0.17 oz Au/ton	15 ft or 0.20 oz Au 200 ft wide zone of up to 0.17 oz Au/ton	Trace sulphide mineralization

* Data from:
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5. Geology of the Mulcahy Lake Gabbro Intrusion

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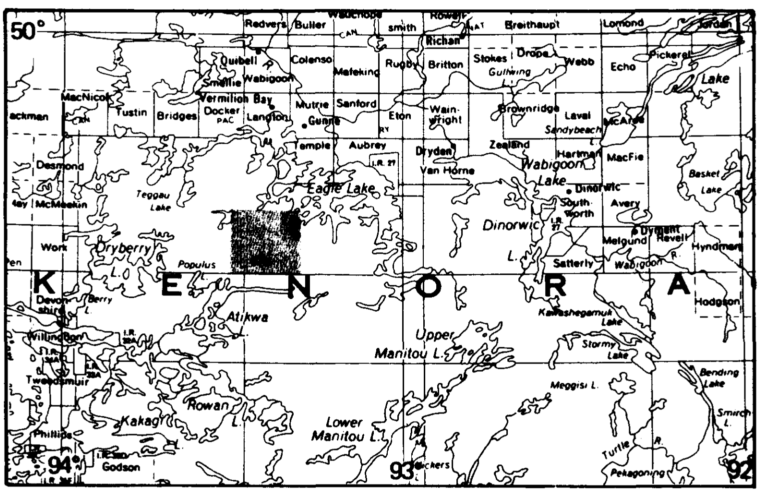
INTRODUCTION

This project is the first year of an investigation of ultramafic and mafic intrusions in the Wabigoon Subprovince. This year's field work summary reports on the geology of the Mulcahy Lake gabbro, a layered intrusion located in the western part of the Wabigoon Subprovince, 45 km southwest of Dryden. This intrusion, which has an iron-rich tholeiitic bulk composition (Morrison *et al.* 1984), displays excellent cryptic and rhythmic layering, and has a well preserved primary igneous mineralogy. These features make the body one of the best examples of an Archean layered intrusion in the Superior Province.

The Mulcahy gabbro is accessible by road from Dryden via Highway 502 and the Great Lakes Pulp and Paper Company camp 69 road which traverses the southern and western parts of the intrusion. The lakes within the area are accessible by portage routes or by float-equipped aircraft.



LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

MINERAL EXPLORATION

The Mulcahy Lake gabbro has been explored primarily for copper and nickel mineralization and, although small amounts of copper mineralization are present, no significant occurrences have been reported to date. The information on exploration activity reported here is taken from the Resident Geologist Files, Ontario Ministry of Natural Resources, Kenora. In 1954, geological mapping by the Canadian Pacific Railway, Development Section, delineated the extent of the intrusion and located 2 small copper occurrences southwest of Mulcahy Lake. The most extensive exploration of the intrusion to date was by Falconbridge Nickel Mines Limited in 1955 and 1956 during which time geological mapping, airborne electromagnetic and magnetic surveys, and diamond drilling (27 holes, 3253 m) was carried out on several claim blocks covering most of the western part of the intrusion. Minor copper mineralization was encountered. In 1956, Kenwood Uranium Mines Limited drilled 6 diamond-drill holes (482 m) in gabbro and peridotite west of Muskeg Bay of Eagle Lake and encountered minor unspecified sulphide mineralization. In 1969 and 1970, M.J. Boylen carried out geological and geophysical surveys and diamond drilling (3 holes, 347 m) on a claim block between Beaverhouse, Mulcahy, and Straight Lakes and reported minor chalcopyrite mineralization. Recent exploration has been minimal. Some reconnaissance exploration was done in 1979 following the report by Blackburn (1978) but no staking was recorded at that time. Staking during 1984 was observed by the field party in the vicinity of Easter Chicken Lake.

GENERAL GEOLOGY

The initial mapping of the intrusion was by Moorhouse (1941) and Davies and Watowich (1958). Blackburn (1978) determined that the intrusion was emplaced as a sheet which has subsequently been tilted vertically. The body faces northwest, is 7 km thick and has a cross-sectional area of approximately 60 km^2 (Figure 1. Based on Blackburn's interpretation Morrison

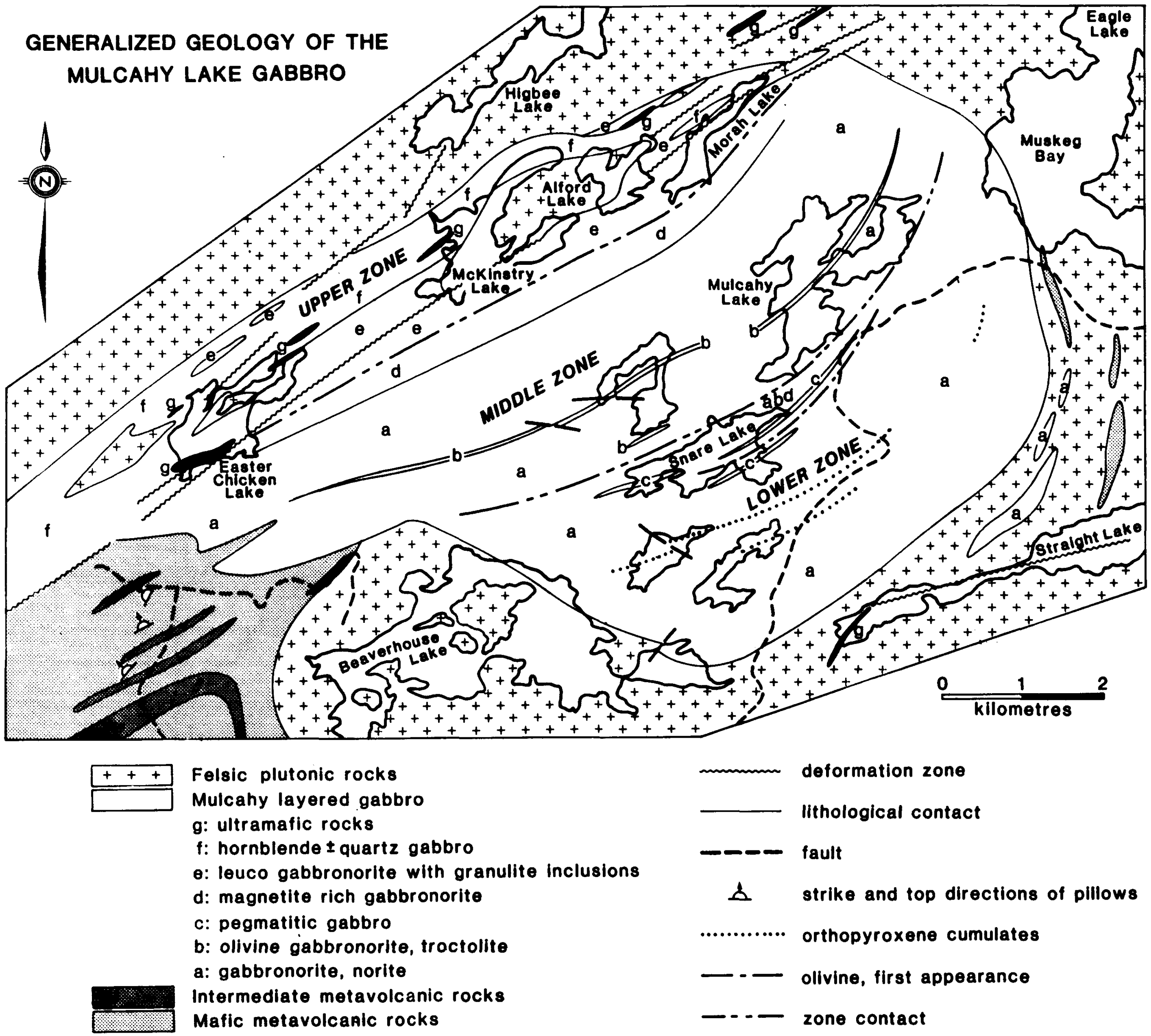


Figure 1. Generalized geology of the Mulcahy Lake layered gabbro, showing the upper, middle, and lower zones and surrounding plutonic and metavolcanic rocks. (Project 5.)

et al. (1982, 1984) studied a cross-section of the intrusion, characterized the mineralogical and chemical variation along the section, and divided the intrusion into 3 zones.

On the northern and eastern contacts of the intrusion, granitoid rocks consisting of predominately biotite-hornblende quartz diorite intrude the Mulcahy gabbro. On the southern margin of the intrusion, in the vicinity of Straight Lake, contact relationships are less certain and the Mulcahy gabbro is in contact with a variety of dioritic rock types ranging from hornblende-clinopyroxene diorite to biotite-hornblende quartz diorite and locally granodiorite. The dioritic rocks locally contain abundant inclusions of amphibolite, mafic diorite, and gabbroic rocks similar to the Mulcahy gabbro. Fine-grained mafic hornfels and intercalated intermediate fragmental rocks are also observed in this zone adjacent to the Mulcahy gabbro. These rocks are interpreted as a relict mafic metavolcanic sequence which has been partially melted to produce dioritic rocks during the emplacement of the Mulcahy gabbro. Peridotite on Straight Lake, previously considered to be stoped from the base of the Mulcahy gabbro (Davies and Watowich 1958) was found to be part of an ultramafic dike intruding the dioritic rocks.

On the western margin of the intrusion, the gabbro intrudes a metavolcanic sequence. The metavolcanic rocks consist of northwest facing massive to pillowed mafic flows, intercalated with intermediate (andesitic) plagioclase-phyric fragmental rocks, and minor tuff and metasedimentary rocks. The substantial intermediate component in the metavolcanic sequence and the presence of abundant enclaves of intermediate rock of possible volcanic origin in the upper part of the Mulcahy gabbro, suggest that the gabbro was intruded into calc-alkaline metavolcanic rocks and therefore is emplaced into a high level of the Wabigoon metavolcanic sequence.

Zircon dating by Morrison *et al.* (1983) gives an age of 2733.2 +1.0/-0.9 Ma for the Mulcahy gabbro. Tonalite from the Atikwa batholith east of the Mulcahy gabbro formed at 2732 ± 2.9 Ma, at most a few million years after crystallization of the gabbro (Davis *et al.* 1982).

Morrison *et al.* (1984) divided the Mulcahy gabbro into lower, middle, and upper zones based on mineral and rock chemistry. They determined that the lower and middle zones are distinct magma pulses which crystallized from the bottom of the zone upwards. The top of the lower and middle zones represent peaks in an iron enrichment trend. The upper zone is considered by Morrison *et al.* (1984) to be a roof cooling regime which fractionated toward the floor. Mapping during the present survey supports the interpretation of the lower and middle zones. The author considers that the upper zone, however, is a roof zone consisting of hornfels of mafic to intermediate composition which has been intruded by sills ranging from peridotite to granite. These rocks are not clearly related to the fractionation sequence in the lower and middle zones.

The 2.5 km thick lower zone consists of a sequence of massive norite grading up into layered norite with orthopyroxenite (orthopyroxene cumulate) and anorthosite (plagioclase cumulate) layers. Higher in the lower zone, clinopyroxene, inverted pigeonite, apatite, magnetite, and finally iron-rich olivine appear as cumulate phases. At the top of the lower zone, the rocks are characteristically well-layered, olivine-bearing, magnetite-rich gabbronorites. In the vicinity of Snare Lake, the lower zone gabbros are extensively uralitized and there are numerous layers of pegmatite gabbro up to several metres thick. These rocks may have developed due to metasomatic replacement of the gabbronorite by intercumulus fluids which concentrated toward the top of the lower zone.

The 2.5 km thick middle zone is characterized by gabbronorite with well defined intermittent modal layering. A 50 to 100 m thick unit of troctolite (olivine-plagioclase cumulate) to olivine gabbronorite (olivine-orthopyroxene-plagioclase cumulate) which is a prominent marker horizon within the intrusion, is located 600 m above the base of the middle zone. Toward the top of the middle zone, magnetite and apatite become more abundant and iron-rich olivine locally reappears. Mappable zones of gabbronorite with coarse poikilitic hornblende, and gabbronorite with gabbro pegmatite dikes are present in the upper part of the middle zone. At the top of the zone the dominant rock is magnetite-rich gabbronorite with pegmatitic clots of clinopyroxene, amphibole, magnetite, and locally quartz.

The upper zone is considered here to begin with the appearance of numerous fine grained, locally plagioclase phyric, mafic to intermediate inclusions in a host of leucocratic gabbronorite to diorite. Morrison *et al.* (1984) interpreted the inclusions to be cognate xenoliths intruded by fractionated gabbro. The author however suggests that these rocks represent a roof zone of a mafic to intermediate volcanic or subvolcanic protolith which has been metamorphosed to a pyroxene hornfels and partially melted. Sills of peridotite, hornblende-quartz gabbro, gabbronorite, quartz diorite, quartz-feldspar porphyry, and granite intrude the hornfels roof zone.

Although the Mulcahy gabbro does not have a chill zone, a distinct marginal facies is associated with the lower and middle zones. The marginal facies is 150 to 300 m wide and is best characterized in thin section by higher concentrations of apatite and magnetite (Morrison *et al.* 1984). Other characteristics of the marginal facies include: clinopyroxene-magnetite clots, similar to the top of the middle zone, which may represent residue from assimilated mafic enclaves; locally well developed fluxion texture; and layering parallel to the contact of the intrusion. Recognition of a distinct marginal zone suggests that the lower part of the Mulcahy gabbro has not been stoped away by the adjacent granitoids.

The Mulcahy Lake gabbro exhibits several types of layering, including planar lamination of feldspar and pyroxenes, rhythmic modal layering of minerals, and cryptic layering defined by systematic compositional variation. Intermittent rhythmic modal layering, defined by a concentration of one or more cumulate phases within a relatively uniform gabbroic host, is a prominent feature of the lower and middle zones. Orthopyroxenite (orthopyroxene cumulate), anorthosite (plagioclase cumulate), troctolite (olivine - plagioclase cumulate), and magnetite cumulate are present as modal layers. The modal layering is typically on a scale of centimetres in width and individual layers are observed to be continuous over a strike length of tens to hundreds of metres.

Trough bedding, crossbedding, and angular unconformities are evidence that flow mechanisms (Irvine 1980) have been locally important in the development of layering within the Mulcahy gabbro. These structures are best developed in orthopyroxene and orthopyroxene-magnetite cumulates which are probably deposited from dense crystal-rich magma flows originating in the walls of the magma chamber.

Mineralogically graded layers, defined by grading of pyroxene and/or olivine versus plagioclase, are common in the middle zone and to a lesser extent the lower zone. This rhythmic type of layering closely resembles intermittent modal layering in the Skaergaard intrusion (McBirney and Noyes 1979, plate 5A) and most consistently is northwesterly facing. The average composition of the modally graded layers are similar to the uniform gabbroic host and therefore the layers are not likely to have resulted from density instabilities. This type of layering probably forms in situ on the floor of the magma chamber by mechanisms such as double diffusive convection (McBirney and Noyes 1979).

STRUCTURE AND ALTERATION

A northwest facing direction for the Mulcahy gabbro is indicated by the predominance of northwest facing modally graded layers (i.e. plagioclase at the top of the layer) and by the systematic iron enrichment trend determined by Morrison *et al.* (1984). Metavolcanic rocks south of Easter Chicken Lake are also northwest facing, indicating a conformable relationship between the western part of the intrusion and the supracrustal rocks.

Although the Mulcahy gabbro displays primary igneous mineralogy over wide areas, alteration of pyroxenes to uralitic amphibole is common in some areas, particulary in the lower zone. Alteration of pyroxene and plagioclase is pervasive in the western part of the intrusion in the vicinity of the metavolcanic rocks.

Several zones of faulting have been identified in the Mulcahy gabbro. Some of these are recognized by offsets of layers and are associated with narrow zones of deformation into which granitic pegmatites are commonly emplaced.

A large previously unrecognized zone of deformation extending across the Mulcahy gabbro near the base of the upper zone is associated with extensive shearing and local carbonatization and quartz veining. This zone can locally be shown to have sinistral displacement and may be responsible for considerable displacement of the upper zone toward the southwest. The deformation zone appears to control the emplacement of ultramafic, quartz-feldspar porphyry, and granitoid sills in the upper zone.

ECONOMIC GEOLOGY

PLATINUM GROUP ELEMENTS AND COPPER-NICKEL

The Mulcahy Lake gabbro warrants investigation for copper-nickel mineralization associated with magmatic sulphide or sulphide associated with late magmatic and metamorphic fluids. Platinum group elements (PGE) also have been shown to be concentrated in immiscible sulphide liquids (Naldrett 1981) and by late magmatic or metamorphic processes (Talkington and Watkinson 1984). The Mulcahy gabbro has potential for both types of mineralization. Traces of pyrrhotite and chalcopyrite are locally observed in stratiform units of the gabbro, particularly near the lower and middle zone contact and in the troctolite layer, and these units may have potential for primary magmatic concentration of copper, nickel, and PGE. Chalcopyrite and pyrite observed in pegmatitic gabbro suggest that these phases warrant investigation for late stage mineralization.

GOLD

The deformation zones within the intrusion are locally carbonatized and contain quartz veins and warrant investigation for gold. The major zone of deformation which extends across the Mulcahy gabbro near the middle zone-upper zone boundary is a regional structure of particular interest since it has not been indicated on previous maps and is along-strike from gold mineralization in the Eagle Lake area.

VANADIUM

The iron-rich nature of the intrusion indicates a potential for elements such as vanadium and titanium. The intrusion has most potential for vanadium associated with magnetite, since ilmenite is not present as a discrete primary phase. Concentrations of magnetite occur in the lower zone associated with orthopyroxene cumulates (up to 50% magnetite over 20 m); at the top of the lower zone (layers of magnetite ~1 to 3 cm wide); and in the margins of the middle zone (up to 50% magnetite over several meters). These areas should be investigated for vanadium content.

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6. Atikokan-Lakehead Compilation Project

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INTRODUCTION

The aim of this project is to produce a new edition of the Atikokan-Lakehead compilation map produced in 1964 (Pye and Fenwick 1964). The revised map, at a scale of 1:250 000 will have revised boundaries to conform to the NTS system. These boundaries are Latitude 50°00'N to the Canada-United States international boundary and Longitudes 88°00'W to 92°00'W.

This summary provides a geological sketch of part of the compilation area which lies within Quetico Park. The described area was mapped in October 1983.

MINERAL EXPLORATION

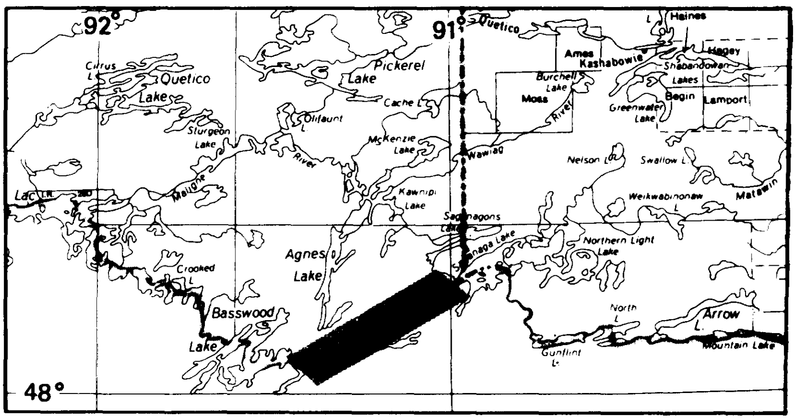
Scattered base metal and gold occurrences exist within the metavolcanic-metasedimentary belt occurring in the park. As exploration work on these was done before the park was created, i.e. before the 1950s, little data is available and since that time exploration within the park has been prohibited.

GENERAL GEOLOGY

The area mapped included the metavolcanic-metasedimentary "greenstone" belt of Archean age which forms part of the Abitibi-Wawa subprovince within Quetico Park west of Saganagons Lake (Figure 1). The metavolcanic-metasedimentary belt extends from Saganagons Lake southwestward to Knife Lake and Birch Lake on the Ontario-Minnesota border. The southward extension of the belt into the United States is known as "the Vermilion greenstone belt" (Morey 1980; Sims and Morey 1972). In the Vermilion District, Morey (1980) described the belt as consisting of the Ely greenstones, mainly basaltic flows and ironstone overlain by metasedimentary rocks of the Knife Lake Group (Ojakangas 1972). Both units are in turn overlain by the Newton Lake Formation with a mafic volcanic member and a felsic-intermediate volcanic member, with the latter dominant at the eastern end of the unit.

This report describes a short reconnaissance of the Canadian part of the belt, herein called the Saganagons-Knife Lake belt.

This portion of the belt consists (Figure 1), in the Cache Bay area, of massive and pillowed mafic flows extending from Saganagons Lake (Harris 1968), southward to a southwest-trending fault which parallels the lake system. The unit is then interpreted to extend southwest for the full length of the belt to Birch Lake. North of this unit, felsic tuff and lapilli tuff extend from the southwest end of Other Man Lake to Birch Lake, a distance of 26 km. This unit appears to fine upward from lapilli tuff and tuff breccia, which, based upon primary structures, presence of pumice, and lack of bedding, is an ash-flow with medium- to thin-bedded, felsic air-fall tuff above it. Graded bedding orientations in the fine rock-types indicate this unit faces south. The felsic unit is bisected by a strike-parallel fault extending the length of the area. North of the felsic unit are pillowed mafic flows which form a unit which is inferred to extend from Inlet Bay of Basswood Lake to This Man Lake. North of Other Man Lake this



LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

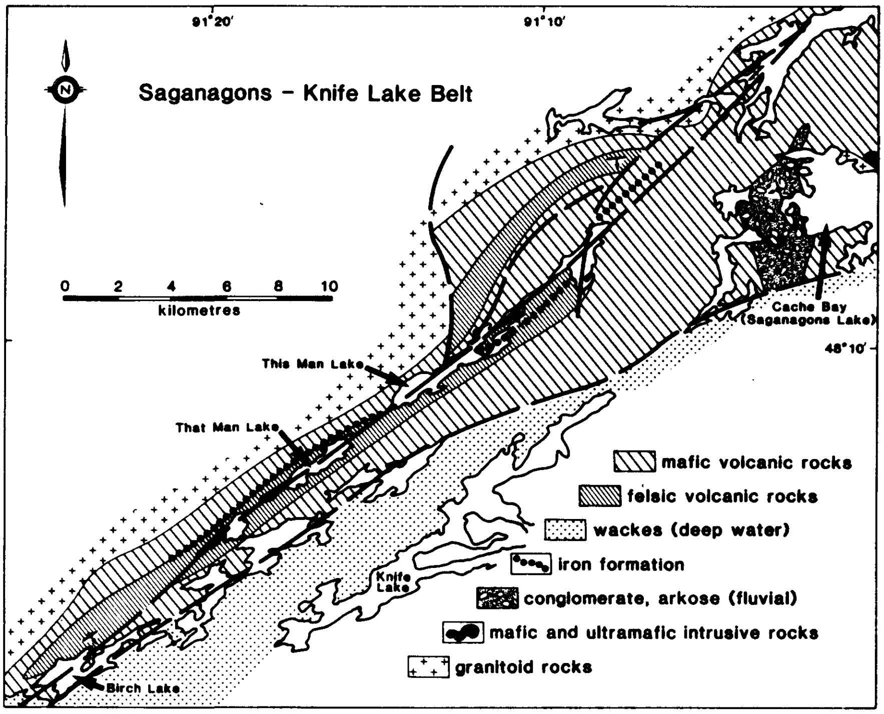


Figure 1. General geology of the Saganagons-Knife Lake belt. (Project 6.)

stratigraphy is repeated. The sequence also includes at Cache Bay, a unit of arkosic sandstone and conglomerate with sandstone interbeds which are interpreted, by analogy with other similar terrains, to be of alluvial fan origin. Oxide facies ironstone separates the mafic and felsic metavolcanic rocks.

South of the Knife River system are volcanogenic wackes of the Knife Lake Group. Sand sized volcanic debris forms the coarse part of 2 to 15 cm thick graded wacke beds.

Precise correlation with the better known sequence in the United States is difficult at the present stage of this compilation. However, the author suggests that the lower mafic unit is correlative with the Ely greenstones based upon the presence of an ironstone unit between the felsic and mafic units. Therefore the felsic unit would correlate with the Upper Ely greenstone. The upper basalt may represent either the Newton Lake formation or a repetition of the Ely greenstone by strike-parallel faulting. Further work on this sequence is planned.

STRUCTURAL GEOLOGY

Most units display a northeast-trending foliation. Top indicators in the felsic rocks face south and no data is available on tops in the mafic sequence. Top data and fault distribution lead to the suggestion that the area is a series of homoclinal "panels" bounded by northeast-trending faults parallel to regional strike. Evidence for the faults includes presence of abundant shearing, carbonatization, and an intense foliation near the faults.

A north-trending fault at Glacier Lake, in conjunction with the northeast-trending Saganagons Lake fault, has produced a repetition of the stratigraphy at the northeastern end of the belt.

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7. Goldie and Horne Townships, District of Thunder Bay

M.W. Carter

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INTRODUCTION

The map area comprises the Townships of Goldie and Horne and the Dawson Road Lots Allowance in the District of Thunder Bay. It is bounded by Latitudes 48°29'30"N and 48°40'30"N and Longitudes 89°46'00"W and 89°54'00"W, and is centred about 50 km northwest of Thunder Bay.

Highway 11-17 crosses the central part of the map area diagonally and Highway 17 traverses the western boundary of Goldie Township in a northerly direction. These, together with a network of gravel roads, provide access to the area. The southeastern part of Horne Township is accessible by helicopter. Thunder Lake, in the extreme southeastern part of the township, is accessible by float-equipped, fixed-wing aircraft.

An area of 187 km^2 was mapped during the summer.

MINERAL EXPLORATION

FELDSPAR

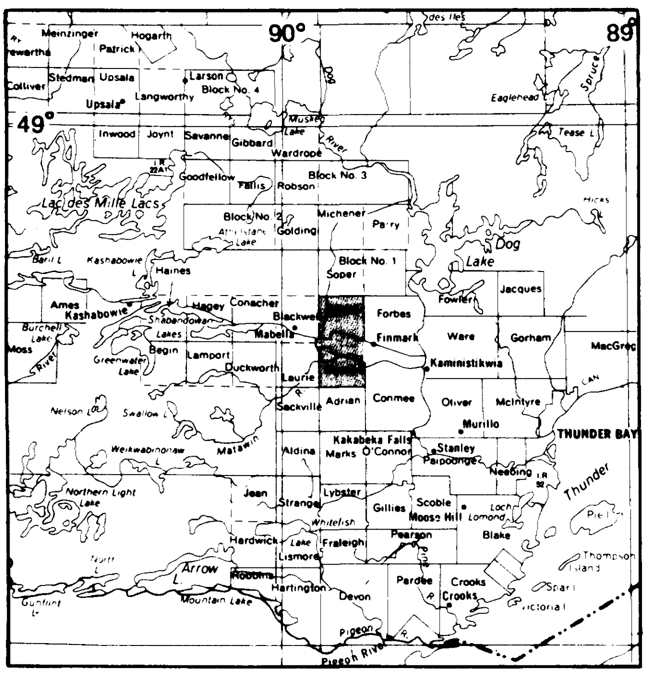
A feldspar deposit in a microcline granite-pegmatite was examined in 1938 and 1939 along the northern boundary of Goldie Township. In 1980 Steep Rock Iron Mines Limited did further exploration, finding at least 6 additional granite-pegmatite bodies.

GOLD

Gold was prospected for on 2 occurrences in the western part of the Dawson Road Lots: the Bylund Occurrence and the West Occurrence.. Birch Bay Gold Mines Limited carried out trenching and drilling on the Bylund Occurrence in 1934 (Thompson 1936). Subsequent activity was carried out from 1946 to 1947 by Mattawin Gold Mines Limited, followed in 1972 by Getty Mines Limited.

The West Occurrence was diamond drilled and trenched after 1936 by Freeport Exploration Company. Mattawin Gold Mines Limited did work in 1946, followed by Cliffs of Canada Limited in 1966. Between 1970 and 1972 Noranda Mines Limited and Getty Mines Limited carried out geological mapping and geophysical and geochemical surveys when several conductors were located. Finally in 1980, M.W. Bartley inspected the trenches for Lynx-Canada Explorations Limited.

Current exploration activity on the Alex Godzik property, believed to be for gold, was observed during the present survey in the central part of the Dawson Road Lots.



LOCATION MAP

Scale : 1 : 1 548 000
or 1 inch to 25 miles

IRON

From 1945 onward exploration for economic ironstone deposits was concentrated in the west central part of Horne Township north and south of the Shebandowan River, which represented the eastern part of the Matawin Iron Range. In 1945 and 1946 Andowan Mines Limited carried out a dip-needle magnetic survey that outlined 2 zones of magnetic ironstone, and Pickands Mather Company sampled and drilled the deposits. This was followed in the latter part of 1956 by a vertical magnetic survey on the Minoletti claims by N.H. Black. South of the Shebandowan River, M.W. Bartley carried out a geological survey on ironstone units in 1952, followed in 1957 by a geological survey by Monpre Mining Company Limited.

BASE METAL SULPHIDES

Sulphide mineralization was explored for in 1969 by Noranda Exploration Company Limited who carried out electromagnetic and magnetic surveys along the southern boundary of Goldie Township. This was followed in 1970 or 1971 by electromagnetic and magnetic surveys in the southwestern part of Horne Township by the same company. In early 1983 Abitibi-Price Incorporated did surficial geochemistry in the former area.

In 1977 Melvin A. Stewart carried out stripping on his claim located in the north central part of Horne Township, apparently searching for base metal sulphide mineralization.

GENERAL GEOLOGY

The map area is underlain by Archean rocks (Figure 1) mantled by Pleistocene and Recent deposits. The area has been previously mapped by Tanton (1931).

The Archean rocks comprise Keewatin-type and Timiskaming-type metavolcanic and metasedimentary rocks, metagabbroic stocks, granitic and syenitic stocks and plutons, felsite and quartz-feldspar porphyry dikes, and diabase and lamprophyre dikes.

The Keewatin-type metavolcanic rocks, which occur in Horne Township, comprise 1 complete mafic to felsic cycle and the mafic-ultramafic base of a second incomplete cycle. The first cycle consists of a lower sequence of mafic pillowed, aphyric, and porphyritic magnesian basalts in northern Horne Township, and an upper sequence of intermediate pillowed, aphyric and porphyritic andesitic and dacitic flows and fragmental rocks, interlayered with less abundant felsic fragmental rocks and subaqueous ultramafic flows of a second cycle. The felsic and ultramafic rocks occur in the southern part of Horne Township. The ultramafic flows are grey and show spinifex texture and pillowed structure. The interlayered metasedimentary rocks comprise mudstones, chert, jasper-magnetite and chert-magnetite ironstone units up to 35 m thick.

The Keewatin-type metasedimentary rocks, hereafter termed Quetico metasedimentary rocks, occur in Goldie Township and consist almost entirely of metawackes which display beds ranging from 6 to 10 cm thick and graded bedding and crossbedding that permit facing directions to be determined. A mafic metavolcanic unit interlayered with the metasedimentary rocks occurs in the southern part of Goldie Township. Migmatites are developed in the metasedimentary rocks in northeastern Goldie Township. The Quetico metasedimentary rocks have been intruded by massive granitic and syenitic rocks with muscovite pegmatites, and by felsite and porphyry dikes that are restricted to the northern part of the map area. The pegmatite dikes have been assessed for their economic importance as sources of feldspar.

The Keewatin-type metavolcanic rocks and metasedimentary rocks have been intruded by lensoid metagabbroic units elongated in the direction of the regional strike.

Unconformably overlying the metavolcanic and metasedimentary unit is a later group of predominantly clastic metasedimentary rocks interlayered with red and grey trachyte and varicoloured, blotchy red and green trachyandesite flows. This sequence occurs in 2 linear belts; the more northern belt trends east-southeasterly, whereas the southern belt trends easterly (Figure 1). The clastic component consists of pink and green polymictic conglomerate, pink and grey arkose, siltstones, and mudstones. The sandstones frequently display crossbedding and occasional small-scale ripple structures, and are interbedded with the conglomerate, and thus most likely represent an alluvial fan environment (Rust 1979, p.9-21). The trachytic flows are up to 50 m wide and do not show pillowed structures.

Both the Keewatin-type and Timiskaming-type sequences are intruded by diabase, and hornblende and mica lamprophyre dikes trending northwesterly, easterly and northeasterly.

The Keewatin-type supracrustal rocks have been metamorphosed to the greenschist and amphibolite facies of regional metamorphism, the metamorphic grade increasing northward. The metavolcanic unit is in the greenschist facies, the metasedimentary unit ranges from the greenschist to amphibolite facies, and biotite, garnet, and staurolite zones can be recognized.

Pleistocene deposits comprise glaciolacustrine sands and gravel in northwestern Goldie Township, thin till in central Goldie Township, and fine red glaciolacustrine clay in Horne Township (Mollard and Mollard 1981).

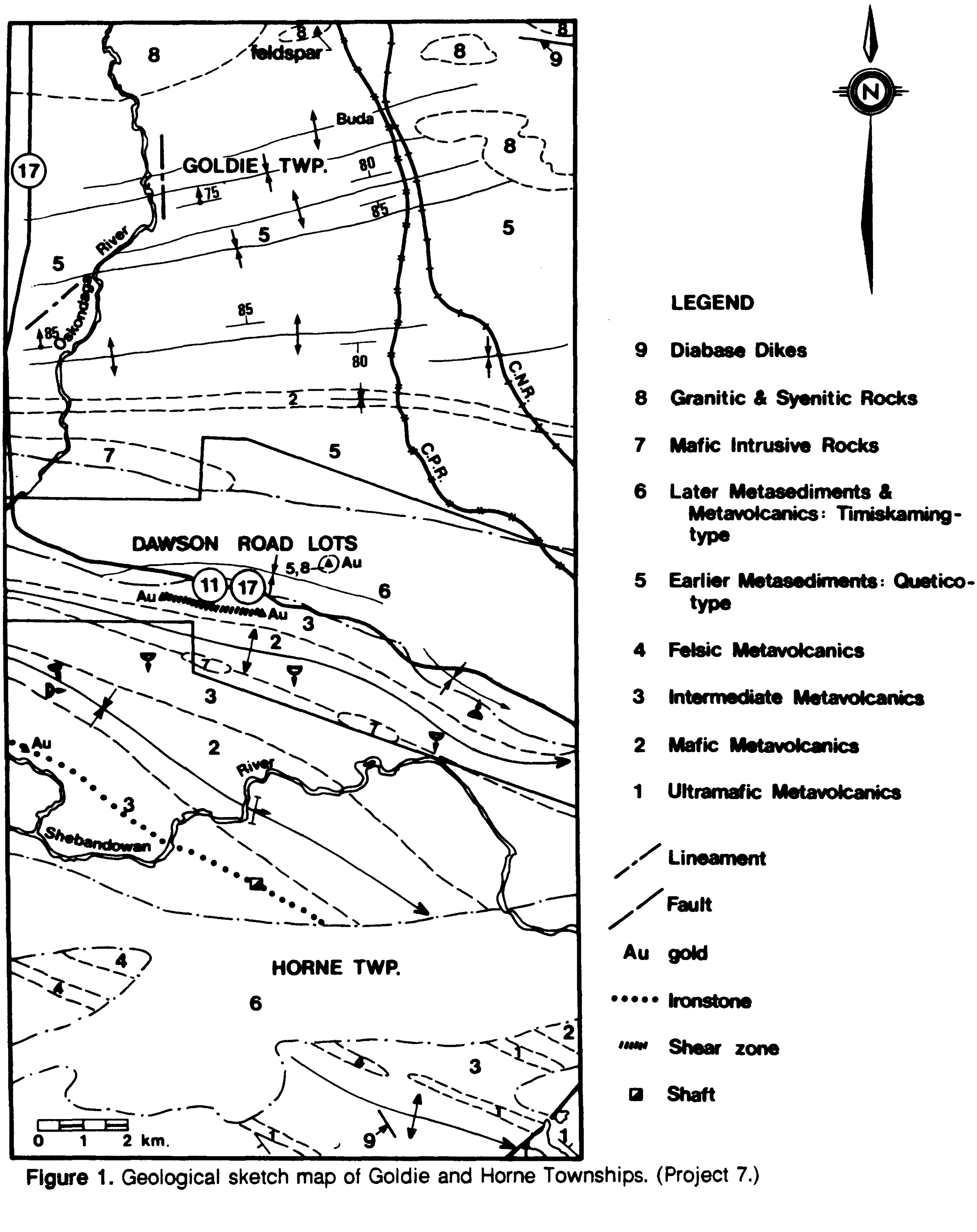


Figure 1. Geological sketch map of Goldie and Horne Townships. (Project 7.)

STRUCTURAL GEOLOGY

The Quetico-type metasedimentary rocks exposed in the northern part of the map area are isoclinally folded about east-trending axes as indicated by facing directions from graded bedding. A moderately developed foliation is present and trends parallel to the fold axes. The Keewatin-type metavolcanic rocks and associated komatiitic ultramafic rocks are steeply folded about southeasterly trending axes plunging southeastward (Figure 1). A weak foliation is developed locally but only in the mafic metavolcanic rocks and this strikes east and dips vertically or steeply to the north. Narrow, short, pyritic shear-zones, locally developed in these rocks, trend approximately easterly to east-southeasterly. These zones are restricted to the mafic metavolcanic rocks and may contain gold mineralization.

The Timiskaming-type metasedimentary rocks also dip steeply and are isoclinally folded about southeast-trending axes plunging southeast. A well developed east-trending foliation in the western part of the map area, swings to the southeast in the eastern part of the area. In the southern belt, foliation is generally absent.

Major lineaments are shown in Figure 1.

ECONOMIC GEOLOGY

FELDSPAR

Pegmatite dikes 2 to 34 m wide and up to 360 m long occur along the northern boundary of the map area in the granitic rocks 2 km northwest of Buda. The pegmatites contain feldspar, quartz, and muscovite with minor garnet and apatite. An early chemical analysis of the Blank dike gave a potash content of 10.61% and a soda content of 0.70% (Assessment Files Research Office, Ontario Geological Survey, Toronto) from an unknown type of sampling, and assay results from 2 grab samples from this dike taken by J. Scott (1981) gave silica values of 65.1% and 66.5%, potash 12.0% and 10.6%, alumina 19.6% and 18.5%, soda 3.08% and 3.43%, lime 0.16% and 0.10%, and iron as Fe_2O_3 0.08% and 0.00% (analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto). On the basis of the trace element concentrations this dike is classed as a rare earth metal pegmatite (Scott 1981). Steep Rock Iron Mines Limited reported dikes ranging from 7 to 140 m in width and 300 to 450 m in length occurring in the area west of the Blank dike.

Current mapping has shown that granite-pegmatite dikes also occur in the western part of the granitic pluton exposed in northwestern Goldie Township.

GOLD

Current mapping has shown that gold occurs in: (1) silicified zones, (2) carbonatized zones, (3) silicified, pyritized shear zones in Archean Keewatin-type altered mudstones, and altered felsic metavolcanic rocks, and (4) a jasper-magnetite ironstone unit interlayered with mafic metavolcanic rocks in the southern half of the map area.

Gold mineralization associated with a metamorphosed mudstone unit intruded by feldspar porphyry occurs on the Alex Godzik claim in the central part of the Dawson Road Lots. A grab sample taken during the current survey of pyritized siliceous rock enclosed in the mudstone, yielded 0.01 ounce gold per ton and <0.10 ounce silver per ton (assays by Geoscience Laboratories, Ontario Geological Survey, Toronto). The mineralized and silicified zone, as it is being currently exposed, is about 30 m wide striking 110° and dipping 80°S.

Gold mineralization associated with silicified zones and pyritized shear zones at the contact of mafic and felsic metavolcanic rocks occurs at the Bylund Occurrence and the West Occurrence in the Dawson Road Lots. A grab sample taken during the current survey from the 10 m wide silicified zone on the Bylund Occurrence, which strikes 080° with an indeterminate dip, assayed 0.12 ounce gold per ton (assay by Geoscience Laboratories, Ontario Geological Survey, Toronto). The best assay on this zone, taken by E.G. Pye, Resident Geologist in 1953, yielded 0.20 ounce gold per ton over 2 feet, 10 inches from an unknown type of sample (assay by Geoscience Laboratories, Ontario Department Department of Mines, Toronto). The best assay from the West Occurrence, taken during the current survey, was from a 13 cm shear zone striking 080° and dipping 70°N and was 0.16 ounce gold per ton and 0.10 ounce silver per ton (assay by Geoscience Laboratories, Ontario Geological Survey, Toronto). Chip sampling on this occurrence by M.W. Bartley in 1948 gave "a weighted average of 0.130 oz. Au per ton over an average width of 8.6 feet and for a strike length of 270 feet" (AFRO).

Gold in jasper-magnetite ironstone was found during the current survey when a grab sample, taken from a 3 m wide ironstone unit interlayered with mafic metavolcanic rocks in northwestern Horne Township, yielded 0.02 ounce gold per ton and <0.10 ounce silver per ton (assays by Geoscience Laboratories, Ontario Geological Survey, Toronto). This auriferous jasper-magnetite ironstone forms a unit in excess of 5.5 km long though poorly exposed. A shaft has been put down at its southern part but a sample from outcrop at this site, collected during the current survey, yielded <0.01 ounce gold per ton (assay by Geoscience Laboratories, Ontario Geological Survey, Toronto). This unit should be prospected further for its gold potential. Although other ironstone units were assayed for gold and silver, all these samples returned a value of <0.01 ounce gold per ton (assays by Geoscience Laboratories, Ontario Geological Survey, Toronto).

A carbonatized zone in mafic metavolcanic rocks exposed beside Highway 11-17 and approximately 170 m wide was grab-sampled during the current survey. Assays by the Geoscience Laboratories, Ontario Geological Survey, Toronto, yielded <0.01 ounce gold per ton. However, it is recommended that this zone be prospected as it occurs in the same unit as the Bylund Occurrence.

Shears within these metavolcanic rocks occur in central and southwestern parts of Horne Township and these also should be prospected for gold.

IRONSTONE

Ironstone occurs as units varying from about 1.5 to 50 m thick and consist of interbanded chert-graphite-hematite, chert-magnetite, chert-hematite, jasper-magnetite, jasper-magnetite-black chert, jasper-limonite, and chert-pyrite layers, as well as magnetite-bearing slate units. These units are mainly of interest for possible gold occurrences.

BASE METAL SULPHIDES

Although no base metal sulphide deposits are known in the area, current mapping has shown that felsic metavolcanic fragmentals occur in southwestern Horne Township, and this area should be prospected for volcanogenic stratabound base metal sulphide deposits.

NICKEL DEPOSITS

No nickel deposits are known in the area but current mapping has shown that ultramafic komatiitic flows and serpentinites occur in the southeastern part of Horne Township interlayered with intermediate flows. It is recommended that this area be prospected for nickel deposits.

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S8. MacGregor Township, District of Thunder Bay

John Scott

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This project was funded by the Ontario Ministry of Northern Affairs.

INTRODUCTION

Geological mapping of the western half of MacGregor Township was initiated in 1984. The completion of the eastern half is scheduled for 1985.

LOCATION AND ACCESS

The geographic township of MacGregor is situated in the Municipality of Shuniah and is located immediately northeast of the City of Thunder Bay. The township has an area of approximately 250 km^2. It is bounded on the south by the waters of Thunder Bay, Lake Superior, and on the north by Latitude 49°30'36"N. Longitudes 89°11'W and 88°48'W mark the western and eastern limits of the map area, respectively.

The Trans-Canada Highway, Highway 11-17, cuts across the southern portion of the township near Lake Superior; Highway 527, the Spruce River Road, traverses northward across the western sector of the township. Hydro lines, pipelines, and bush roads provides access to more than 75% of the township. The least accessible sector is the northwestern quadrant away from Highway 527. Access by float plane is restricted to the Penassen Lakes, Waller Lake, and Bently Lake, all in the northwestern quadrant, and all quite small. Several well-used trails access a few of the lakes in the area.

PREVIOUS WORK AND EXPLORATION HISTORY

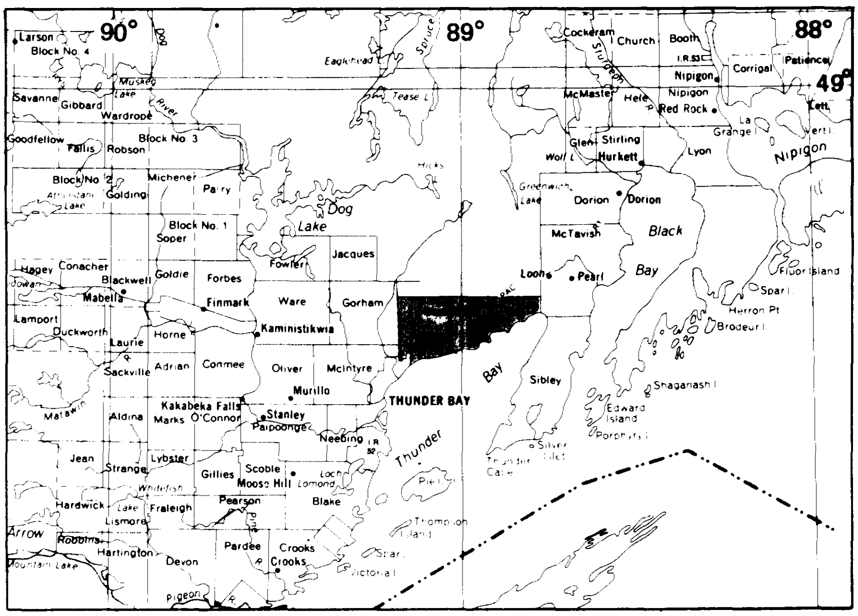
The northwestern sector of the township was mapped by MacDonald (1939). Moorhouse (1960) mapped the Middle Precambrian Gunflint Formation located in the southern section of the township. McIlwaine (1971a, 1971b, 1975) mapped McTavish Township, which lies immediately east of the present map area. Tanton (1926), mapped parts of the northeastern sector of the township. McKellar (1874), described some of the earliest discovered mineral occurrences of the area.

MacGregor Township and adjacent areas have had a colourful exploration history dating back to the first settlements in the area around the 1800s. The bulk of the intensive mineral exploration occurred during the silver boom of the middle to late 1800s. During that period, more than 16 silver occurrences were developed into "mines". Some of the mines, such as the Shuniah Mine and the 3A Mine, had extensive underground developments. There was also prospecting for iron deposits, the last active period being the 1950s.

Silver production figures are generally minor and unreliable as not all the silver produced was recorded.

GENERAL GEOLOGY

Early, Middle, and Late Precambrian rocks are found in MacGregor Township. The Early Precambrian rocks are situated in the Abitibi-Wawa Subprovince and consist of metavolcanic and associated metasedimentary rocks, mafic to ultramafic intrusions, hornblende syenites, granite, and quartz monzonites. The



LOCATION MAP

Scale : 1 : 1 548 000 or 1 inch to 25 miles

metavolcanic rocks consist of a felsic pyroclastic sequence that ranges from coarse felsic fragmentals to pumiceous tuffs; the mafic to intermediate volcanic rocks are pillowed to massive, and in places amygdular flows. Blue quartz-eye porphyry and quartz-feldspar porphyry sills intrude the metavolcanic rocks. The associated metasedimentary rocks are conglomerates, crossbedded and/or graded argillaceous arenites or wackes, fine-grained argillaceous units, and iron formation. The conglomerates and associated crossbedded arenites are possibly correlative with the Timiskaming-type units found to the west (Carter, this volume).

Mafic to ultramafic intrusions are represented by small gabbroic and hornblendite plugs. The hornblendite bodies are usually very coarse grained with individual hornblende crystals up to 2.5 cm across. They probably intrude the surrounding rocks, though contacts were not observed; they form discrete plug-like units; some may represent recrystallized mafic metavolcanic rocks near the margins of granitoid bodies.

Two major granitoid bodies exist in the western half of the township. The southern body, the MacKenzie Granite, is a large granitic intrusion consisting of medium- to coarse-grained, pink to slightly greenish granite composed primarily of microcline, oligoclase, quartz, and biotite, with accessory sphene, apatite, opaque minerals, and secondary sericite and epidote, (Rogers 1979).

The northern body, the Penassen Lakes Stock, is coarse-grained and ranges in composition from a porphyritic quartz monzonite to hornblende syenite to hornblendite. The syenitic and hornblendite phases appear to be restricted to the area of Highway 527 and westward. East of Highway 527, the rock is a coarse to very coarse grained porphyritic quartz monzonite.

Both granitic bodies have a pronounced positive topographical relief. The Penassen Lakes Stock is characterized by steep cliffs with near vertical drops of up to 61 m (200 feet). Elevations rise up to 566 m (1857 feet) above sea level or 382 m (1256 feet) above Lake Superior. The topographic expression of the MacKenzie Granite is more subdued, but still pronounced.

The Middle to Late Precambrian rocks of MacGregor Township consist of clastic and chemical sedimentary rocks of the Animikie and Sibley Groups. The Animikie Group consists of 2 conformable formations, the Gunflint Formation, and the Rove Formation; the Sibley Group consists of 3 conformable formations, the Pass Lake Formation, the Rossport Formation, and the Kama Hill Formation. Both these groups have been described in the literature and thus will not be described here. The reader is referred to Tanton (1931), Franklin (1970), Morey (1967), and Franklin *et al.* (1980), for detailed descriptions of these Groups. Late Precambrian diabase sills and dikes cut all rock types in the map area and are presumed to be Keweenawan in age.

STRUCTURAL GEOLOGY

The metavolcanic-metasedimentary sequence in the map area has a general easterly trend. Schistosity strikes parallel to the trend of the units and has in many instances destroyed primary structures. The schistosity dips very steeply to vertical. Locally, the strike of the schistosity is undulating and may vary several 10s of degrees in outcrop. Shearing along fault zones has locally severely deformed the rocks, and in some cases, mylonitic textures are evident. Near the granitoid contacts, primary features, such as pillows in the volcanic rocks and graded bedding or crossbedding in the sedimentary rocks, were obliterated.

Where facing directions are discernable, they indicate a southerly facing sequence; locally some units face north, probably reflecting local folding in the metavolcanic rocks.

Several major regional fault directions have been interpreted to occur in the map area. The most predominant fault directions are northeast, north-northeast, and northwest. Some of the more prominent faults contain diabase dikes.

ECONOMIC GEOLOGY

MacGregor Township is known for old silver occurrences. These always occur as vein deposits (*see* Tanton 1931; Franklin 1970). Usually these veins occupy fault or shear zones and contain sphalerite, galena, chalcopyrite, native silver, argentite, fluorite, calcite, amethyst, pale quartz, and barite. The vein systems appear to cross-cut all lithologies and are best exposed along Highway 11-17 east of Thunder Bay. Veins mapped in the 1984 field season varied in width from a few centimetres to a metre, and strike generally in a northerly direction. Veins of this type might offer excellent potential for amethyst, but are not economic for base metals.

Pyrite is disseminated throughout the felsic volcanic rocks exposed north of Highway 11-17, but to date no noteworthy assays of gold, silver, or base metals, have been obtained.

Samples taken from <2 cm wide siliceous veins crosscutting mafic volcanic rocks by Bill Hayne (Prospector, Thunder Bay) yielded up to 0.15 ounce Au per ton, 15.2% Zn, and traces of arsenopyrite (assays by Geoscience Laboratories, Ontario Geological Survey, Toronto). The veins are located on the northwestern side of Highway 11-17 near the junction with Nelson Road. Most samples, however, yielded trace values.

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9. Hemlo Stratigraphic Study

T.L. Muir

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INTRODUCTION

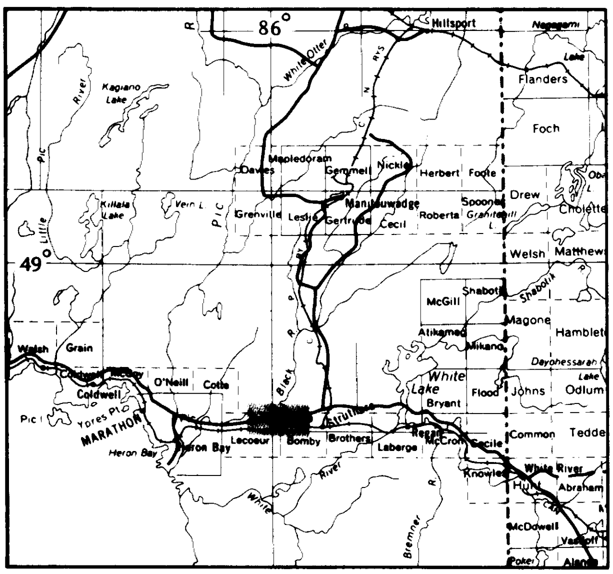
Numerous studies, some of which have been completed, have been initiated to study the various geological aspects of the recently discovered Hemlo gold deposit (*see* Patterson 1983). The Ontario Geological Survey recognized the need for an overview of the deposit area which would tie together the geology of the various properties. This overview, to be undertaken over a period of a few years, will involve mapping at a scale of 1:5000. Associated with the various studies of the Hemlo-Heron Bay area is a multi-year geochronology study initiated in 1984.

The map area initially designated is bounded by Latitudes 48°40'30"N and 48°43'00"N and by Longitudes 85°51'30"W and 86°02'00"W. Mapping this field season was limited to selected parts of the map area in order: to develop an appreciation for the main lithological units and their associated problems, of which many are emerging due to other more specific, detailed studies; and to examine outcrops destined for elimination by construction projects. Much of the information obtained this summer is confidential at this stage, thus limiting detailed points that can be made in this summary.

MINERAL EXPLORATION

The entire map area has been staked for a few years. The following properties (listed alphabetically) lie wholly or partly within the map area (based on property map, Northern Miner, January 19, 1984, p.B4-B5):

Americ Mines Limited,
Arctic Red Resources Corporation,



LOCATION MAP

Scale: 1:1 584 000
or 1 inch to 25 miles

Bel-Air Resources Limited (Westfield Minerals Limited option),
Brigade Resources Incorporated (Noranda Exploration Company Limited option),
Cannon Mines Limited,
Caravelle Resources Limited/Boulder Mountain Resources Limited/Charger Resources Limited,
Caulfield Resources Limited/Vulcan Resources Limited,
Consolidated Montclerg Mines Limited/Davidson Tisdale Mines Limited,
Dakota Energy Corporation,
Golden Sceptre Resources Limited (Noranda Exploration Company Limited option),
Goliath Gold Mines Limited (Noranda Exploration Company Limited option),
Harlin Resources Limited/Admiral Mines Limited,
Interlake Development Corporation (Noranda Exploration Company Limited option),
International Corona Resources Limited (Teck Corporation option),
Lac Minerals Limited (Exploration Group),
Lac Minerals Limited (Nabigon claims),
Lac Minerals Limited (Williams Property),
Lynx-Canada Explorations Limited/Sparton Resources Incorporated,
Melrose Resources Limited,
Pryme Energy Resources Limited/International Damascus Resources Limited (Noranda Exploration Company Limited option),
Rabbit Oil and Gas Limited/Marilyn Resources Limited,

Seemar Mines Limited,
Tandem Resources Limited,
TGR Resources Limited,
Vanstates Resources Limited
Youngman Oil and Gas Limited.

Minor to extensive exploration work has been undertaken on these properties. Diamond drilling, and trenching and/or stripping was undertaken during the field season on properties held by Bel-Air Resources Limited, Golden Sceptre Mines Limited, Goliath Gold Mines Limited, Interlake Development Corporation, and Lac Minerals Limited. Shaft development is continuing on properties held by Goliath Gold Mines Limited (Golden Giant Mine - Noranda Incorporated), International Corona Resources Limited (Teck-Corona Operating Corporation), and Lac Minerals Limited ("main" shaft and "A" shaft).

GENERAL GEOLOGY

The map area is largely underlain by east-trending supracrustal rocks which have previously been mapped by Thomson (1931, 1932), Muir (1982a, 1982b), and Siragusa (1984). Muir (1983, 1982a, 1982b) tentatively subdivided these rocks into 2 groups: the Playter Harbour Group which in the map area lies adjacent to the Pukaskwa Gneissic Complex and consists of massive and pillowed mafic high-iron tholeiitic flows, with minor mafic breccias and intercalated metasedimentary rocks; and the Heron Bay Group which consists of calc-alkalic pyroclastic rocks of andesitic, dacitic, and rhyolitic composition, associated reworked metasedimentary rocks composed largely of volcanic detritus, high-iron tholeiitic flows similar to those of the Playter Harbour Group, and mixed clastic metasedimentary rocks comprised of arenites, wackes, and mudstones of undetermined provenance.

The metavolcanic and metasedimentary rocks within the map area have been tentatively subdivided into the Cache Lake, Rule Lake, Moose Lake, and Cedar Creek Formations based on generalized lithologic "packages" (Noranda Exploration Company Limited, 1983; P. Cooper, Senior Project Geologist, Noranda Exploration Company Limited, personal communication, 1984). The Cache Lake Formation consists of mafic metavolcanic rocks and amphibole-rich metasedimentary rocks. The Rule Lake Formation consists primarily of light to medium grey laminated metasiltstones. The Moose Lake Formation, which largely hosts the mineralization, consists mainly of felsic pyroclastic rocks, associated metasedimentary rocks, feldspar- and quartz-feldspar porphyritic rocks, and sericitized equivalents. The Cedar Creek Formation consists of units of metasiltstone, pelite, laminated feldspathic metasedimentary rocks, and metaconglomerate. Refinements in the description of these formations is ongoing, and the author considers that all of these formations lie within the Heron Bay Group.

Relatively detailed descriptions of the host rocks and mineralization have been published in McMillan and Robinson (1984), and Patterson (1984).

The map area also includes parts of the Pukaskwa Gneissic Complex, the Heron Bay Pluton, and the Cedar Lake Pluton and Cedar Lake Stock. Numerous, slightly discordant plagioclase- and quartz-plagioclase porphyritic dikes of various ages and composition have intruded the supracrustal rocks. Only some of the dikes are related to the aforementioned plutons. Locally there are small porphyry plugs, or zones in which 80% of the rocks consist of porphyritic dikes.

Amphibolitized gabbro dikes are much less common than the porphyritic rocks but are nonetheless widespread. Rare, slightly discordant, schistose, gabbroic to dioritic dikes with numerous mafic to ultramafic inclusions occur. These dikes are similar to those reported near Lake Superior (Muir 1982a) which are anomalously high in alkalies and/or phosphorus. Ultramafic dikes occur in several spots near Highway 17 close to the contact between mafic metavolcanic and metasedimentary rocks and appear to be spatially associated with the Hemlo Fault.

Virtually all of the above mentioned dikes display a weakly to strongly developed penetrative foliation; some have also been folded and/or boudinaged. Subsequent to major deformation, all rock types have been intruded by north- and northwest-trending subalkalic diabase dikes and by later, uncommon, north-trending, pyroxene-magnetite and biotite lamprophyre dikes similar to some of those that are common along the Lake Superior shoreline in the Heron Bay area (Muir 1982a).

STRUCTURAL GEOLOGY

Whereas the rocks in the vicinity of Heron Bay range from strongly deformed in shear zones and fold hinges, to weakly deformed in *lithons* (lens-shaped bodies of rock surrounded by sheared equivalents), the rocks in the Hemlo map area range from moderately to intensely penetratively deformed. There are several zones of intense ductile deformation in the map area, at least one of which appears to spatially coincide with the main deposit.

Reliable stratigraphic facings in the map area are few and are found away from the zones of intense deformation. Reversals in facing direction are locally common. Tight to very tight isoclinal folds are exposed on all properties. These folds occur north and south of the main deposit and overall are evident on a scale ranging from several centimetres to a few hundred metres across. Fold axes plunge moderately steeply to the west. Locally the primary foliation (S_1) has been refolded about steeply east-plunging folds, some of which have a chevron configuration. Green mica (roscoelite), commonly associated with the mineralized rocks, is present as elliptical pancake-shaped lenses that locally are folded and/or display crenulated cleavage. Tourmaline crystals within the lenses are randomly oriented.

East and west verging, small-scale folds are present but the predominant sense of relative movement as indicated by shearing is dextral. Boudinage is common where units of contrasting competency are present. Compression during ductile/brittle stages is indicated by boudin-like terminations which are now overlapping.

The crenulated cleavage and both dextral and less prevalent sinistral shearing indicate that either polyphase deformation or complicated progressive deformation has taken place. An understanding of the structure of the area is of paramount importance in determining the stratigraphic succession within the map area and in resolving the present configuration and origin of the deposit.

ECONOMIC GEOLOGY

The Hemlo gold deposit has been incompletely outlined and presently stands at approximately 69 million tonnes with an average grade of 8.2 grams of gold/tonne (*see* Patterson 1984). Gold is found in silicified rocks containing pyrite, and locally is visible to the naked eye. Other notable minerals within the deposit are molybdenite, stibnite, and cinnabar, and the main gangue minerals are quartz, muscovite, potassium feldspar, barite, rutile, sphene, and tourmaline (Noranda Exploration Company Limited 1983; Harris 1984).

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10. White Lake Area and Animons Lake Area, District of Thunder Bay

G.M. Siragusa

Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto.

INTRODUCTION

During the 1984 field season 2 separate map areas were mapped at the scale of 1:15 840.

The smaller of these 2 areas is bounded by Latitudes 48°37'30"N and 48°40'54"N, and Longitudes 85°32'30"W and 85°36'56"W. This area, hereafter referred to as the Animons Lake area, is centered about Animons Lake and covers approximately 25 km². Animons Lake is 8.2 km southeast of the Village of Mobert, and is connected to Mobert by an approximately 10 km long bush road. The Animons Lake area is at the junction of the east-trending and northwest-trending belts of supracrustal rocks, adjacent to the southeastern margin of the Cedar Lake Pluton, which were previously named respectively the Main belt and the Northern belt (Siragusa 1984a, 1984b).

The larger area is bounded by Latitudes 48°45'00"N and 48°52'30"N and by Longitudes 85°35'00"W and 85°50'30"W and covers approximately 266 km². This area, hereafter referred to as the Theresa Lake area, extends west of the eastern shore of the main body of White Lake, and was previously mapped by Milne (1968) as part of a larger mapping project (Black River Area; Milne 1968). Highway 17, which crosses the White Lake Narrows about 32 km west of the town of White River, gives access to the eastern part of the Theresa Lake area. Access to the western part of the area is by Highway 614, (the Manitouwadge Highway) and by the Theresa Lake and Dead Otter Lake dirt roads which extend from Highway 614 and are about 14 and 8 km long, respectively. The Theresa Lake road also gives access to Wabikoba Lake in the south central part of the Theresa Lake area. Wabikoba Lake is approximately 9 km from Highway 614 via the Theresa Lake road.

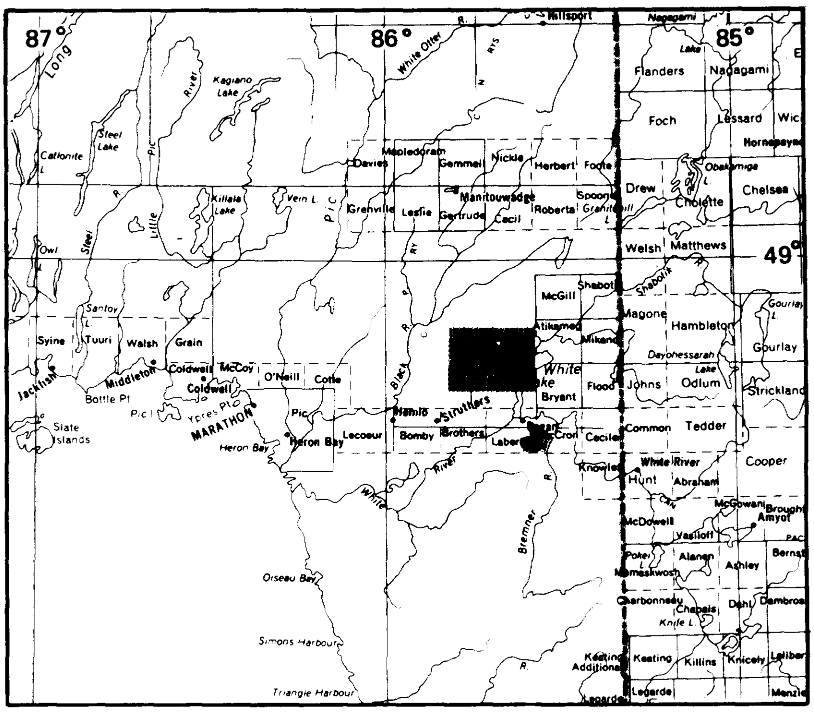
MINERAL EXPLORATION

During the 1984 field season, field crews of Lac Minerals Limited were engaged in detailed geological mapping, geophysical surveys, and soil sampling on the large property owned by this company situated south of Cedar Lake and west of the Animons Lake area. A limited amount of diamond drilling was also carried out on this property (B. Valliant, Exploration Manager, Lac Minerals Limited, Toronto, personal communication, 1984). Exploration was also carried out on the property of Qued Resources Corporation in the Theresa Lake area, and in an adjacent property owned by Noranda Mines Limited. Assistance provided in the field by J. Dumouchel, I. Campbell, and B. Stagg, geologists of Orequest Consultants Limited, is gratefully acknowledged.

GENERAL GEOLOGY

ANIMONS LAKE AREA

The limited field work carried out in 1984 in this area was primarily aimed at establishing whether the east-trending Main belt and the southeast-trending Northern belt (Siragusa 1984a, 1984b) join as limbs of a continuous fold enveloping the southeastern tip of the Cedar Lake Pluton. The results of this summer's mapping clearly indicate that they



LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

do not. In fact, it was found that the Main belt extends eastward at least as far as the western bank of the Bremner River, whereas the Northern belt is truncated approximately 2.5 km west of the Bremner River by a southward-narrowing wedge of pegmatitic granitic rocks that locally contain metasedimentary xenoliths. Field observations suggests that the southwestern margin of this granitic wedge is bounded by a northwest-trending fault. This interpretation is supported by the presence of a well defined northwest-trending lineament on airphotographs of the area.

The outcrop pattern and the attitude of foliation in the supracrustal rocks of the Animons Lake area suggest that the Main and Northern belts are remnants of a formerly continuous fold which: (1) had a northwest-trending axial plane, subvertical plunge, and southeast convexity, and (2) underwent axial plane shearing and eventually faulting during a later stage of granitic intrusion. The interaction of deformational and igneous processes in this area are interpreted by the author as favourable to gold mineralization (*see* section on "Economic Geology").

THERESA LAKE AREA

The outlines of the main metavolcanic and metasedimentary units, and the major structural features found by present mapping in this area are generally in agreement with those reported by Milne (1968) between Longitudes 85°35'00"W and 85°50'30"W. Results of the present, more detailed survey indicate some changes in lithology and structural interpretation on the west side of the felsic metavolcanic unit in the southern part of the mafic metavolcanic belt underlying the area (compare Ontario Department of Mines Map 2147; Milne 1968, with the sketch map in the Figure 1).

Part of the area is underlain by a northwest-trending, south-dipping, and south-facing belt of mafic metavolcanic rocks that extend from the Dead Otter Lake area to the Spruce Bay area of White Lake (Figure 1). Gossan zones that are generally associated with small shear zones are common throughout this belt. In addition, the pillowed mafic volcanic rocks of this belt locally contain interbeds of ferruginous wacke, which can be conspicuously garnetiferous, as well as bands of chert-magnetite ironstone that are commonly 0.6 to 1.5 m thick although they can be up to 3 m thick. These interbeds seem to occur preferentially in the upper stratigraphic section, located to the south of the belt, and have significant gold potential (*see* section on "Economic Geology"). The upper stratigraphic section of the belt also contains a pyroclastic unit which has an overall intermediate composition, and is about 200 to 650 m thick; it is significant that a similar intermediate pyroclastic unit also occurs in the White River Dam-Pickerel Bay area of the Main belt (Siragusa 1984a, 1984b). Feldspar and quartz-feldspar porphyritic sills of varied thicknesses are common in the mafic metavolcanic belt. The largest porphyritic sill seen in the area is about 200 m thick, contains quartz "eyes" and feldspar phenocrysts, and occurs on the property of Qued Resources Corporation, about 2300 m north of the western tip of Solong Lake.

The mafic metavolcanic belt described above is bounded to the south by granitic rocks that are part of the Musher Lake Pluton (Milne 1968). The area south of this pluton is underlain by a metasedimentary belt that has a maximum width of 7.2 km, and extends beyond the southern boundary of the present map area. The general character and microscopic features of these metasedimentary rocks were described by Milne (1968). Present mapping indicates that conglomerate interbedded with whitish-tan (mafic-poor) arenite and/or siltstone appears to occur mostly in the northern section of the belt, while whitish-tan arenite and siltstone occur in the central part. Relatively mafic-rich (biotite) arenite, wacke, and paragneiss are more common in the southern part of the belt. Due to the poor outcrop exposure of the metasedimentary rocks these suggestions can only be considered tentative at this time.

ECONOMIC GEOLOGY

THERESA LAKE AREA

During present mapping many grab samples were collected by the field party and submitted to the Geoscience Laboratories, Ontario Geological Survey, Toronto, for Au assays. At the time of writing, however, the results of only a few assays are available. One of these assay results was 8850 parts per billion Au in a grab sample collected by the author from a thin layer of ferruginous wacke interbedded with mafic metavolcanic rocks in the mid-section of trench QT-1, on the property of Qued Resources Corporation. This property is

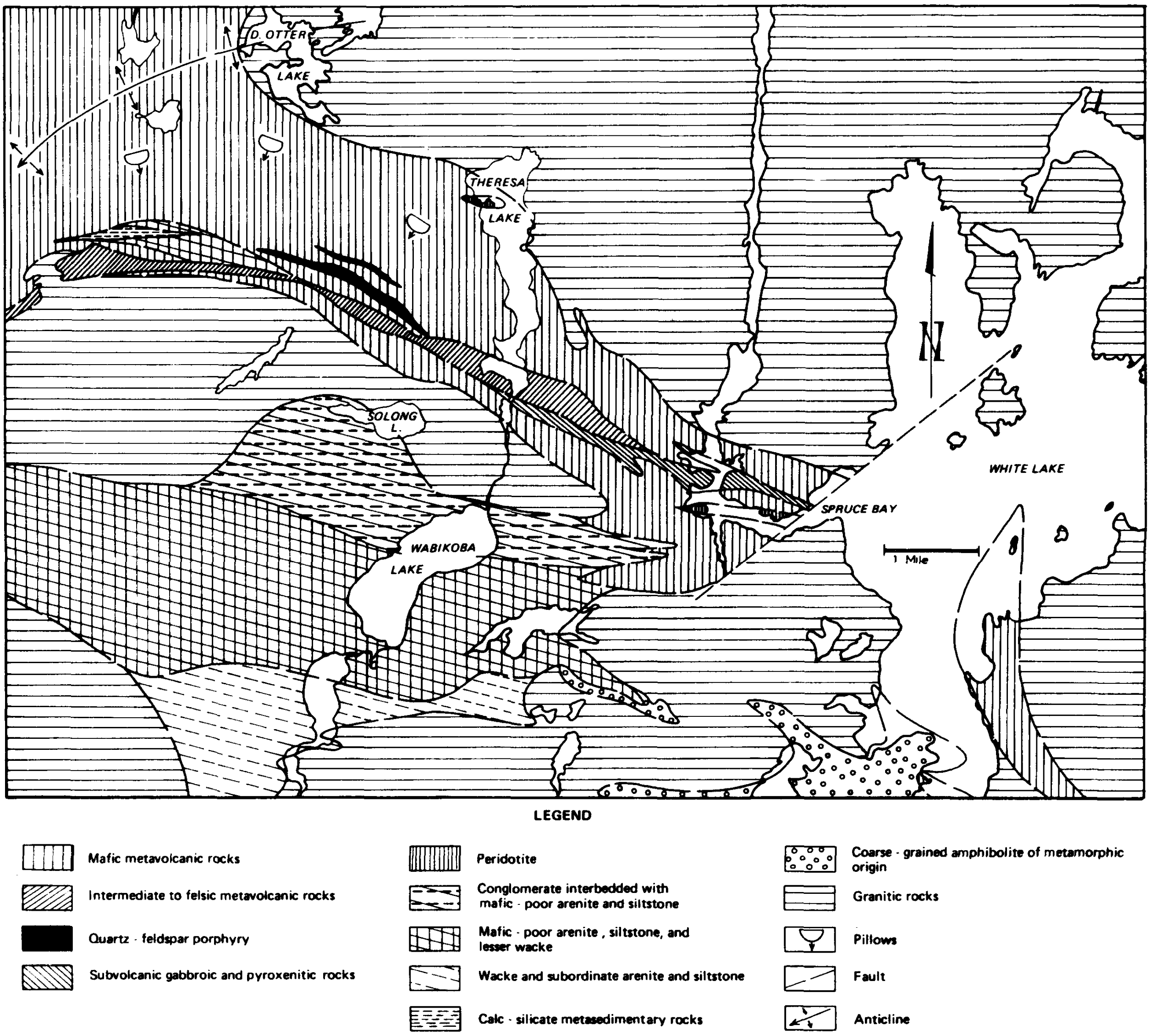


Figure 1. Generalized sketch map illustrating the main geological features of the Theresa Lake area. (Project 10.)

located in the mafic metavolcanic belt of the Theresa Lake area, 2.3 km south of the southeastern tip of Dead Otter Lake. This assay value is consistent with the observation (J. Dumouchel, Geologist, Orequest Consultants Limited, Qued property, personal communication, 1984) that in the Qued property significant gold values are predominantly found in interflow sediments and in banded ironstone interbedded with the mafic metavolcanic rocks. The occurrence of gold in these rocks could indicate that there was a favourable interaction of sedimentary and exhalative processes during periods of relative quiescence between extrusive phases of active volcanism. Thin units of these rocks appear to be more common in the upper stratigraphic section of the mafic belt (*see* section on "General Geology"). Such conditions, *per se*, make the southern half of the belt an attractive terrain for gold prospecting. Gold exploration in this area, however, should not be confined to interflow wackes and ironstone bands alone, because metamorphic features could have equal or greater merit as targets. This is suggested by the occurrence of visible gold in the nose of a small (0.5 m^2) fold (J. Dumouchel, personal communication, 1984). At the time of the author's visit to the Qued property the sample containing visible gold had been removed. As observed by the author, the folded mafic metavolcanic rocks also display moderate shearing and gossan development. The occurrence of a prominent unit of quartz-feldspar porphyry in the area (*see* section on "General Geology") is an additional positive element in relation to the gold potential of the southern half of the belt.

In the Spruce Bay area of White Lake the whole belt is truncated by the White Lake fault (Milne 1968). During present mapping several gossan zones were noted in the mafic metavolcanic rocks along the western side of the southern channel of Spruce Bay. Some of these gossan zones are accompanied by pronounced silicification and/or hematization. A sharp contact was observed between variably sheared metavolcanic rocks and granitic rocks in a large outcrop located along the fault, about 500 m south of the southernmost gossan. The presence of these gossans, and their possible genetic relationship to the White Lake Fault, could justify prospecting of this area.

ANIMONS LAKE AREA

The complex deformation undergone by the supracrustal rocks in the Animons Lake Area could have resulted in local conditions favourable to gold mineralization. A metasedimentary unit which is about 50 m thick and is affected by west-northwest trending shearing, is exposed along the eastern side of a narrow north-trending swamp located 1170 m west-southwest from the southern tip of Animons Lake. This unit contains abundant "eyes", lenses, and hook-shaped "shreds" of bluish-grey quartz up to 60 to 70 cm in size. The hook-shaped quartz shreds are not sheared or fractured; this and their shapes indicate that ductile shearing of the whole rock mass occurred while silicification was in progress, rather than shear-folding of pre-existing quartz veins. The northern end of this unit is marked by an apparently narrow although conspicuous gossan zone. Due to the apparent interaction of metasomatic (i.e. silicification) and deformational (i.e. shearing) processes this locality is recommended to prospectors. Other localities which could be of interest to prospectors include the northern part of the small lake located 1220 m east-southeast from the southern tip of Animons Lake, and a gossan located along the western bank of the Bremner River east-southeast of the same reference point. The former locality is approximately 300 m southwest of the inferred fault crossing the Animons Lake area (*see* section on "General Geology"), and the latter is along it. Thus the structural conditions are similar to those previously described for the White Lake Fault.

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11. Josephine-Goudreau Area, District of Algoma

R.P. Sage

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INTRODUCTION

As part of the continuing long-range mapping program of the Wawa area (Sage 1983, Figure 2) portions of 5 townships were mapped during 1984. Mapping of 1 township, LeClaire, was completed.

MINERAL EXPLORATION

AGUONIE TOWNSHIP

Mapping in 1984 was conducted along and east of the Algoma Central Railway (ACR) tracks, and along a logging access road that straddles the Aguonie-Bird Township boundary. Mineralization was not previously known to occur in the area of the ACR tracks examined this year. Approximately 2.8 km south of Goudreau and 0.4 km east of the ACR tracks a trench containing sphalerite mineralization was located and documented by the field party (Figure 1). No previous record of this sphalerite occurrence is listed in the files of the Resident Geologist Office, Ontario Ministry of Natural Resources, Sault Ste. Marie. The trench was heavily overgrown and displayed no evidence of recent work.

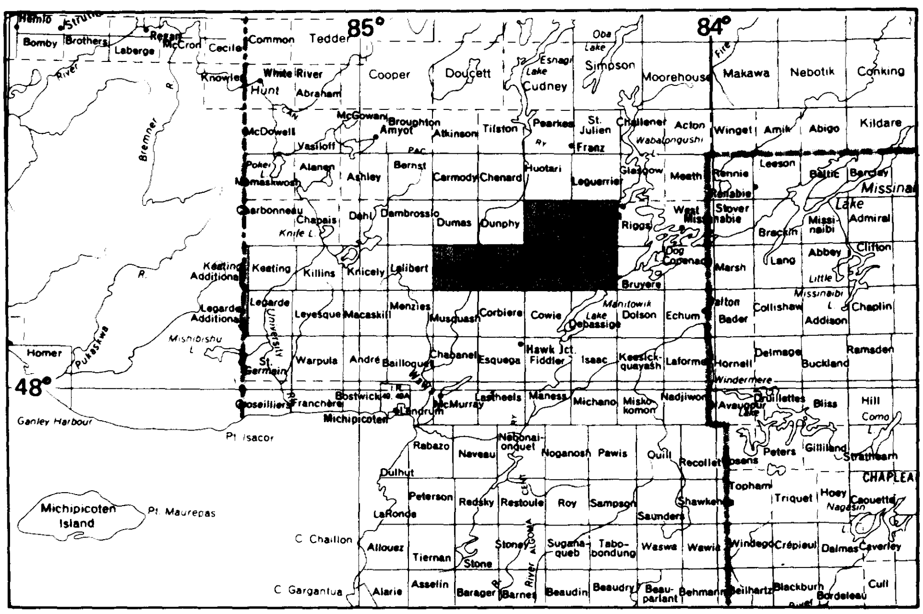
At the southern end of this trench, 92 cm of sheared, carbonatized, and silicified intermediate to felsic tuff is cut by sphalerite-filled fractures up to 3 cm wide. North of and adjacent to this sphalerite-rich zone, an additional 45 cm contains up to 8 mm wide sphalerite-filled fractures. A total width of 137 cm of visible sphalerite mineralization is present. Galena and chalcopyrite are not present in significant quantities, and disseminated pyrite is the only sulphide occurring in notable concentration along with the sphalerite.

Assays by the Geoscience Laboratories, Ontario Geological Survey, Toronto, indicate the presence of little gold, trace to minor silver, and major quantities of zinc. Table 1 shows the assay data and Figure 2 indicates the position of the samples.

Logging activity has provided road access to the eastern part of Aguonie Township. The area has been prospected in the past and is presently being examined by Manwa Exploration Services Limited.

BIRD TOWNSHIP

Manwa Exploration Services Limited is currently examining the western part of the township where logging operations have permitted road access.



LOCATION MAP

Scale : 1 : 1 548 000 or 1 inch to 25 miles

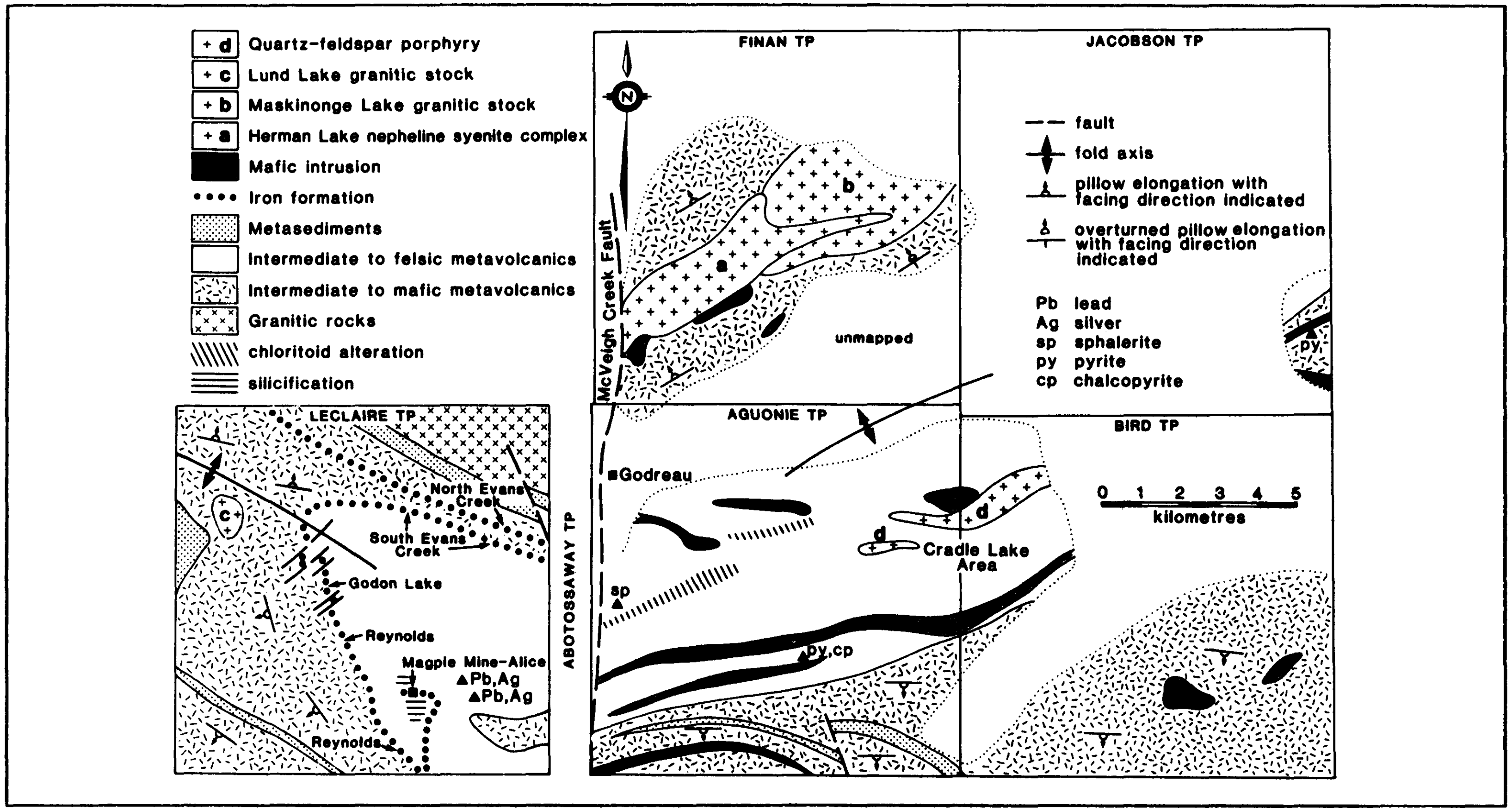


Figure 1. Sketch map of geology encountered in the map area. Diagram includes work completed in previous years. (Project 11.)

The field party encountered no evidence of recent or past exploration activity in the Manitowik Lake area. Assessment File records in the Resident Geologist Office, Sault Ste. Marie, and the Assessment Files Research Office in Toronto, indicate that several gold occurrences are present in the area of Manitowik Lake; however, these were not located during the current field season.

FINAN TOWNSHIP

Mapping was concentrated within the west central area of the township. Mapping outlined the Herman Lake nepheline syenite complex. Staking is evident in the area but evidence of surface work is generally absent. The area north and south of the syenite complex is underlain by metavolcanic rocks, and does not display evidence of recent prospecting activity although recent claim staking and line cutting were observed.

LECLAIRE TOWNSHIP

Mapping within this township was completed in 1984. Work was concentrated in the southwestern quarter of the township and in scattered areas of the southeastern corner. The area contains a number of iron formations which have been extensively prospected in the past (*see* Sage 1983). The iron formations have been tested by The Algoma Steel Corporation Limited and the area examined for its base metal potential by Acme Gas and Oil Limited, Umex Exploration Limited, and Noranda Exploration Company Limited. The area is now being investigated by Manwa Exploration Services Limited.

TABLE 1: ASSAY DATA FROM SPHALERITE OCCURRENCE, AGUONIE TOWNSHIP. (PROJECT 11.)

Sample	Au (oz/ton)	Ag (oz/ton)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Sample Width
1	0.01	1.59	1290	92	11.4%	92 cm
2	<0.01	0.16	282	34	4.78%	137 cm
3	<0.01	<0.10	43	24	8550	183 cm
4	<0.01	<0.10	31	316	780	61 cm
5	<0.01	<0.10	23	120	435	51 cm
6	<0.01	<0.10	18	110	1440	43 cm
7	<0.01	<0.10	64	20	3860	46 cm
8	<0.01	<0.10	222	228	5.95%	92 cm

Sample	Type of Sample	Comments
1	chip	Main mineralized zone
2	chip	Total width of "good" mineralization
3	chip	Altered intermediate to felsic tuff, up to 2% pyrite
4	channel	Sheared tuff marginal to quartz vein
5	channel	Sheared tuff, carbonatized, disseminated pyrite
6	channel	Quartz vein
7	channel	Sheared and altered sericite schist
8	channel	Main mineralized zone

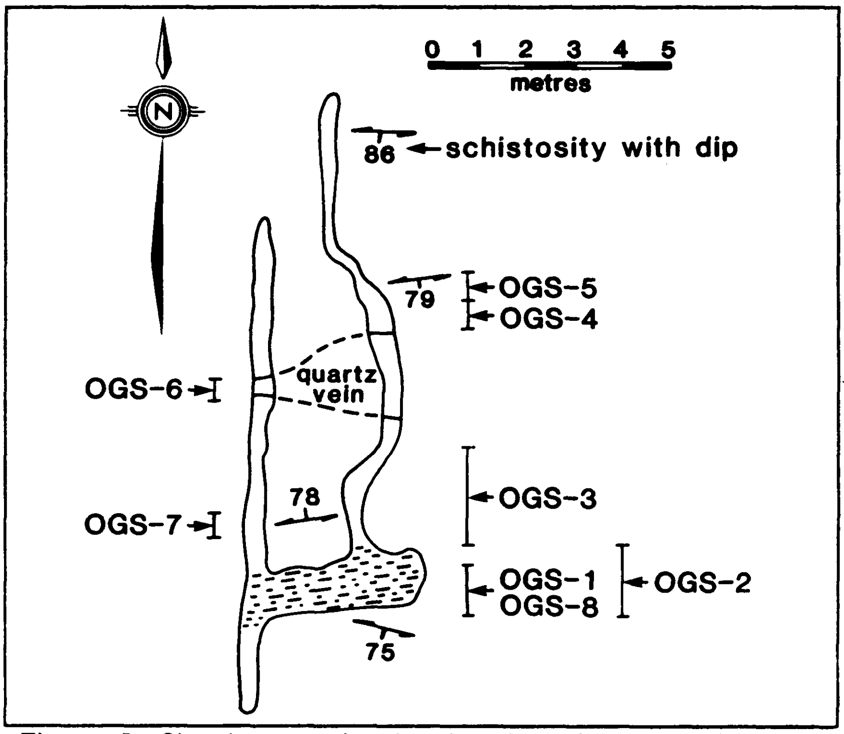


Figure 2. Sketch map showing location of samples from the Augonie Township sphalerite occurrence. (Project 11.)

JACOBSON TOWNSHIP

One narrow band of pyrite was encountered in a old water-filled trench on the southern shore of Old Cabin Lake. Evidence of prospecting activity was not encountered in the area mapped, but gold occurrences are present north and west of the area examined.

GENERAL GEOLOGY

AGUONIE TOWNSHIP

The area along and east of the Algoma Central Railway tracks is mostly underlain by intermediate to felsic tuff and feldspar crystal tuff intruded by fine-grained quartz diorite. The rocks are schistose and contain abundant carbonate minerals.

The area along the southern boundary of Aguonie Township adjoining Bird Township is underlain by intermediate to mafic metavolcanic rocks consisting of tuff, and pillowed to massive flow units. North of the mafic metavolcanic rocks is an extensive area of coarse volcanic breccia, of intermediate to felsic composition, with subordinate amounts of tuff, lapilli tuff, and feldspar crystal tuff of similar composition. The intermediate to felsic rocks are intruded by a fine-grained quartz diorite containing fine-grained blue opalescent quartz. The coarse breccia is centred south and southwest of Cradle Lake.

Near the northern boundary of the township several quartz-feldspar porphyry bodies have been partly delineated. The large areal extent of coarse breccia and quartz-feldspar porphyry intrusions represents the greatest volume yet encountered for these units in the Wawa area.

A narrow band, approximately 1 km wide, of fine-grained wacke strikes just south of east along the southern edge of the township.

BIRD TOWNSHIP

The geology from south to north along the logging access road situated along the western boundary of this township is the same as that found in Aguonie Township. The rocks in the southeastern corner of the township are intermediate to mafic in composition. These rocks consist of tuffs and pillowed to massive flow units.

Rocks of andesitic to dacitic composition reported by Downes (1983) to be present in the northwestern corner of Dolson Township, adjacent to the southeastern corner of Bird Township, were not encountered. Several minor cherty iron formations and several narrow, intermediate to felsic, laminated tuff units were encountered during mapping.

FINAN TOWNSHIP

Mapping in the west central part of the township completed the delineation of the Herman Lake nepheline syenite complex. The complex consists of a coarse-grained nepheline syenite rim and a coarse-grained cancrinite syenite core. The cancrinite is likely an alteration of nepheline and the 2 varieties of syenite likely comprise the same phase.

The nepheline syenite complex is cut by fine-grained quartz syenite to granite dikes. The intrusion is poorly exposed.

The rocks north and south of the syenite complex are dominantly massive and pillowed mafic metavolcanic flows.

LECLAIRE TOWNSHIP

The southwestern half of the township is underlain mostly by massive and pillowed intermediate to mafic metavolcanic rocks. A narrow unit of siltstone-wacke strikes northwest along the southern half of the township and is bounded on both sides by intermediate to mafic metavolcanic rocks. Wackes also occur along the western margin of the township and extend beyond the limits of the township.

Carbonate facies iron formation comprises the Magpie Mine iron range, and along strike it passes into the oxide (magnetite) facies of the Alice iron range. The transition may be the result of metamorphism as granitic rocks are encountered in scattered outcroppings east of Alice Lake, which implies the presence of a granitic intrusion.

Exploration of these iron ranges was summarized by Sage (1983).

JACOBSON TOWNSHIP

Outcroppings in the Old Cabin Lake area are sparse. Mapping indicated the presence of intermediate to mafic metavolcanic rocks consisting of massive to pillowed flow units, and schistose tuffs of intermediate to felsic composition. Fine-grained quartz diorite intrudes the metavolcanic rocks.

STRUCTURAL GEOLOGY

AGUONIE TOWNSHIP

On the basis of pillow shapes within the massive to pillowed section of metavolcanic rocks and on the basis of sedimentary structures in the metasedimentary rocks, the sequence examined faces south. There is essentially a total lack of bedding and consequently facing data in the intermediate to felsic rocks. The extensive development of coarse breccia in the Cradle Lake area suggests either repetition of section or an oblique section through the coarse breccia. The lack of facing data inhibits structural interpretation. The intermediate to felsic rocks of the Cradle Lake area are commonly fissile, displaying a penetrative schistosity. The south-facing section in Aguonie Township in conjuction with a north-facing sequence in adjacent Finan Township to the north indicate a regional anticlinal structure as suggested by Goodwin (1962).

In the southeastern corner of Aguonie Township, a previously unrecognized fault offsets the metasedimentary unit approximately 1.0 km.

The western margin of Aguonie Township is marked by a prominent topographic lineament. This lineament reflects the McVeigh Creek fault. Major compositional variations within the metavolcanic rocks allow a general correlation to be made across the fault. Correlation suggests both horizontal and vertical offsets of indeterminate displacements.

BIRD TOWNSHIP

On the basis of pillow shape and grain gradation in narrow tuffaceous bands, the sequence in the southeastern corner of the township faces south. Some north-facing grain gradations were encountered in the metasedimentary unit in Aguonie Township and in the southwestern corner of Bird Township. Additional mapping will be required to determine if this reversal in facing data is the result of faulting or folding or both.

The rocks commonly display a pronounced schistosity which becomes better developed as the southern boundary of the township is approached. Manitowik Lake occupies a pronounced regional lineament and is the locus of major faulting which parallels faulting trends within the Kapuskasing Structural Zone. Correlation of units across the fault is not possible.

Structures encountered along the western margin of Bird Township are described under Aguonie Township.

FINAN TOWNSHIP

On the basis of pillow shapes occurring north and south of the structureless Herman Lake syenite, the stratigraphy faces north.

LECLAIRE TOWNSHIP

Mapping in LeClaire Township covered the southern limb of the Centre anticline of Goodwin (1962). On the basis of pillow shape and rare primary sedimentary structures, the stratigraphy faces south, becoming slightly overturned in the extreme southwestern corner. Primary sedimentary structures in the sedimentary rocks along the western boundary of the township face predominantly west; however, numerous reversals were encountered. On the basis of regional stratigraphy the section most likely faces west.

JACOBSON TOWNSHIP

Within the area mapped facing data is absent. Some of the metavolcanic rocks are fissile, indicative of intense shearing.

ECONOMIC GEOLOGY AND RECOMMENDATIONS TO PROSPECTORS

AGUONIE TOWNSHIP

Iron staining of the intermediate to felsic tuffs is common in proximity to, and along strike from, the sphalerite occurrence in Aguonie Township; the author suggests that this area warrants prospecting. The presence of large volumes of coarse intermediate to felsic volcanic breccia south of Cradle Lake indicates a proximal vent facies which is favorable for base metal sulphide mineralization. North of the area mapped, several gold and scattered base metal occurrences are present.

BIRD TOWNSHIP

The area mapped along the western margin of Bird Township has a similar economic potential to that described for Aguonie Township.

The southeastern corner of Bird Township has potential for gold mineralization and several occurrences are reported to be present in the area, though these were not located during the past field season. Minor sulphide mineralization occurs with the iron formation, however this mineralization appears to be exclusively barren pyrite.

FINAN TOWNSHIP

Mineralization is not known to occur within the Herman Lake syenite complex. The orange-yellow cancrinite in the grey syenite would make an attractive ornamental stone.

The intermediate to mafic metavolcanic rocks north and south of the syenite stock have a potential for gold even though occurrences are not known within the area mapped.

LECLAIRE TOWNSHIP

Diamond drilling of the iron formation and surface sampling by members of the field party failed to detect mineralization of economic interest other than iron. Drill testing of several conductors by Acme Gas and Oil Limited and Umex Exploration Limited also did not locate mineralization of economic interest.

Two quartz veins situated east of the Magpie Mine containing galena, pyrite, fluorite, and calcite, were extensively tested by trenching many years ago. Silver and gold is reported to be present (Assessment Files Research Office, Ontario Geological Survey, Toronto).

The rocks mapped in LeClaire Township are favorable for gold, iron, and base metal mineralization. More effort should be spent prospecting for gold even though past efforts have not been successful.

JACOBSON TOWNSHIP

The sulphide occurrence on the southern shore of Old Cabin Lake was mapped as iron formation by Bruce (1940). On the basis of trench samples, the iron formation, if present, does not exceed 0.3 m in width and has a relatively minor iron content.

The geological setting encountered near Old Cabin Lake is favorable for both base metal and gold mineralization.

GENERAL COMMENTS

Several past exploration efforts have involved extensive geophysical surveys with follow-up efforts centred on anomaly testing. These surveys have repeatedly identified the same anomalies. Long linear anomalies known to coincide with iron formation have generally not been seriously examined. While repeating a geophysical survey can possibly be justified if more sophisticated equipment is used or flight direction/spacing is changed, there comes a point of diminishing returns for money expended.

While the use of geophysical techniques will remain an important component of any exploration program within the Wawa area, much greater use of geological mapping, geochemical surveys, and metallogenic modeling studies is required than has been the case in the past. Such studies will aid in outlining potential areas for investigation within the iron formations and those mineralized areas that have little if any geophysical expression. Airborne surveys examined by the author indicate a lack of geophysical expression for the sphalerite occurrence in Aguonie Township, a lack of geophysical expression for the galena-silver-fluorite mineralization east of the Magpie Mine in LeClaire Township, and only very weak anomalies in the general area of the Kozak Pb-Zn-Ag-Au occurrence in Abotossaway Township (Sage 1983). Gold, a commodity of considerable interest in the Wawa area, has no geophysical expression, and unless one is restricting the search for gold only to conductive zones, then one should use such surveys with caution.

Given the state of existing technologies and available data, the search for precious metal and some base metal deposits should involve an integrated program with greater emphasis on geology and geochemistry than has been the case in the past. Any comprehensive exploration program will therefore likely involve a commitment to carefully planned mapping and sampling techniques.

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12. Batchawana Synoptic Project

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INTRODUCTION

A synoptic study of the Batchawana area has been in progress since 1981 in order to integrate and summarize existing and new geological information. The field work component of this study has been completed and the remainder of the study will be directed towards understanding geological environments to assist in the assessment of the economic mineral potential of the area. Geological mapping at detailed and reconnaissance scales has been carried out in areas of known high mineral potential and in previously unmapped areas. Field, mineral deposit, lithogeochemical and thin section data are being compiled into a geological computer database to provide an integrated system for investigative and archival purposes.

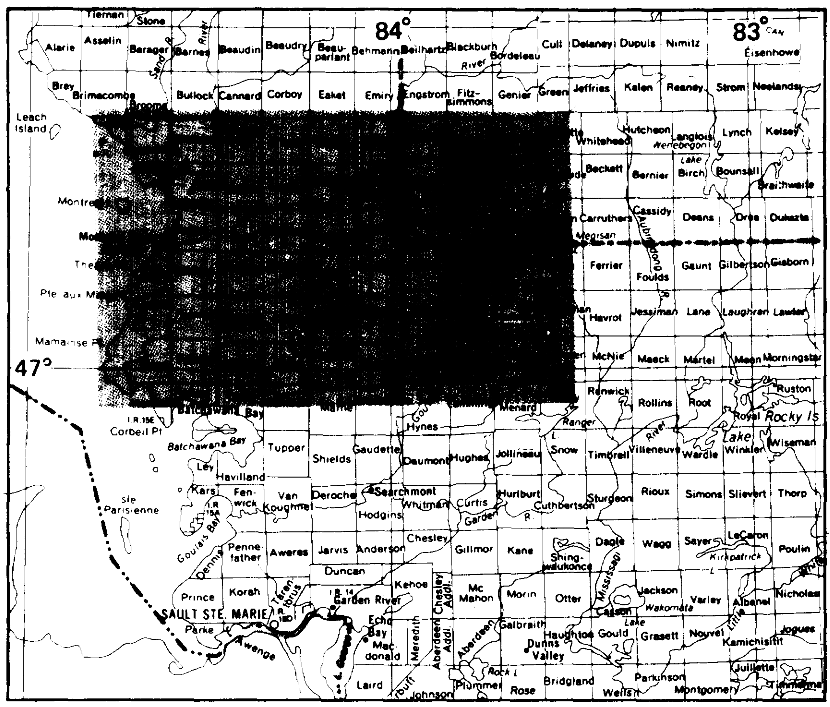
The stratigraphy, chemistry, alteration, geochronology, and structure of the Archean supracrustal assemblage and the types, structures and ages of the surrounding high grade metamorphic rocks and plutonic rocks are being examined in order to determine the history of development of the supracrustal assemblage and its subsequent deformation. A review of the main mineral occurrences and mines is being compiled. U-Pb age determinations have been carried out by the Royal Ontario Museum (Corfu and Grunsky 1984, also *see* "Geochronological Studies in the Batchawana Area" (Project 13.) this volume). Paleomagnetic studies of diabase dikes in the area have been carried out by E. Shaw (1984) and H.C. Halls at the University of Toronto (*see* Project 13, this volume).

A computer-based format for recording field data has been developed by Grunsky and Stott (*see* Ambrose *et al.* this volume). The system has been used since 1982 and is being modified and refined for broader applications. Currently, field data are being recorded in field base camps on a battery operated microcomputer with cassette tape mass storage and modem hook-up to a PDP 11/34 mini-computer at the Ontario Geological Survey in Toronto. The objective of this system is to create computer-accessible files containing the field notes of any given area. These field data files have been created for the Batchawana area and will be integrated with the data files listed above.

A bibliography of geological maps, reports, papers, and theses for the Batchawana area has been compiled. Preliminary maps (scale 1:50 000) are being prepared which will incorporate previous geological maps, mineral exploration company maps and reports, and the author's field work.

MINERAL EXPLORATION

Exploration for gold has resulted in a number of companies investigating the Batchawana area. Massive Energy Corporation holds a 263 claim group in the Davieaux Township area (Figure 1), where they are carrying out a regional exploration program. They are also evaluating a gold occurrence currently known as the Hammer-Bridge Property and previously known as the New Hiawatha Mines Occurrence. Significant gold values have been reported in 1 locality. Other precious and base-metal occurrences are also being investigated by Massive Energy Corporation. Detailed geological mapping is being carried out over much of the



LOCATION MAP Scale : 1 : 1 584 000 or 1 inch to 25 miles

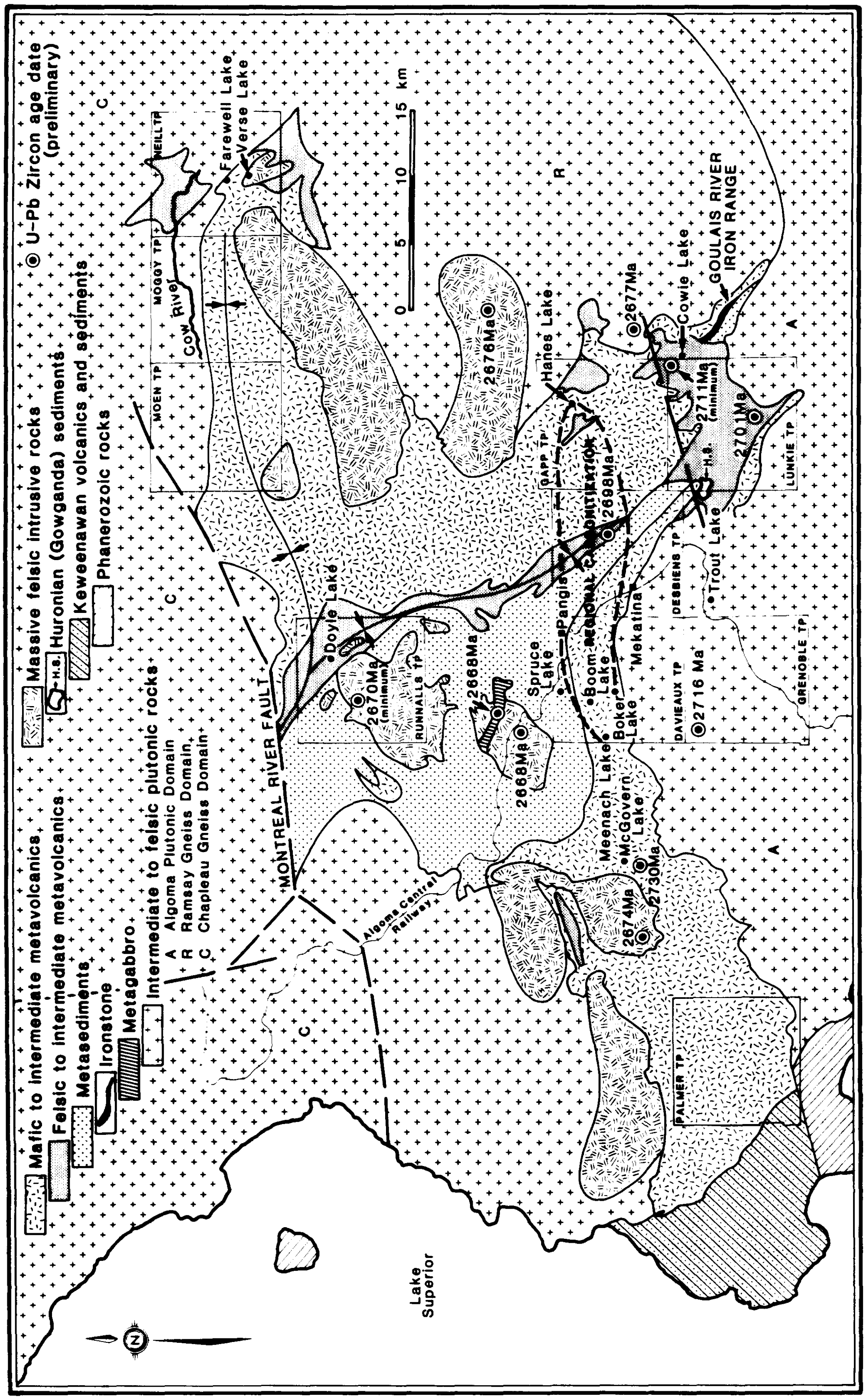


Figure 1. Generalized geology and preliminary U-Pb zircon age dates in the Batchawana synoptic area. (Project 12).

area held by them. To date, 15 drillholes have been put down and a number of horizons containing anomalously high gold values have been intersected.

Investigation of a reported gold occurrence in the Neill Township area is being carried out by Hollinger Argus Limited. A gold occurrence reported in felsic metavolcanic rocks and metasedimentary rocks west of Verse Lake is being investigated by the same company (Figure 1). The author submitted several samples from this area for assay. Gold values submitted were low (only one sample >200 parts per billion (ppb)). The area was stripped by Hollinger Argus Limited in 1 locality where an anomalous gold value occurs. Geological mapping was carried out by Hollinger Argus Limited in the Waverley Creek area of Neill Township.

Noranda Exploration Company Limited carried out an aeromagnetic survey in areas of Moen, Moggy, Neill, and Schembri Townships in early 1984. The survey covers a number of claim groups held by them. The effects of magnetite ironstone and diabase dikes mask any subtle features that might be reflected in the bedrock and subsequently no recommendations were made for further exploration.

A trench located in Neill Township, on what is locally known as the Burns Property, has been cleared out and several plugger holes were observed. No further information is available.

Dejour Mines Limited has been carrying out a geochemical soil sampling survey on a group of claims immediately south of the ground held by Massive Energy Corporation. Dejour Mines also holds ground in Neill Township for which a geological map has been prepared by the company.

Manwa Exploration Limited holds a large group of claims throughout the Batchawana area. A geological report with recommendations has been prepared and an airborne geophysical survey has recently been flown.

Noranda Exploration Company Limited carried out geophysical work over a group of claims in the Hanes Lake area of Gapp Township. This group of claims is currently held by Mid-Canada Salvage and Mr. R. Fraser. A detailed geological map and report of an area containing a massive sulphide Zn-Cu showing in the claim group area has been prepared by Mr. Fraser (Assessment Files, Resident Geologist Office, Ontario Ministry of Natural Resources, Sault Ste. Marie).

The machinery of the Tribag Mine in Nicolet Township is being removed from the mine site. No additional work has been reported on the Tribag Mine since Jonpol Explorations Limited took over the area from DeKalb Corporation in 1983.

GENERAL GEOLOGY

METAVOLCANIC AND METASEDIMENTARY TERRAINS

Davieaux Township Area

Supracrustal rocks are composed of mafic metavolcanic tuffs and flows, and metasedimentary rocks (wackes, mudstones, and siltstones) with minor intercalated units of dacitic tuff.

The environment of formation is interpreted as distal volcanic and deep water. To the south, mafic tuffs and flows predominate. To the north, the metasedimentary rocks become increasingly abundant. Further north in the Wart Lake area, bedded siltstones, wackes, and conglomerates predominate (Siragusa 1981).

The supracrustal rocks that extend from the Hanes Lake area in Gapp Township into the Meenach Lake area in Davieaux Township also contain zones of carbonatization (*see* Figure 1). These zones strike east-west and pervasive carbonatization occurs within metasedimentary rocks and metatuffs. Carbonate veins accompanied by some pervasive carbonate replacement within mafic flows may be related to the numerous east-west faults that occur throughout the south central part of the Batchawana Belt. Several samples were collected by the author to determine if there is any regionally anomalous zones that may have economic significance.

The southern portion of the supracrustal assemblage in Davieaux Township has in part been mapped by Dejour Mines Limited. Dejour Mines Limited reports that the area is underlain by a mixed volcanic sequence consisting of mafic to felsic metavolcanic rocks, tuffs, and clastic metasedimentary rocks. Several interflow units composed of felsic metavolcanic tuffs, arkose, and argillaceous metasedimentary rocks occur between mafic to intermediate metavolcanic flows. Pillow top determinations indicate tops are to the north. Silicification has been reported in the mafic metavolcanic rocks. There are also locally developed zones of carbonatization throughout the sequence.

Neill Township Area

The east central part of the township is underlain by a massive granodiorite stock, the centre being covered by Verse Lake. Eastward the stock becomes increasingly foliated and quartz porphyritic towards the margin. The supracrustal rocks at the eastern contact are quartz-plagioclase-biotite ± hornblende schists. Their composition, and the presence of relict clasts suggest that these rocks were wackes, arenites, and conglomerates. The eastward extent of these units has not been mapped out although it is unlikely the supracrustal rocks extend more than 1 km to the east. A geological report submitted for assessment credits by Hollinger Argus Limited describes the area west of Verse Lake. The 2 most common units encountered west of Verse Lake are a fine-grained tuff that with increasing metamorphism is transitional to a light green-grey quartz-plagioclase-muscovite ± hornblende ± biotite ± pyrite schist and a fine-grained hornblende feldspar-quartz amphibolite. These rocks have been interpreted by the author as distal felsic tuffs, quartz arenites (reworked/waterlain tuffs), wackes, mudstones, and mafic tuffs.

Gapp Township

A re-examination of a sequence of metavolcanics along a recently constructed road in Gapp Township has shown that an area previously interpreted to be underlain by felsic and mafic metavolcanic rocks is in fact underlain by massive and pillowed mafic metavolcanic flows with interbedded metasedimentary rocks comprised of debris flows, pyrite-chert ironstone, wackes, siltstones, and argillites. The lowest part of the section extends from Hanes Lake westward and up section to Watson Lake. The metasedimentary rocks in the upper part of the section are generally finer grained than in the lower part. Extensive carbonatization has developed in both the metavolcanic rocks and metasedimentary rocks. The development of the carbonatized zones is possibly related to a major east-west fracture/fault west of Hanes Lake.

ECONOMIC GEOLOGY

The economic potential of the Batchawana area has been previously described (Grunsky 1983).

A number of base-metal sulphide occurrences are situated at the mafic metavolcanic-felsic metavolcanic interface in the Gapp-Lunkie Townships area. This potentially favourable interface extends northwestward into Desbiens, Way-White and Runnalls Townships. Running and Schembri Townships also host base-metal occurrences at the mafic metavolcanic-metasedimentary interfaces. Several base metal and precious metal occurrences have been reported in the waterlain felsic tuff sequence in the Doyle Lake area of Runnalls Township (Grunsky 1981). The tuffs grade from quartz-bearing crystal tuffs in the eastern part of Runnalls Township into waterlain distal facies tuffs and interbedded sedimentary rocks west of Doyle Lake. Along the east side of Doyle Lake, several significant sulphide-bearing quartz-plagioclase-sericite schists occur. These sulphide-bearing schists may have been deposited during the hiatus between the underlying predominantly felsic tuffs and the overlying metasedimentary domain. Such a hiatus zone may be favourable for exploration for base metals. Minor amounts of Au and Ag have been reported throughout the Grey Owl Lake-Doyle Lake area (Grunsky 1981).

The area in Gapp Township underlain by metavolcanic rocks and metasedimentary rocks warrants further attention. As mentioned, sulphide-bearing metasedimentary rocks occur interbedded within the mafic metavolcanic rocks in the Hanes Lake area. Also several carbonatized zones that strike westerly and are possibly related to fractures and faults of the same attitude are present. The presence of sulphide mineralization within the mafic metavolcanic rocks and interbedded metasedimentary rocks suggests a potential for massive sulphide deposits; the carbonatization and associated structural breaks may have potential for precious metal mineralization.

To the west in Davieaux Township, a zone containing gold mineralization has been outlined by Massive Energy Corporation. The gold occurs in a pyrite-chert ironstone horizon, about 5 m wide, that is underlain by a massive mafic metavolcanic flow and overlain by felsic crystal tuff. The gold mineralization appears to be in part structurally controlled. Two grab samples taken from the property by the author in 1982 contained 1880 and 2280 (ppb) gold (Geoscience Laboratories, Ontario Geological Survey, Toronto).

Additional samples collected within the Hammer-Bridge area by the author in 1983 and during the current field season show a high backround in gold values (>200 ppb). Additional samples from the Hammer-Bridge property indicate 5800 ppb and >1 parts per million (ppm) Au. The rocks stratigraphically above the sulphide-bearing schists are strongly carbonatized. Anomalous gold values are present within several quartz - plagioclase - sericite - pyrite schists within the Davieaux Township area and Massive Energy Corporation has drilled 15 holes that intersected sections with anomalously high gold values (Assessment Files, Resident Geologist Office, Ontario Ministry of Natural Resources, Sault Ste. Marie). The area is underlain by a mixed sequence of mafic metavolcanic flows and intrusions, felsic tuffs, and interbedded metasedimentary rocks. To the west in the Meenach Lake-McGovern Lake area this sequence is principally composed of mafic metavolcanic flows and intrusions. Eastward, into Desbiens Township, the rocks are more tuffaceous and sedimentary in character. Several faults trending east-west and northeasterly are present in the Davieaux Township area. Associated with many of these faults are zones of carbonatization that trend easterly into Desbiens and Gapp Townships. These areas warrant further investigation for precious metal potential.

During the field season of 1983 the author visited a showing in Palmer Township known as the Bjoorna Property (Assessment File fiche Palmer-0018, Resident Geologist Office, Ontario Ministry of Natural Resorces, Sault Ste. Marie). Two samples of mafic metavolcanic rocks containing sulphide mineralization in veins and pods were collected by the author and assayed by the Geoscience Laboratories, Ontario Geological Survey, Toronto, they contained 970 ppb Au, 460 ppb Au, and 1320 ppm Cu. The sulphide mineralization occurs in the shear zones within interflow units and is parallel to the strike of the bedding. The Mamainse Lake-Palmer Township area is underlain principally by massive and pillowed mafic metavolcanic rocks; however, these sulphide-bearing zones may also be significant within the western mafic metavolcanic rocks and give the area additional potential for massive sulphide and precious metal deposits.

In the centre of Davieaux Township, 1 km north of Buker Lake, a previously unreported occurrence of numerous beds of sulphide-bearing chert ironstone interflow units, up to 10 cm thick, occur within mafic metavolcanic rocks. The units are composed of pyrrhotite and recrystallized chert. Samples have been collected for assay.

A magnetite-chert ironstone occurrence (previously known as the Gimby prospect) in south central Palmer Township is currently being investigated for its gold potential.

The Neill Township area has been examined for gold by Hollinger Argus Limited. To date, the best gold value has been 0.066 ounce per ton and occurs within a felsic metavolcanic tuff (Assessment Files, Resident Geologist Office, Ministry of Natural Resources, Sault Ste. Marie). The area around the assay location has been stripped and further work has been carried out. The Neill Township area may be a favourable area for gold exploration because of the abundance of quartz-plagioclase-muscovite-pyrite schists, several stratiform pyrite-bearing zones within these rocks, and a quartz-feldspar porphyry that intrudes along strike. The rocks are structurally complex and units can seldom be traced for any distance along strike. The area warrants further attention, specifically detailed mapping.

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13. Geochronological Studies in the Batchawana Area, Paleomagnetic/Lithogeochemical Studies of Diabase Dikes in the Batchawana Area.

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INTRODUCTION

In the past several years various geochronological, paleomagnetic, and lithogeochemical studies have been conducted in the Batchawana area. Results and future plans for continuation of these studies are summarized below (also *see* Grunsky, this volume, for discussion of the Batchawana area).

The geochronology studies have helped to unravel and in many cases confirm proposed stratigraphic relationships of the Batchawana area. Determining the relative timing of supracrustal formation and emplacement of batholithic complexes has helped in the interpretation of the tectonic evolution of this area.

Paleomagnetic studies have aided structural interpretation of the Lake Superior Basin (Shaw 1984). Initial lithogeochemical studies suggest that it may be possible to distinguish the various dike swarms on the basis of their lithogeochemistry. Future studies are planned to test and refine this conjecture.

GEOCHRONOLOGICAL STUDIES

Corfu and Grunsky (1984) summarized the results of their age determination studies of the Batchawana belt.

The upper metavolcanic sequence located in the southeastern corner of the map area decreases in age to the southwest as seen in Figure 1 of the previous report on the Batchawana Synoptic area. The oldest date in the upper metavolcanic sequence, just west of Cowie Lake, gives an age of $2711.8^{+3.3-2.8}$ Ma, and the youngest age of $2698.3^{+2.2-2.0}$ Ma occurs just east of Gavor Lake. The younger age occurs within a band of felsic metavolcanic tuffs that are situated within the centre of a syncline that strikes northwesterly into Runnalls Township.

Three plutonic domains are present in the area (Card 1979, Card *et al.* 1980). A tonalite pluton of the Algoma Plutonic Domain (*see* Figure 1 of the previous report) gives a zircon (U-Pb) age of 2716.8 ± 1.8 Ma which suggests that this pluton was emplaced prior to or during the development of the upper metavolcanic sequence to the northeast. A massive tonalite from the Ramsay Gneiss Domain gives a zircon (U-Pb) age of $2676.1^{+1.8-1.6}$ Ma, and a massive granodiorite within the same domain gives a zircon (U-Pb) age of $2676.8^{+2.9-2.2}$ Ma. A massive diorite near the edge of the granite-"greenstone" contact gives an age of 2677.4 ± 2.0 Ma.

The massive intrusive stocks that intrude the "greenstone" belt are characteristically younger than the plutonic rocks around the belt. The Grey Owl Lake stock gives a sphene age of 2673 ± 4 Ma, the Griffin Lake Stock a zircon age of 2674.3 ± 2.8 Ma, the Mongoose Lake monzonite a zircon age of $2668.5^{+1.7-1.5}$ Ma, and the Mongoose Lake gabbro a zircon age of 2668.3 Ma.

A preliminary age of approximately 2730 Ma has been reported by F. Corfu, (geochronologist, Royal Ontario Museum, Toronto, personal communication, 1984) for the western mafic metavolcanic group near McGovern Lake. This age date supports the concept that an older mafic metavolcanic group existed prior to being intruded in the south, around 2716 Ma, by the Algoma Plutonic Domain. The younger metavolcanic rocks are predominantly calc-alkaline in composition, range in age from 2700 to 2698 Ma, and are found in the southeastern part of the belt. Coeval with the accumulation of these felsic metavolcanic rocks, a sedimentary basin composed of arenites and waterlain felsic metavolcanic tuffs, which developed in the Grey Owl Lake area of the belt, marks the stratigraphic top of the second cycle of volcanic rocks.

A crystal tuff in Lunkie Township dated by the U-Pb zircon method yielded an age of 2701 Ma. The sphene dating method however, yielded an age of 2647 Ma, which postdates both the regional metamorphism and post-tectonic intrusions. The sample taken for study was less than 10 m from a diabase dike and the sphene age may represent the age of intrusion of the dike. This may be an indirect method of dating diabase dikes that are known to be low in zircon content (Corfu and Grunsky, in preparation).

PALEOMAGNETIC AND LITHOGEOCHEMICAL STUDIES OF DIABASE DIKES

A study of the paleomagnetism of diabase dikes has been carried out by Eric Shaw of the University of Toronto under the direction of H.C. Halls. Shaw (1984) has shown that at least 4 different ages of diabase dikes are present based on the paleomagnetic study. Matachewan, post-Huronian, Sudbury, Keweenawan, a possible Kenora-type, and several previously unknown paleomagnetic directions have been determined.

The author collected 67 diabase dike samples for whole rock geochemical analysis. A subsequent statistical analysis (correspondence factor analysis and dynamic cluster analysis) using the major elements (SiO_2, Al_2O_3, Fe_2O_3, FeO, MgO, CaO, Na_2O, K_2O, TiO_2, P_2O_5, MnO, CO_2, S, and H_2O) distinguished 2 significant groups of samples. The distinction between these populations is that 1 population has higher amounts of Na_2O, K_2O, CO_2 and H_2O. This effect is possibly due to alteration or contamination from the country rock, and at present cannot be conclusively used to distinguish different diabase swarms. When the following trace elements were determined: Ba, Co, Cr, Cu, Li, Ni, Zn, Sc, Sr, U, Y, Zr, only 1 group of diabase dikes is recognized. A study using a combination of major oxides and trace elements (SiO_2, Al_2O_3, Fe_2O_3, FeO, MgO, CaO, Na_2O, K_2O, TiO_2, Ba, Cr, Ni, Zn, V, Y, and Zr) shows 4 distinct groups. One group (32 samples), the largest, represents typical tholeiitic diabase. The second group (9 samples) represent Cr-enriched diabase, the third group (15 samples) represents Zn-enriched diabase, and the fourth group (7 samples) represents Ba, Zr, and K_2O enriched diabase.

At this time it is not known if these groups are representative of different dike swarms. The 2 groups that show, respectively, Zn, and Ba, Zr, K_2O enrichment may represent fractionated and/or altered diabase dikes. The group enriched in Cr may represent a distinct dike swarm, or could represent a difference of sampling between phases that occur within a particular dike; for example, dike margins may contain more Cr than dike centres. A correspondence factor analysis and dynamic cluster analysis was then applied to Barth-Niggli normative minerals calculated from the chemical analyses (major oxides only). Two distinct groups were determined, 1 (20 samples) contains more orthoclase, albite, magnetite, ferrosilite, and quartz than the second group (37 samples), which is more abundant in anorthite, enstatite, diopside, forsterite, and fayalite. These 2 groups appear to distinguish diabases that contain more SiO_2, K_2O, Na_2O and Fe_2O_3 from diabases enriched in CaO, MgO, FeO. This distinction may reflect heterogeneiity in the sampling; that is, dike margins versus dike centre, or it might represent the presence of 2 distinct swarms. An olivine-bearing diabase dike sample known to be part of the Sudbury swarm was grouped within the olivine-enriched group, suggesting that the latter interpretation of 2 geochemically distinct dike swarms may be valid. Further work with a greater number of samples and careful sample selection control needs to be carried out.

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14. Snider Township, District of Sudbury

J.M. Martins

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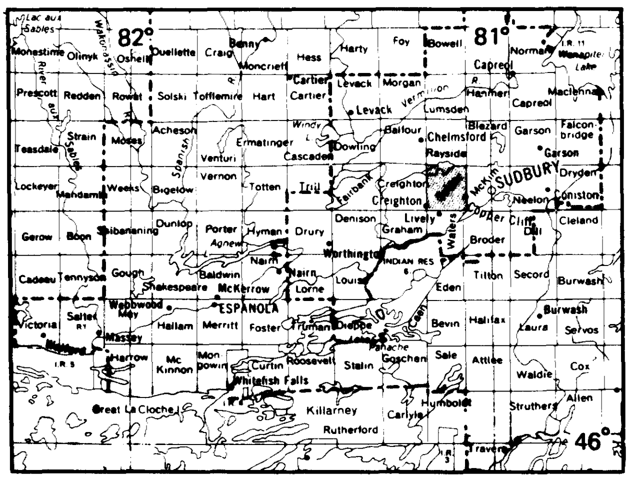
INTRODUCTION

Snider Township is situated 3 miles west of Sudbury. The southeastern corner of the township lies at Latitude 46°27'00"N, and Longitude 81°04'20"W. Highway 17W transects the southeastern corner, Highway 144N the northeastern corner, and Highway 536 terminates in the southwestern corner at Creighton Mine. The remainder of the area is accessible by power lines, bush roads, pipeline roads, a spur of the Canadian Pacific Railway, and Whitewater Lake. Mapping was carried out at a scale of 1:15 840 and covered an area of approximately 58 km^2.



LOCATION MAP

Scale : 1 : 1 548 000
or 1 inch to 25 miles

MINERAL EXPLORATION

There are 3 producing nickel-copper mines in Snider Township, all owned and operated by Inco Limited.

Creighton Mine, situated in a large embayment of the Sudbury Igneous Complex extending out into footwall granite (concession I, lot 10) has been in more or less continuous production since 1900. Nickel was first discovered in the Sudbury area in 1856, a few hundred metres west of the present open-pit. Exploration drilling has outlined the ore down-dip to a depth of more than 3000 m. The most northerly shaft (the No.9) is 2141 m deep and is the deepest continuous shaft in North America (Geological staff, Inco Limited, personal communication, 1983). Ore is shipped to the Clarabelle concentrator.

Copper Cliff South Mine is situated on the narrow quartz diorite Copper Cliff Offset which extends several kilometres south from the Main Mass of the Sudbury Igneous Complex (concession I, lot 1). The orebody was discovered in 1885 along with several others in the same dike. No.2 shaft was sunk in the late 1960s, reaching a vertical depth of 690 m. No.1 shaft was sunk to 1274 m by 1972. A 20° ramp was also completed during this period reaching a vertical depth of 203 m, and is used to mine ore in the Evans orebody to the north. Production at Copper Cliff South Mine commenced in 1970 and continues today. South Mine now includes the original Copper Cliff No.1 Mine which produced 23 452 tons of ore grading 3.39% Cu and 3.55% Ni from open pit workings between 1887 and 1903 (information from Ontario Bureau of Mines, Annual Reports).

To the north the Copper Cliff Offset widens and eventually joins with the Sudbury Igneous Complex. Mineralized zones were discovered in 1884 at the Copper Cliff North Mine (concession III, lot 1). Underground development began in 1960 and 2 shafts were sunk, the No.1 to a vertical depth of 1240 m, and the No.2 to 350 m. Production commenced in 1967 and the mine closed in 1978 due to unfavourable economic conditions. Early in 1983, the North Mine was reopened on a research basis with limited production to test mining methods and equipment.

There are several other nickel-copper deposits in the township which are not presently being worked. Three ore bodies (Copper Cliff Nos. 4, 5, and 6 Mines) discovered in the mid 1880s just to the west of the present North Mine underwent sporadic production around the turn of the century. No further activity occurred until 1960 when the properties were incorporated into a single open pit operation—the Clarabelle No. 1. Ore was produced between 1961 and 1973.

In the late 1800s the North Star orebody was discovered (concession II, lot 9). Production began in 1902 from an open pit, and in 1904 an inclined shaft was put down to 51 m. Total production between 1902 and 1914 when the mine closed was 54 274 tons grading 0.8% Cu and 2.1% Ni.

A small nickel-copper occurrence (Tam O'Shanter property) was discovered in 1893, 2.4 km to the northeast along the Sudbury Igneous Complex contact in lot 6, concession III. Trenching and pitting was carried out in 1895 and some diamond drilling in the 1960s. All of the above properties are presently held by Inco Limited.

Inco Limited carried out a drilling program on granophyre along the southern shore of Whitewater Lake in 1952 (Resident Geologist Files, Ontario Ministry of Natural Resources, Sudbury). All drillholes were vertical and the deepest, at 370 m, was still in granophyre. Two drillholes were also put down on the northern shore of Kelley Lake in 1960 to test the extension of the Copper Cliff Offset dike.

GENERAL GEOLOGY

Published geological maps of the area include compilation maps by Collins (1938), Cooke (1946), Thomson (1956, 1961), Card (1965, 1969, 1978), Card and Lumbers (1977), Burwasser (1977), and Dressler (1983).

The rocks in Snider Township can be broadly subdivided into 3 main groups: the older sequence of Huronian metavolcanic rocks and metasedimentary rocks intruded by the Creighton Granite and the Nipissing diabase in the southern part of the township; the Whitewater Group which infills the Sudbury Basin and occurs in the northern part of the township; and the various units of the Sudbury Igneous Complex striking northeast through the centre of the township. Younger trap and olivine diabase dikes cut all rock types. The Huronian rocks, the Whitewater Group, and the rocks of the Sudbury Igneous Complex of Blezard Township northeast of the present area were described by the author (Martins 1983).

The major difference in the geology between Snider Township and Blezard Township lies in the nature of the granite intruding the Huronian rocks. In Blezard Township the Murray Granite is an equigranular quartz monzonite, whereas the Creighton Granite in Snider Township is a complex, foliated, porphyritic intrusion of quartz monzonite, granite, and granodiorite. A U-Pb zircon age of 2333 Ma for the Creighton Pluton was obtained by Frarey *et al.* (1982). The Murray Granite has been dated at 2230 Ma by Gibbins *et al.* (1972) using Rb-Sr isotopes. The coarsely porphyritic nature of the Creighton Granite becomes less pronounced to the northeast, and at the eastern limit of the township it is equigranular and rather similar in appearance to the Murray Granite in Blezard and McKim Townships. Patches of equigranular granite enclosing main porphyritic Creighton Granite are common, and late-stage leucogranites occur as dikes and veins. Rare earth analyses of the various components within the Creighton and Murray plutons show increasing depletion of the light and middle rare earths from the mafic Creighton granodiorites through the Murray granite to the late-stage leucogranites (Figure 1).

The granitic sills and dikes which characterize the norite and quartz gabbro in Blezard Township north of the Murray Granite become less common north of the Creighton Granite. They are also more varied in nature, one variety being a finer-grained plagioclase-rich aplite, and another a coarser-grained granite with micrographic intergrowth and discontinuous perthite-pegmatite margins. One distinctive series of granodiorite bodies has well developed chilled margins, and inclusions of country rock (quartz gabbro) were noted. This rock is characterized by large phenocrysts of feldspar which under the microscope show advanced saussuritization. Irregular quartzofeldspathic patches up to 0.5 m in diameter and cobble-like quartz bodies are common within the granodiorite.

Within rocks of the Sudbury Igneous Complex, relationships are much as noted in Blezard Township (Martins 1983). One feature of the granophyre which deserves comment is the large number of inclusions within its central portion. The inclusions are subangular to well rounded and up to a 1 m in diameter. Compared to the surrounding coarse-grained pink granophyre they are finer

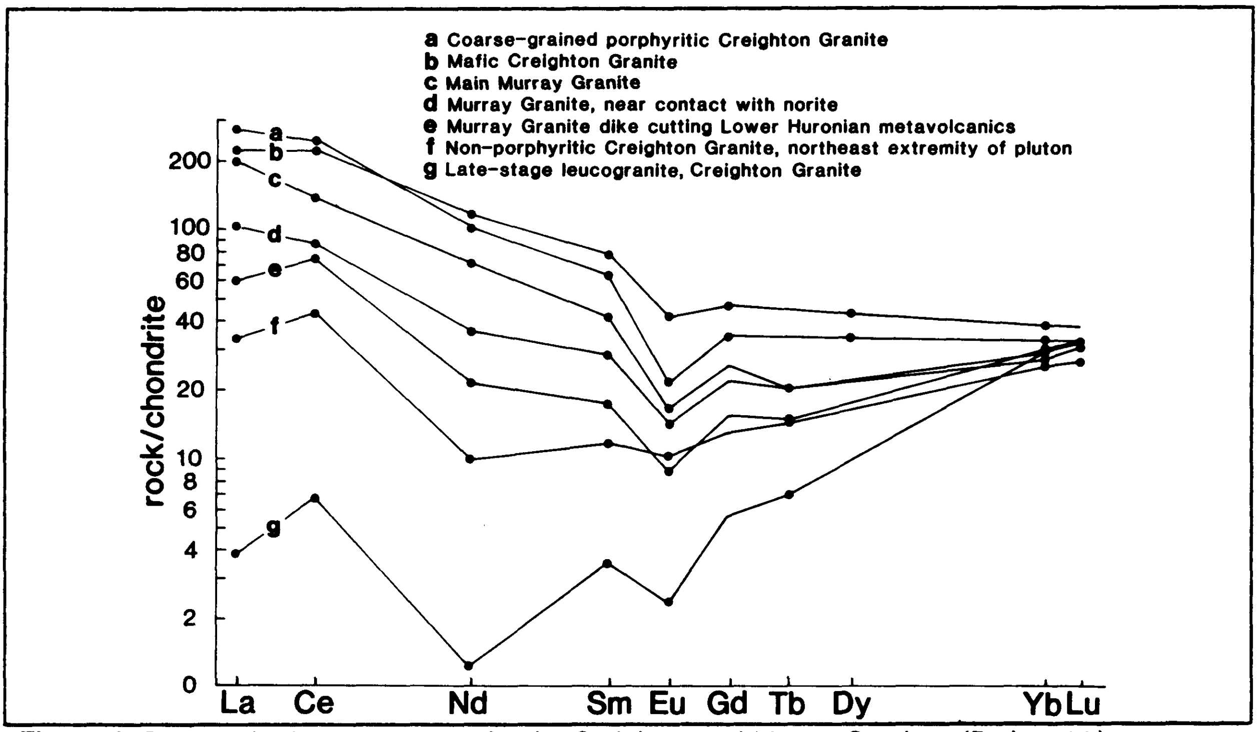


Figure 1. Rare earth element patterns for the Creighton and Murray Granites. (Project 14.)

grained and light grey. The small lathy plagioclases and the reduced quartz and micrographic intergrowth content suggest that these inclusions represent the "plagioclase-rich granophyre" of Perederv and Naldrett (1975) caught up in the later main mass of the granophyre.

A major offset dike, the Copper Cliff Offset, extends from the Sudbury Igneous Complex into the country rock in the eastern portion of the township. Several past producers of Ni-Cu ore and 2 active mines occur along this dike. The noritic zones of the offset are packed with small lenticular to subrounded inclusions of metasedimentary rocks and gabbros, and have complex relationships with the quartz-dioritic barren areas of the offset.

A large body of Nipissing diabase strikes northeast through the southeastern corner of the township. It intrudes arenites and wackes of the McKim Formation.

In the south central part of the township in the Creighton Granite there is a large (5 by 1.5 km) inclusion of Stobie Formation metasedimentary and metavolcanic rocks. This has been interpreted from its weak gravity signature by Dutch (1979) as a possible roof pendant floating in the surrounding granitic rock.

STRUCTURAL GEOLOGY

The strike of the major rock units through the township is northeast. In general, foliations in the various zones of the Sudbury Igneous Complex follow this direction with local variations, and dip to the south. northeastern sector of the granite body they range from 170° with a moderate dip to the east; granite in the southern sector is foliated 050° with steep dips to the north; and in the southwestern sector foliation trends about 070° with steep dips to the south. These variations appear to be related to the proximity of the large Stobie Formation inclusion and are presumably primary features imposed at the time of intrusion. Within the inclusion itself structures are highly deformed with intense ptygmatic folding and *lit-par-lit* granite injection, particularly at the margins. Sudbury Breccia is common throughout the Creighton Granite and its inclusion, foliation directions are disrupted in the breccia zones and apparently antedate the brecciation event. Sudbury Breccia bodies are also common in the other rocks of the Footwall of the Sudbury Igneous Complex.

The Creighton Fault strikes east-southeast (dip

88°N) through the township, displacing the Copper Cliff Offset dike some 400 m to the west. Another major fault trending 035° bounds the northwestern contact of the quartz gabbro with the granophyre in the north central part of the township. The quartz gabbro is also apparently offset to the southeast in lot 9, concession IV by a fault trending 135°, a common direction for the several olivine diabase dikes which were encountered. Another set of diabase dikes ("trap dikes") strikes at 080°. The trap dikes are older than the olivine diabase dikes.

ECONOMIC GEOLOGY

The mineral deposits of Snider Township are the classic Ni-Cu and associated metals deposits of the Sudbury Igneous Complex. No other type of mineralization has been reported. A gossan zone with pyrite was noted in the upper part of the granophyre on the southern shore of Whitewater Lake (concession V, lot 8). On the northern shore of this lake in lot 9, concession VI, trenches were observed on narrow quartz veins cutting the Onaping Formation. Iron staining was present, but no mineralization of significance was observed by the author.

ACKNOWLEDGMENTS

Inco Limited and Falconbridge Limited are thanked for their cooperation in allowing access and sampling on mine properties. I am indebted to M. Gorton of the University of Toronto for his invaluable advice and guidance, with respect to rare-earth element interpretations.

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15. Footwall and Sublayer of the Northwestern Sudbury Igneous Complex, District of Sudbury

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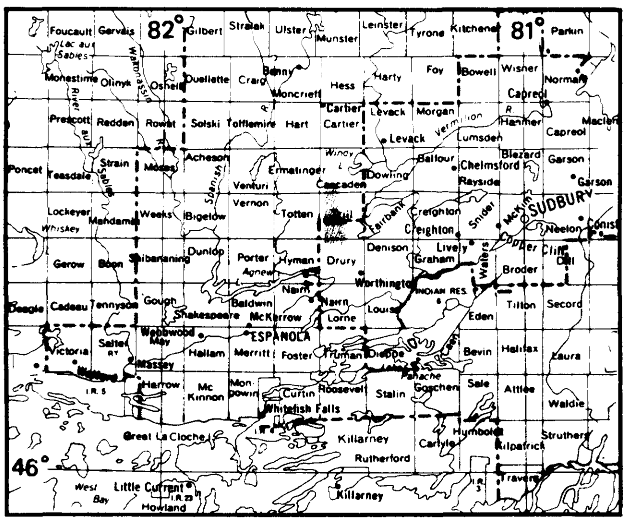
INTRODUCTION

The area of investigation covers approximately 40 km^2 and is located at the western boundary of the Sudbury Igneous Complex in Cascaden, Trill, and Drury Townships. Access to the area is provided by a gravel road that extends off Highway 144 at Windy Lake Provincial Park to Worthington, and Highway 17.

The 1984 investigations were carried out under a volunteer agreement between the Ontario Geological Survey and the Research Group "Earth-Moon-System", University of Muenster, Federal Republic of Germany. The aim of the present study is to come to a better understanding of: (1) the origin of the breccias in the footwall of the Sudbury Igneous Complex, (2) the origin of the Sudbury Structure itself, (3) of the controls on and potential variety of sulphide mineralization environments associated with the Sublayer of the Sudbury Igneous Complex and the Footwall Breccia. The investigations are in partial fulfilment of the requirements for the Master of Science (Diploma) degree in the Geologisch - Palaeontologisches Institut, University of Muenster, and represent the initiation of scientific cooperation between the Ontario Geological Survey and the Research Group "Earth-Moon-System", University of Muenster.



LOCATION MAP

Scale : 1 : 1 548 000
or 1 inch to 25 miles

MINERAL EXPLORATION

It is beyond the scope of this report to describe in detail the mineral exploration carried out in the area under investigation. The 2 major mineral occurrences of the study area are the Sultana and Trillabelle Occurrences. The work done on these is briefly described.

The Sultana Occurrence in southern Trill and northern Drury Townships was discovered by B. Boyer in 1891. Early work on the occurrence included trenching and diamond drilling. Three shafts were sunk, the deepest to a depth of approximately 40 m. In 1930 McVittie-Graham Mines Limited conducted an extensive exploration program that included diamond drilling. Part of the occurrence is presently held by Falconbridge Limited, and part by Inco Limited.

The Trillabelle Occurrence was discovered by R. Gillespie in 1891. The nickel-copper mineralization lies at the southern boundary of the Trillabelle Embayment where several test pits and a 20 m deep exploration shaft are located. The occurrence is presently owned by Inco Limited.

FIELD INVESTIGATIONS

During the field work, the authors placed emphasis on the following subprojects:

STUDY OF THE SUDBURY BRECCIA

Sudbury Breccias are pseudotachylites and are very common in the area. They occur in rocks older than the Footwall Breccia and have also been observed in fragments in the Footwall Breccia and in inclusions in the Sublayer. Many specimens of Sudbury Breccia were taken for petrographical and geochemical investigations and for comparison with breccias from meteorite impact craters and other terrestrial structures.

The Sudbury Breccias form dikes and irregularly shaped bodies that range in size from a few millimetres thick and several centimetres long to 0.35 km thick and approximately 11 km long (Dressler 1982). The largest breccia body in the present area lies east and southeast of West Cameron Lake and, based on somewhat limited exposure, possibly is 0.3 by 2 km in size.

Fragments in the Sudbury Breccia bodies are subangular to rounded, commonly derived from host rocks and set in a fine-grained rock flour, or, in very few places, in an igneous or recrystallized glass matrix.

STUDY OF THE FOOTWALL BRECCIA

The Footwall Breccia occurs as lenses and discontinuous sheets up to about 200 m thick along the lower contact of the Sudbury Igneous Complex. Fragments are derived from nearby footwall rocks and are angular to rarely subrounded. The matrix is contact metamorphic, exhibiting petrographic features such as porphyroblasts of pyroxene, hornblende, biotite, plagioclase, and quartz. Decussate to stubby plagioclase has replaced primary plagioclase. Relict shock metamorphic features were observed in mineral and rock fragments. The footwall rocks below the Footwall Breccia bodies have been intruded in places by Footwall Breccia material forming a "megabreccia" (Pattison 1979) up to about 300 m thick.

DETAILED MAPPING OF THE SUBLAYER

The Sublayer was mapped in detail and specimens were taken for petrographic and geochemical investigations. The field relationships of the Sublayer with the Footwall Breccia commonly underlying the Sublayer suggest that the Footwall Breccia is older than the Sublayer. The breccia is also older than the norite of the main mass of the Sudbury Igneous Complex as both norite and Sublayer contain inclusions of Footwall Breccia. No contacts of the Sublayer with the norite have been observed during the present field observations. Inclusions in the Sublayer are, in order of decreasing abundance: mafic metavolcanic rocks, very similar to the Huronian metavolcanic rocks occurring south of the Sudbury Igneous Complex, gabbroic rocks, granitic rocks, gneisses, anorthosite, Footwall Breccia, arkose, and conglomerate. The last 2 lithologies were derived from rocks of the Huronian Supergroup.

STUDY OF SHOCK METAMORPHIC FEATURES IN THE FOOTWALL ROCKS

Many specimens of granitic, gabbroic, and gneissic rocks were collected for a detailed study of shock metamorphic features and their spatial distribution within the area under investigation. Shock metamorphic features are known to occur in the North Range footwall rocks up to a distance of 10 km away from the Sudbury Igneous Complex (Dressler 1984).

ECONOMIC GEOLOGY

It is not the purpose of the present study to investigate in detail the nickel-copper mineralization known to occur in both the Sultana and Trillabelle Occurences. These occurrences have been studied by the present owners, namely Falconbridge Limited and Inco Limited, and the reader is referred to Lafleur and Dressler (in preparation) for a more detailed account of the economic geology of the study area.

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16. Digby-Lutterworth Area, Haliburton and Victoria Counties

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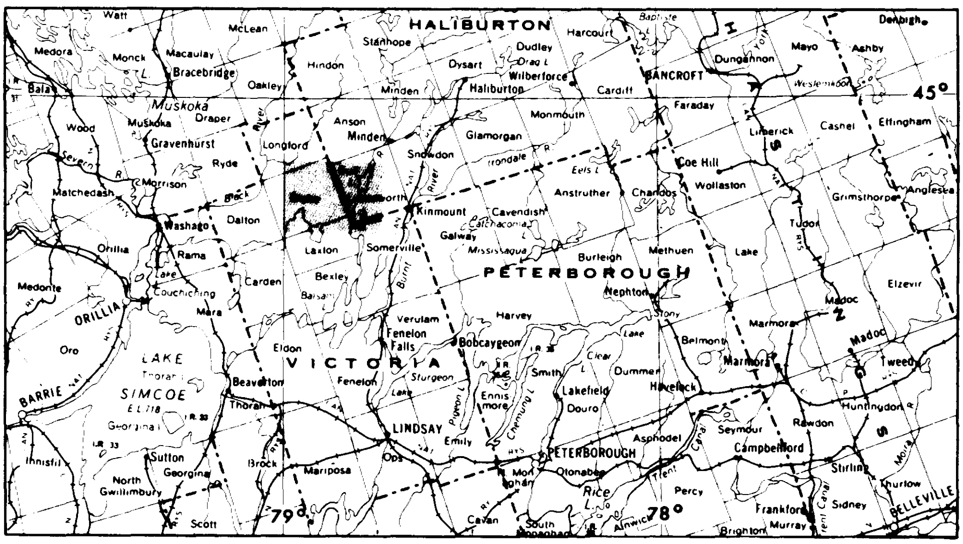
INTRODUCTION

The Digby-Lutterworth map area is located 140 km northeast of the City of Toronto and includes parts of Digby, Laxton, Longford, Lutterworth, and Somerville Townships. The map area covers about 270 km^2 and is bounded by Longitudes 78°45′W and 79°00′W, and by Latitudes 44°45′N and 44°52′30″N. The northeastern corner of the map area lies 5 km south of the Town of Minden, and access is provided by Highway 35 which traverses the eastern part of the map area, and Highway 503 which parallels the southern boundary of the map area. Access to the northwestern and northcentral parts of the map area is by canoe or float-equipped aircraft. The adjacent Howland area to the east was mapped by the senior author in 1983 (Easton 1983; Easton and Bartlett 1984).

MINERAL EXPLORATION

Recorded exploration within the map area has been very limited (Assessment Files Research Office, Ontario Geological Survey, Toronto (AFRO)) and has focused on uranium, molybdenum, and zinc mineralization in the marble breccia zone that underlies the eastern third of the map area (Figure 1). Hans Lundberg conducted a radiation survey in Lutterworth Township in 1955, and identified anomalies in the vicinity of South Beaver Lake, East Moore Lake, and at Shadow Lake, 3 km south of the southeastern corner of the map area. Jorex Limited (name changed to Canadian Jorex Limited in 1984) conducted an airborne gamma-ray survey over the eastern half of Lutterworth Township in 1978, and in 1978 and 1979 conducted geological surveys and diamond drilling on the South Beaver Lake and Shadow Lake properties found by Lundberg. Low grade uranium mineralization was found at both properties (AFRO). St. Joseph's Exploration Limited (now Sulpetro Minerals Limited, name change 1981), conducted extensive geophysical surveys over Buller Lake between 1976 and 1981 (AFRO) while exploring for zinc mineralization. Molybdenum exploration has focused on the Shadow Lake area since the discovery of molybdenum deposits there in 1916. The central and western part of the



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

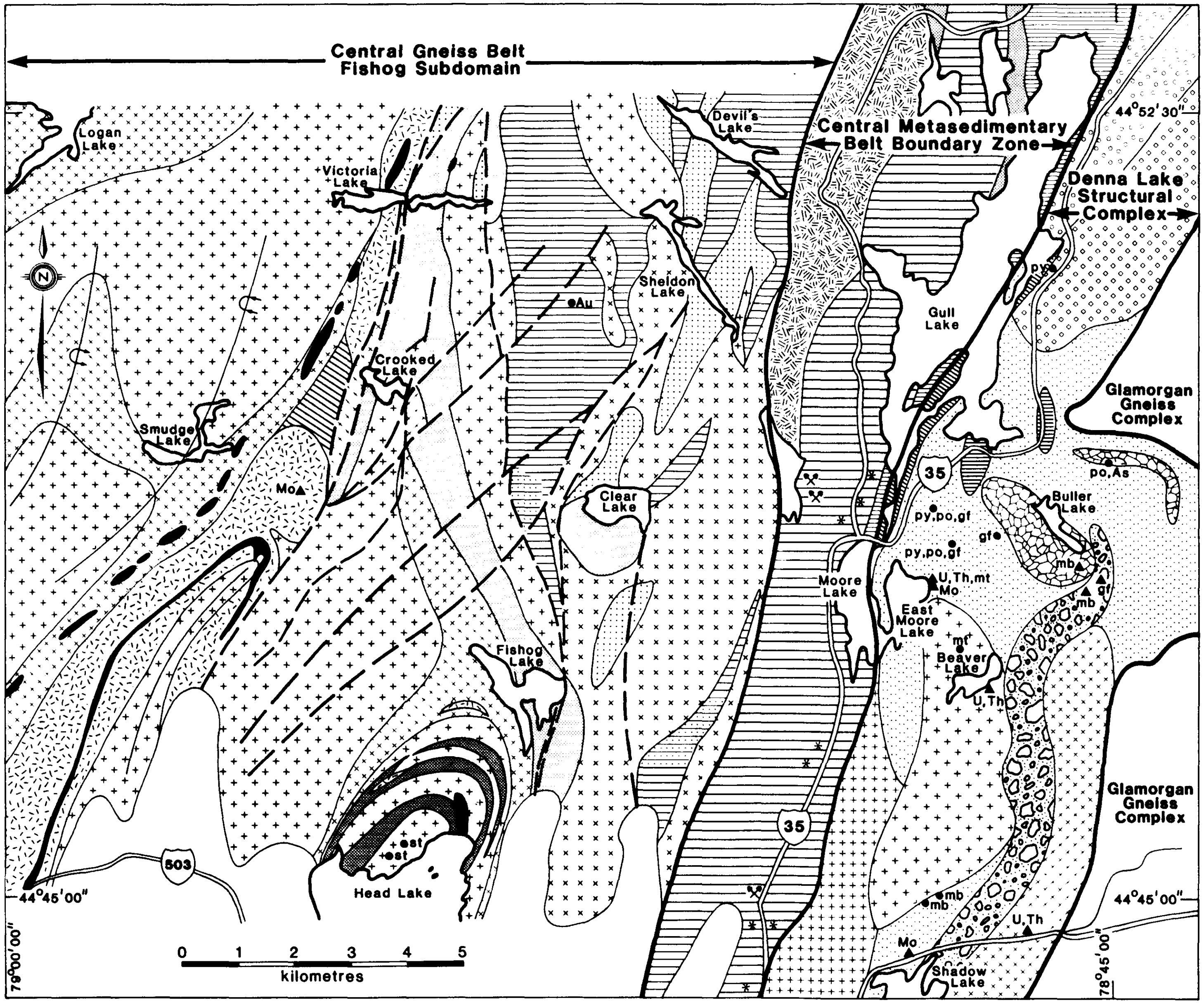


Figure 1a. Map of the Digby-Lutterworth area showing the location of mineral occurrences, major tectonic zones, and general geology. (Project 16.)

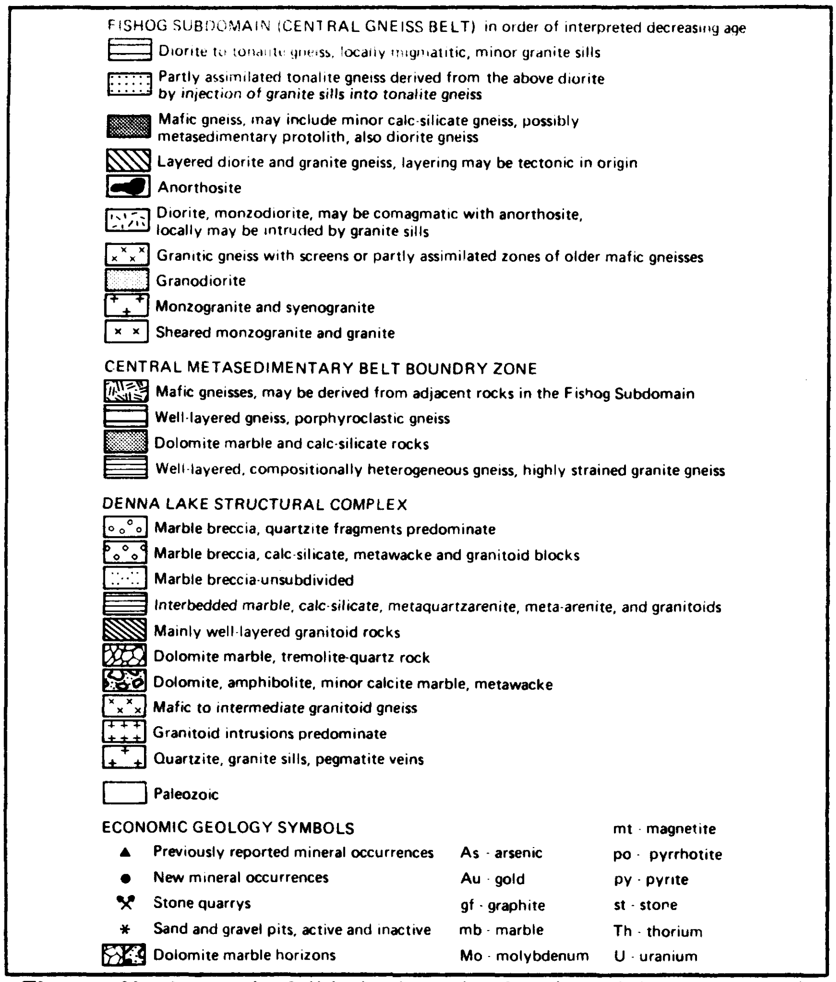


Figure 1b. Legend of lithologic units for the Digby-Lutterworth area. (Project 16.)

map area is underlain mainly by granitoid rocks, and has been virtually unprospected. Previously reported mineral occurrences, in addition to new occurrences located by field party personnel, are shown in Figure 1.

GENERAL GEOLOGY

A simplified geological map of the Digby-Lutterworth area is presented in Figure 1. The area is underlain mainly by Precambrian rocks. Flat-lying Ordovician limestone of the Gull River Formation, and calcareous arkose and shale of the Shadow Lake Formation cover the Precambrian succession in the southern part of the map area.

Precambrian rocks in the Digby-Lutterworth area are of Middle Proterozoic age, and straddle 2 major tectonic zones of the Grenville Province: the Central Metasedimentary Belt (CMB) to the east, and the Central Gneiss Belt (CGB) to the west (Wynne-Edwards 1972). Deformed rocks in the Gull Lake area form the boundary zone between the 2 terranes (Figure 1), and the boundary zone has been termed the Central Metasedimentary Belt Boundary Zone (CMBBZ) (Davidson *et al.* 1984).

The Precambrian rocks may be divided into 4 main groups, which also correspond to major tectonic zones (Figure 1). In order of interpreted decreasing ages these are:

1. The Fishog Subdomain (CGB) which underlies the western two-thirds of the map area, and which consists of a metamorphosed igneous terrane. These rocks correspond, in part, to the Algonquin Batholith of Lumbers (1982).

2. The Glamorgan Gneiss Complex (CMB) (Easton 1983, in press) which occurs along the eastern boundary of the map area and which may be basement to the Grenville Supergroup.
3. The Denna Lake Structural Complex (Easton 1983, in press) (CMB) which consists of tectonically disrupted Grenville Supergroup rocks which underlie the eastern third of the map area.
4. The Central Metasedimentary Belt Boundary Zone (CMBBZ) which separates the Fishog Subdomain and the Denna Lake Complex, and is a zone of tectonically disrupted gneisses.

FISHOG SUBDOMAIN

The Fishog Subdomain consists of metamorphosed rocks of predominantly igneous origin. These rocks can be subdivided on the basis of lithology, structure, and cross-cutting relationships into 5 groups. In order of interpreted decreasing age these are:

1. an older diorite group
2. meta-anorthosite and related rocks
3. monzonite and monzogranite plutons
4. granodiorite plutons
5. syenogranite sills and plutons.

The older diorite group is found mainly near Sheldon Lake, in the Head Lake oval, and in the vicinity of Smudge Lake. Near Sheldon Lake it consists of migmatitic, protomylonitic diorite, granodiorite, and tonalite gneiss with a quartz-plagioclase leucosome. These rocks are intruded to varying degrees by syenogranite sills, which locally have partly assimilated and mixed with the mafic rocks. In the Head Lake area, rocks of the diorite group define a dome, into which are intruded sills and sheets of anorthosite and related rocks, monzonitic rocks, and syenogranite. The diorites in the Head Lake area are more heterogeneous than those at Sheldon Lakes, and are present with calc-silicate gneiss and quartz-rich gneisses of probable metasedimentary origin. In the Smudge Lake area, dioritic rocks occur as screens between anorthositic and monzonitic rocks, and in the nose of the broad synform south of Smudge Lake (Figure 1). The rocks of the diorite group are characterized by their overall mafic composition, intrusion by all later igneous rocks, and the fact that fold structures within these rocks influence the siting of later igneous events.

The anorthosite group of rocks consists of anorthosite and anorthositic gabbro, as well as a group of diorite to quartz monzodiorite and monzonite rocks, which are spatially and temporally associated with the anorthosites. All of these rocks may have been part of an igneous complex at one time. Three major sheets of anorthosite are present in the map area: (1) in the Head Lake Dome, (2) as a boudinaged sheet southeast of Smudge Lake, and (3) a large, folded sheet southeast of Smudge Lake. The anorthosite sheet southeast of Smudge Lake was intruded prior to folding, as not all the observed strain in the sheet can be accounted for by folding alone. The anorthosite and related rocks of this group would correspond to the mafic anorthosite suite of Lumbers (1982). The anorthosite sheets in the area are unique in their association with monzonitic rocks, and the lack of associated gabbro and ultramafic rocks. The amount of gabbro associated with the anorthosite sheets is much less than that found with anorthosites near Georgian Bay (Van Kranendonk 1984), and no mylonitic or high-strain zones are found in association with the sheets in the map area.

Monzonitic to monzogranitic plutons intrude rocks of the older diorite and anorthosite groups. These plutons are located west and north of Smudge Lake, are compositionally variable, and have xenolith-rich margins of several hundreds of metres in width. In addition, these bodies were either intruded into, or deformed with, the major fold structures present in this part of the map area (Figure 1). These rocks would correpond to the monzonitic group of the anorthosite suite of Lumbers (1982). Together, the anorthosite group and monzonite group rocks comprise the Algonquin Batholith of Lumbers (1982).

Massive to weakly foliated granodiorite plutons, which may be roughly lenticular in form, intrude the older rocks. In turn, the granodiorite is intruded by syenogranite sills and plutons which underlie about half of the Fishog Subdomain.

GLAMORGAN GNEISS COMPLEX/DENNA LAKE STRUCTURAL COMPLEX

The Glamorgan Gneiss Complex has been described in detail by Easton (1983, in press). Syenogranite gneiss of the Crego Lake Lithodeme is the only unit of the Glamorgan Complex that outcrops in the map area.

The Denna Lake Structural Complex has also been described in detail by Easton (1983, in press). It consists mainly of marble tectonic breccia, comprising a variety of fragments including amphibolite, calc-silicate gneiss, metaquartz-arenite, and other siliceous clastic metasedimentary rocks and disrupted granodioritic to granitic rocks. All lithologies present in the Denna Lake Complex have undeformed counterparts 20 km to the east on the eastern side of the Glamorgan Gneiss Complex (Easton 1983, in press). It is possible to subdivide the Denna Lake Complex into a number of zones on the basis of dominant clast lithology and the presence of competent units, such as quartz-arenite horizons. Some of these zones are shown in Figure 1 as letters A to K. The presence of these zones within an otherwise disrupted terrane is of significance, since an economically favourable horizon of competent rock may be locally continuous (e.g. dolomite marble horizon, Figure 1).

CENTRAL METASEDIMENTARY BELT BOUNDARY ZONE (CMBBZ)

The CMBBZ separates the Central Gneiss Belt (Fishog Subdomain in the map area) from the Central Metasedimentary Belt (Denna Lake Structural Complex in the map area). Rocks within this zone have been tectonically modified. Descriptions of these rocks can be found in Schwerdtner and Mawer (1982, their type 1 tectonite) and in Davidson *et al.* (1982). The CMBBZ can be divided into 3 zones in the map area, from east to west:

1. The first zone consists of well-layered, highly strained granite and granitoid gneisses of indeterminate protolith.
2. The second zone consists of highly-disrupted rocks. Within this zone are found the porphyroclastic gneisses of Davidson *et al.* (1982). The protolith of many rocks in this zone is indeterminate.
3. The third zone, in the northern part of the CMBBZ is, a belt of disrupted and strained mafic gneisses, which are probably derived from mafic gneisses in the adjacent Fishog Subdomain. In the southern part, granite layers become more abundant in the western part of the CMBBZ, and in part this may reflect the presence of granite in the adjacent Fishog Subdomain.

The thinness of the CMBBZ in the southern part of the map area may be due to structural onlap of the Denna Lake Structural Complex (*see* Figure 1).

METAMORPHISM AND STRUCTURAL GEOLOGY

Metamorphic grade in the Precambrian rocks across the map area is upper amphibolite facies. No evidence of granulite facies mineral assemblages was observed in granitoid rocks of the Fishog Subdomain.

The structural geology of the area is dominated by the major tectonic zones which serve to separate the main rock groups in the map area. Other structural elements of note are the fold structures in the western part of the Fishog Subdomain which fold the older diorite, anorthosite, and monzonitic rocks, but not the late granites. The central Fishog Subdomain is cut by a north-trending fault set, which converges near Victoria Lake, and a later, northeast-trending set of faults which cut all units in the Subdomain. Deformation in the late granites of the Fishog Subdomain, mainly flattening and development of a southeast plunging lineation, increases towards the CMBBZ. Rocks near the CMBBZ, in the CMBBZ, and in the Denna Lake and Glamorgan Complex all contain a southeast, shallow plunging lineation. Structures within the map area are consistent with a model of northeast-directed thrusting of the CMB over the CGB (Davidson *et al.* 1984), however, the Fishog Subdomain has had a long tectonic history, and further detailed work is needed to outline the structural sequence of the map area.

ECONOMIC GEOLOGY

BASE METAL

Dolomitic marbles in the Howland area to the east contain significant zinc mineralization (Easton 1983) and 2 zones of dolomitic marble in the Denna Lake Structural Complex may represent favorable exploration targets. The first is a zone of interbedded dolomite marble and amphibolite trending from the southern part of the map area, along the Buller Road, towards Buller Lake (Figure 1). The second is a large area of dolomite marble, now in part metamorphosed to tremolite-quartz-diopside assemblages, on the southern shore of Buller Lake (Figure 1). During 1976 and 1981, St. Joseph's Exploration Limited performed extensive geological and geophysical work over Buller Lake but not in the area south of the lake. Additional work in this zone may be warranted, as the dolomitic marbles have not been as disrupted as other units within the Denna Lake Structural Complex.

Within the Fishog Subdomain, the older, mafic gneiss terrane has the greatest potential for hosting base-metal mineralization, particularly copper. The area south and north of Devil's Lake, and the area west of Sheldon Lake (Figure 1) are the most favorable areas, as they are the least affected by later granitoids.

OTHER METALLIC AND PRECIOUS MINERALS

Occurrences of uranium and thorium mineralization previously recorded in the area are shown in Figure 1. All of these areas have significant scintillometer anomalies (up to 10 times background) and lie within regional airborne gamma-ray spectometric anomalies (Geological Survey of Canada 1984). Uranium and thorium mineralization in the area is confined to the Denna Lake Structural Complex, and is hosted in syenogranite to granitic pegmatite veins and disseminated within some calcite marble horizons.

Molybdenite is present throughout the map area (Figure 1). Disseminated molybdenite crystals are present in marble breccia at Miner's Bay, on the eastern shore of East Moore Lake (lot 23, concession V, Lutterworth Township) (Adams and Barlow 1910), and in tonalite gneiss (lot 16, concession VII, Digby Township) (Adams and Barlow 1910) in the Fishog Subdomain. The latter occurrence could not be located during the current survey, and is probably overgrown. At Shadow Lake, 3 km south of the map area, in the Denna Lake Structural Complex, assays of up to 4% MoS_2 have been reported (AFRO), and similar occurrences may extend north into the map area. The Denna Lake Structural Complex is the most favourable zone for molybdenite exploration.

A previously unreported gold occurrence is located in Digby Township west of Sheldon Lake (Figure 1) within the area bounded by lots 2 to 10, concessions VIII to XI (I. Wells, pilot and prospector, Head Lake, personal communication, 1984). This area is underlain by older mafic gneiss of the Fishog Subdomain. Field party personnel could not locate the occurrence, probably because of heavy vegetation overgrowth in the area since its discovery over 30 years ago, but the rocks are lithologically favourable for gold mineralization. Assays on samples collected by field party personnel are in progress. In addition, deformed and sheared rocks within the CMBBZ may also be favourable hosts for gold mineralization, because shear zones in Archean terrains are commonly associated with gold mineralization.

NONMETALLIC MINERAL RESOURCES

Dolomite in the Buller Lake area (Figure 1) has been metamorphosed to diopside-quartz-tremolite assemblages. These marbles are relatively pure (<5% silicate impurities) and could be used as a source for tremolite in the plastics industry. Extensive tremolite deposits also occur within the adjacent Howland area to the east (Easton 1983). Relatively pure dolomite marbles (<2% silicate and other impurities) occur within the Denna Lake Structural Complex (south of Buller Lake, along the Buller Road, and on lot 16, concession I, Lutterworth Township) and the CMBBZ (lot 13, concession XIV, Lutterworth Township) as well as pure calcite marble (lot 22, concession XIV, Somerville Township) in the Denna Lake Structural Complex. These marbles are potentially useful for building and crushed stone and as a refractory material in industry. Adams and Barlow (1910) report that serpentinized tremolite marble from lot 16, concessions IV and V, Lutterworth Township, was polished and used as a building stone in Montreal. Further examination of the industrial mineral potential of the marbles should be undertaken.

Dolomitic limestone beds are present in the Ordovician Gull River Formation in the southern part of the map area and could be used for building or crushed stone, or as a refractory material.

Two stone quarries are presently operating in the map area, both are located in the CMBBZ and produce flagstone. Three pits at Black Lake (lot 26, concession VII, and lot 25, concession VIII, Lutterworth Township) quarry a pink, foliated leucogranite layer within well-layered heterogeneous gneisses of the CMBBZ. Another quarry located on lot 10, concession X, Laxton Township, extracts a variety of lithologies from well-layered, compositionally heterogeneous gneiss. This horizon extends from the quarry north through Black Lake to north of Minden, and quarrying activity could be greatly expanded. Many other potential building stones are present within the map area, including a red, well-layered granite at Head Lake (lots 17 to 20, concession I, Digby Township), and anorthositic rocks in the western part of the map area.

Extensive, good quality sand and gravel deposits occur along the Gull River south of Gull Lake. Many well-formed minerals are present in the marbles within the Denna Lake structural complex, making this area of interest to mineral collectors.

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17. Mellon Lake Area, Hastings and Lennox and Addington Counties

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INTRODUCTION

The Mellon Lake map area is located 40 km northeast of the City of Belleville and 55 km northwest of the City of Kingston. It covers about 275 km^2, includes parts of Hungerford, Sheffield, Kaladar, and Elzevir Townships, and is bounded by Longitudes 77°00'W and 77°15'W and by Latitudes 44°30'N and 44°37'30"N. The southwestern corner of the map area lies 6 km east of the Village of Tweed, and access is provided by Highways 7, 37, and 41. Township roads, an abandoned Canadian National Railway right-of-way, cottage roads, and logging roads provide good access to most of the area except the region to the north and west of Mellon Lake in the northeastern part of the map area.

MINERAL EXPLORATION

The history of mineral exploration and production in the Mellon Lake area dates back to the 1880s. Information on this section is recorded either in the assessment files (Assessment Files Research Office, Ontario Geological Survey, Toronto), or by Carter (1984). From about 1903 to 1916 massive pyrite was extracted and treated for its iron content by the Canada and Hungerford Mines in the southwestern corner of the map area (Figure 1).

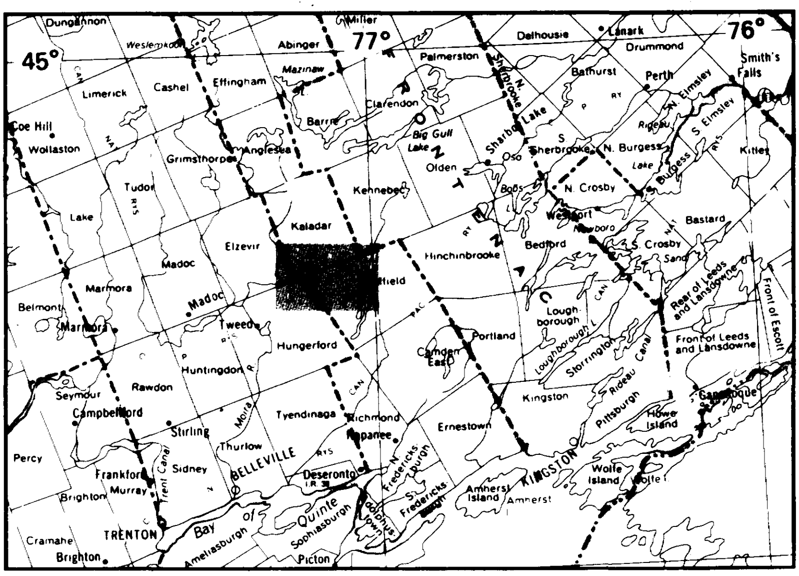
Exploration within the area has been very limited. During the mid-1950s, hematite mineralization in the marbles to the northwest of Mellon Lake was examined by Kaladar Iron Mines (Canadian Institute of Mining Consultants). In 1952, in this same part of the map area, New Jersey Zinc Exploration Company (Canada) Limited examined several occurrences of marble-hosted zinc mineralization, including the Spry zinc deposit. The same marbles were re-examined by Glenshire Mines Limited for their base and precious metal potential during the late 1970s. At that time, the company also examined several radioactive occurrences at the eastern end of its property.

Exploration for uranium in the map area was first carried out during the late 1960s in the southeastern part of the map area, for example by Canadian Geary Mining Corporation Limited and Zurick Exploration Limited.

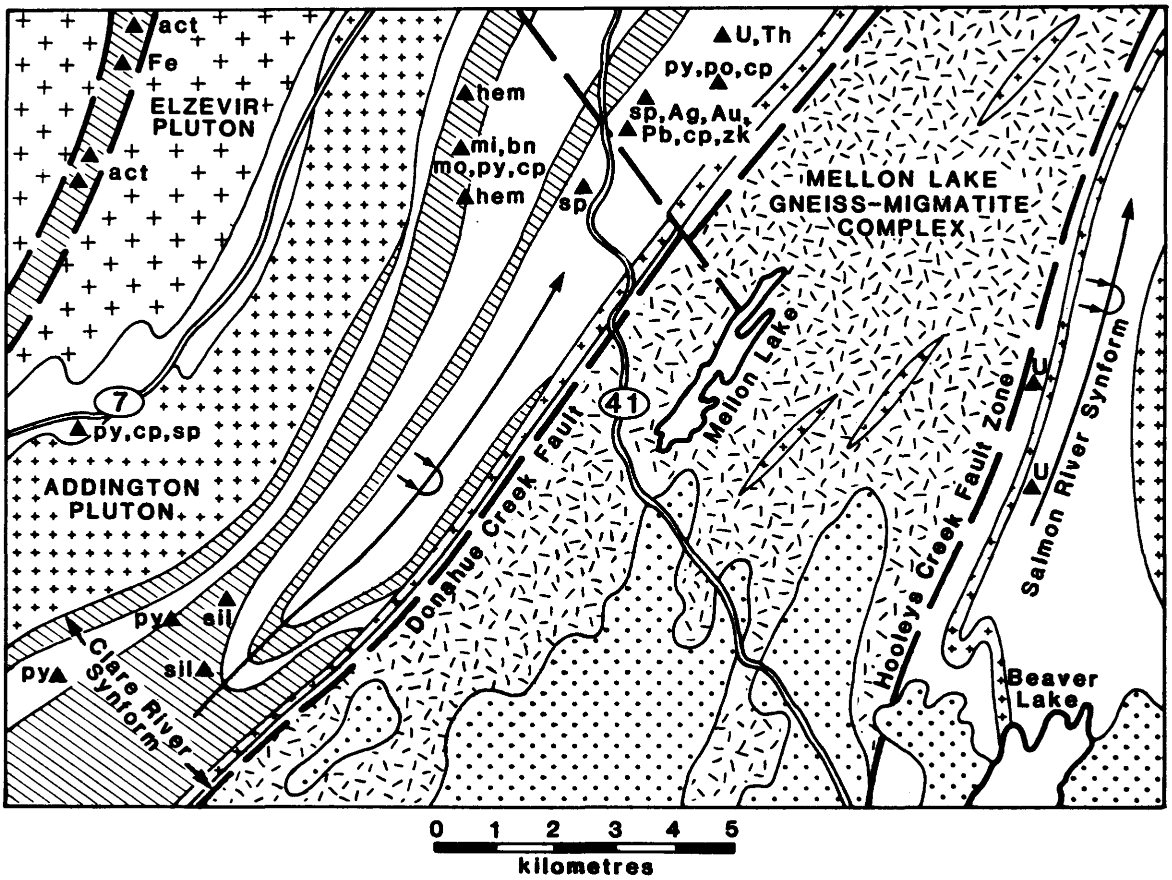
In 1978, a potentially economic deposit of flake muscovite was discovered in the aluminous metapelites to the west of Highway 41 near the north central boundary of the map area. This mica deposit, now called the Kaladar Aimko Deposit, was first examined by Omya Incorporated during 1978 to 1979. It is presently under investigation by Koizumi Group Canada Limited. In the fall of 1981, this company shipped a 200 ton bulk mica sample to Japan, followed by a 5000 ton sample in 1982 for testing of the material (Verschuren 1983).

GENERAL GEOLOGY

The area is underlain mainly by Precambrian rocks (Figure 1). Flat-lying Ordovician carbonate rocks and minor calcareous arkose cover the Precambrian rocks in the southeastern part of the map area. The Paleozoic strata have been described by Carson (1981).



LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles



PALEOZOIC

Ordovician Carbonate Rocks

PRECAMBRIAN

MIDDLE PROTEROZOIC

METAMORPHOSED PLUTONIC ROCKS

Addington Plutonic Rocks - granite, quartz monzonite, granodiorite

Elzevir Pluton - granodiorite, trondjhemite, quartz monzonite

SUPRACRUSTAL ROCKS

Flinton Group - clastic and carbonate metasediments

Grenville Supergroup - metavolcanics, metasediments

GNEISS – MIGMATITE COMPLEX (Possible Basement)

Mellon Lake Gneiss - Migmatite Complex

act	actinolite	Fe	iron	mo	molybdenite	sil	sillimanite
Ag	silver	hem	hematite	Pb	lead	sp	sphalerite
Au	gold	mi	mica	po	pyrrhotite	Th	thorium
bn	bornite	cp	chalcopyrite	py	pyrite	U	uranium
						zk	zinkenite

— — Fault   Overturned synform (arrows indicate direction of dip)

Figure 1. Generalized geology of the Mellon Lake area and locations of mineral occurrences. (Project 17.)

Precambrian rocks in the Mellon Lake area are of Middle Proterozoic age and form part of the Central Metasedimentary Belt (Wynne-Edwards 1972) of the Grenville Province and may be subdivided into 5 main groups (Figure 1), which in order of interpreted decreasing age are:

1. The Mellon Lake Gneiss-Migmatite Complex, which may be basement to the Grenville Supergroup
2. Supracrustal rocks of the Grenville Supergroup
3. Metamorphosed granodiorite to quartz monzonite plutonic rocks
4. A supracrustal succession, the Flinton Group (Moore and Thomson 1972, 1980)
5. Metamorphosed granite to quartz monzonite plutonic rocks, the relative age of these with respect to the Flinton Group is not known.

MELLON LAKE GNEISS–MIGMATITE COMPLEX

This complex is fault-bounded, and consists of a heterogeneous, amphibolite facies rock assemblage of migmatitic biotite±muscovite granodiorite to quartz monzonite gneiss, and layered migmatite. Mafic inclusions and biotite-rich metasedimentary rafts and septa are locally abundant in the vicinity of Mellon Lake.

The layered gneisses and the granitic mobilizate of the migmatites exhibit an early fabric folded prior to the development of a late, northeasterly trending regional foliation. The migmatization event recorded in this complex is absent in the adjacent rocks of the Grenville Supergroup of the Clare River and Salmon River Synforms. The complex may be basement to the Supergroup.

GRENVILLE SUPERGROUP

Metavolcanic rocks and carbonate and clastic metasedimentary rocks, which the author correlates with the Hermon Group as defined by Lumbers (1967) in the Madoc area 20 km to the west of the map area, occur in the following 3 areas:

1. In the northwestern corner of the map area, a narrow northeasterly trending zone of upper greenschist to amphibolite facies Hermon Group clastic and carbonate metasediments (with minor metavolcanics) occurs.

2. In the west central part of the map area, the Hermon Group rocks are the oldest rocks in the Clare River Synform (Chapell 1978). Here these rocks are unconformably overlain by, and tightly infolded with, rocks of the Flinton Group (Figure 1). In order of decreasing abundance, the 3 main lithologies of the Hermon Group, all of upper greenschist to amphibolite facies rank, are: (a) foliated, in places layered, mafic to felsic metavolcanic rocks; (b) calcitic and dolomitic marbles; (c) metawacke and feldspathic meta-arenite with minor para-amphibolite and quartzitic meta-arenite.

3. In the eastern part of the map area, amphibolite facies rank Hermon Group rocks underlie the entire Salmon River Synform. Foliated, in places layered, mafic to felsic metavolcanic rocks are the dominant lithology followed by calcitic and dolomitic marbles, calc-silicate gneiss, and minor siliceous clastic metasedimentary rocks.

METAMORPHOSED GRANODIORITE TO QUARTZ MONZONITE

This early suite of plutonic rocks is restricted mainly to the Elzevir Pluton whose southeastern margin underlies the northwestern corner of the map area. Here the southeastern margin of this large pluton is subdivided into 2 distinctly different sub-units by a narrow, fault-bounded, northeasterly trending unit of Flinton Group rocks. Northwest of this band of Flinton Group rocks, the Elzevir Pluton consists of greenschist to amphibolite facies rank, massive, in places lineated, and locally foliated biotite granodiorite to trondhjemite. Southeast of the same unit, the Elzevir Pluton, here called Northbrook Batholith by Wolff (1982), intrudes the Grenville Supergroup and consists mainly of middle to upper amphibolite facies rank gneissic biotite granodiorite to quartz monzonite. Here it locally contains numerous, small, mafic to felsic country rock inclusions and late tectonic granitic rocks.

FLINTON GROUP

In the map area, the Flinton Group rocks (Moore and Thomson 1972, 1980) are restricted to the following 2 regions:

1. In the Clare River Synform they form narrow continuous to locally discontinuous bands that are tightly infolded with rocks of the Hermon Group. In the northeastern part of the synform, the Flinton Group consists mainly of upper greenschist to amphibolite facies rank, aluminous pelitic schists, rusty metawacke, feldspathic meta-arenite, calcitic to dolomitic marble, and subordinate quartzitic metacon-

glomerate and quartzitic meta-arenite. In the southwestern part of the synform, the group consists mainly of upper amphibolite facies rank calc-silicate gneiss and calcitic to dolomitic marble with subordinate aluminous pelitic schist, and minor metawacke, feldspathic meta-arenite, and metaconglomerate.

2. In the fault-bounded segment of Flinton Group rocks within the Elzevir Pluton, the dominant lithologies are upper amphibolite facies rank quartzitic and polymictic pebble metaconglomerate, feldspathic meta-arenite, and metawacke, with minor para-amphibolite, marble, and aluminous pelitic schist.

METAMORPHOSED GRANITE TO QUARTZ MONZONITE

This suite of metamorphosed plutonic rocks forms large plutons like the Addington Pluton, as well as numerous large and small dikes throughout the map area. Gneissic, in places lineated, pink to pinkish grey, biotite granite to quartz monzonite and leucocratic granite are the dominant lithologies. Intrusive contacts between cross-cutting dikes of this group and all other major lithologies except the Flinton Group were observed by the author (Figure 1). The age relationship with the rocks of the Flinton Group is uncertain, as all observed contacts with it appear to be tectonic.

LATE TECTONIC GRANITIC ROCKS

Unmetamorphosed, late tectonic granite pegmatite dikes intrude the Precambrian rocks throughout the map area. These dikes are particularly abundant near major, northeasterly trending fault zones and within, or adjacent to the margins of the larger granitic plutons and dikes.

METAMORPHISM

Metamorphic grade in the area changes abruptly across several of the regional, northeasterly trending faults shown on Figure 1. In general, all rock units east of the Donahue Creek fault zone exhibit middle to upper amphibolite facies rank mineral assemblages. Northwest of this fault, the metamorphic grade, in general, increases towards the southwest from middle to upper greenschist facies along Highway 41, to upper amphibolite facies near the closure of the Clare River Synform.

STRUCTURAL GEOLOGY

In general, all major units strike north to northeast and have moderate to steep dips to the southeast. In the northwestern segment of the Elzevir Pluton, dips are moderate to the northwest.

The Mellon Lake Gneiss-Migmatite Complex, the Grenville Supergroup and the Flinton Group have been subjected to at least 2 major periods of deformation. Within the Clare River and Salmon River Synforms an earlier set of north- to northeast-trending folds has been refolded to produce upright to southeasterly overturned, northeasterly plunging folds. These same 2 fold sets were observed by the author in the Mellon Lake Complex along Highway 41. In general, all rock units except the younger late tectonic granite pegmatites, exhibit a penetrative LS-fabric with a shallow to moderate, northeasterly plunging lineation.

ECONOMIC GEOLOGY

BASE AND PRECIOUS METAL DEPOSITS

Stratiform zinc deposits to the north of Mellon Lake occur discontinuously over a 3 km strike length in northeasterly trending carbonate rocks of the Clare River Synform on lots 1 and 2, concession VI, lot 2, concession VII, and lot 3, concessions VII and VIII, Kaladar Township. Some of the largest occurrences are shown in Figure 1.

The sphalerite mineralization is hosted by 3 cm to 5 m thick tremolite-rich dolomitic marble layers within a layered, tightly folded succession of calcitic marble, dolomitic marble, tremolite-rich dolomitic marble, and minor siliceous clastic metasedimentary rocks. In several places along Highway 41, the mineralized layers are spatially associated with stromatolites. The sphalerite mineralization generally occurs as disseminations or locally massive stringers. Zinkenite is present in places. Very minor pyrite, chalcopyrite, and locally azurite also occur.

Selective grab samples of sphalerite mineralization taken by Glenshire Mines Limited in 1975 from lots 2 and 3, concession VII, Kaladar Township returned assays ranging from 18.71% to 29.29% zinc, and 0.04 to 0.14 ounce silver per ton (AFRO). A selected sample of zinkenite mineralization from the southwest 1/4 lot 3, concession VII, Kaladar Township, returned an assay of 0.55% lead, 0.08 ounce gold per ton, and 11.18 ounces silver per ton. Carter (1984) re-examined and sampled the Spry zinc deposit on lot 3, concession VII, Kaladar Township. A representative chip sample taken by him across 5 m of the main zone of mineralization contained 3.88% zinc, 10 parts per million lead, and trace amounts of silver. The main zone was traced continuously along strike for at least 500 m.

In 1975 Glenshire Mines Limited also examined and diamond drilled several occurrences of pyrite-pyrrhotite-minor chalcopyrite, and locally minor sphalerite mineralization in a sequence of rusty weathering, muscovite-quartz schists and muscovite-quartzofeldspathic gneisses north of Mellon Lake, on lots 4 and 5, concession XI, Kaladar Township (*see* Figure 1).

Similar rusty schists containing local vugs of minor chalcopyrite and sphalerite mineralization were observed by the author as thin units in the marbles exposed along Highway 7, near the western boundary of the map area.

IRON DEPOSITS

Two types of stratabound iron deposits occur in the map area within the Clare River Synform:

1. Massive to disseminated pyrite and very minor pyrrhotite in siliceous clastic metasediments
2. Massive to disseminated hematite in marble.

Massive to disseminated pyrite deposits containing up to 40% sulphides occur over a strike length of about 3 km along the northern flank of the Clare River Synform, near its southwestern closure, east of the Village of Tweed. The deposits are hosted by a basal unit of muscovitic and quartz-rich clastic metasediments of the Flinton Group, which stratigraphically separates the older Hermon Group metavolcanics and the younger Flinton Group marbles and calcareous metamudstones. The Canada, and Hungerford Mines pyrite occurrences belong to this type of mineralization. Also related to this type are pyritic schists in the Flinton Group, in other regions of the Clare River Synform, that locally contain minor chalcopyrite mineralization.

Massive to disseminated hematite deposits occur in Flinton Group calcitic marble at 2 structurally separate, but possibly related stratigraphic horizons, to the northwest of Mellon Lake on lot 5, concession V and lot 1, concession IV, Kaladar Township (Figure 1).

OTHER METALLIC MINERALS

Uranium and thorium mineralization in the eastern part of the map area occurs in late tectonic granite pegmatite dikes, which intrude the rocks of the Grenville Supergroup near and adjacent to the fault-bounded contacts between the supergroup and the older Mellon Lake Gneiss-Migmatite Complex.

Disseminated pyrite-bornite-molybdenite-minor chalcopyrite mineralization occurs locally in some pyritic quartz-rich, clastic interbeds within the Flinton Group biotite-muscovite schists exposed in the southeast walls of the Aimko mica pit (discussed below).

NON-METALLIC MINERAL OCCURRENCES

Tightly folded aluminous, pelitic schists of the Flinton Group, containing various amounts of biotite, muscovite, kyanite, sillimanite, staurolite, and garnet, occur along the northwestern flank of the Clare River Synform. At the Kaladar Aimko (former Omya Mica) Deposit, where the rocks are in greenschist facies, these rocks contain up to 60% muscovite on lot 4, concession V, Kaladar Township (Figure 1). Southwest of the deposit towards the closure of the Clare River Synform, the regional metamorphic grade increases towards amphibolite facies. Here, higher rank metamorphic pelitic schists in places contain up to 60% sillimanite (Figure 1). These sillimanite-rich rocks warrant a detailed exploration effort.

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18. Geological Computer Software Developments

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INTRODUCTION

The Precambrian Geology Section of the Ontario Geological Survey has developed a package of general purpose computer programs for geological applications. The purpose of the programs is to allow the examination of geochemical and structural data using universally standardized plots (AFM, SiO_2 *vs* Na_2O+K_2O, stereonet projections, etc.) and to standardize field-note formats for use in the development of computer accessible files. The system of programs can operate on and between mini, micro, and mainframe computers.

PROGRAMS

The programs are written in Fortran IV but earlier, more limited versions of some of the programs are available in Basic. The package includes the following programs: BINARY, QAPF, TERNARY, and STRNET.

BINARY PROGRAM

Source Language: Fortran IV, Basic

Machine: PDP-11/34, Commodore PET

This program draws binary plots according to predefined formulas or user-defined formulas. The length of the axes, the labels for the axes, the title, and the style and colour of the points are user-defined. The scaling may be done automatically or may be user-defined.

The predefined formulas are:

SiO_2 *vs* Na_2O+K_2O
SiO_2 *vs* K_2O/Na_2O
SiO_2 *vs* K_2O
TiO_2 *vs* Cr
Mg/Mg+Fe(t) *vs* Cr
Cr *vs* Zr

The user-defined formulas may be composed of logarithms, nested brackets, major oxide values, trace element values, numbers, addition, subtraction, multiplication, and division. Data input may either be from a disk file or entered via the keyboard as the program is running.

QAPF PROGRAM

Source Language: Fortran IV

Machine: PDP-11/34

This program draws quartz-alkali feldspar-plagioclase-feldspathoid (QAPF) diagrams following the modal classification scheme of Streckeisen (1976). The quaternary diagrams are 12 cm wide and 21 cm high. Each side of the triangle is divided into 10 sections and category boundary lines are drawn. The title of the plot and the style and colour of the points are user-defined. Data input may either be from a disk file or entered via the keyboard as the program is running (*see* Figure 1).

TERNARY PROGRAM

Source Language: Fortran IV, Basic

Machine: PDP-11/34, Commodore PET

This program draws 3 types of ternary diagrams:

1. Jensen cation diagrams ($Fe_3+Fe_2+Ti+Mn$-Al-Mg) (*after* Jensen 1976)
2. Na_2O+K_2O-FeO(total)-MgO diagrams (AFM) (*after* Thompson 1957)
3. quartz-alkali feldspar-plagioclase diagrams (QAP) (*after* Streckeisen 1976)

For each diagram the sides of the triangle are divided into 10 sections and boundary curves are drawn. The title of the plot and the style and colour of the points are user-defined. Data input may either be from a disk file or entered as the program is running (*see* Figure 1).

The Basic version (Commodore PET) enables user-defined ternary parameters.

STRNET PROGRAM

Source Language: Fortran IV, Basic

Machine: PDP-11/34, Commodore PET

This program draws equal area (Schmidt) stereonet projections of either planar or linear data. The radius of the net, the title of the plot, and the style and colour of the points are user-defined. The data input may either be from a disk file or entered via the keyboard as the program is running. (*see* Figure 1).

SUMMARY

These programs use standard Calcomp plotting routines and a Hewlett Packard 7220C plotter. Source listings of the programs are available for either the Fortran IV or Basic versions and documentation is available for the Fortran IV versions. Figure 1 shows examples of some of the diagrams generated by these programs. For systems other than a PDP 11/34 minicomputer, modifications may be required.

The package of programs also includes the following routines and subroutines:

Correspondence Factor Analysis

Dynamic Cluster Analysis

Irvine and Baragar Rock Classification from chemi-

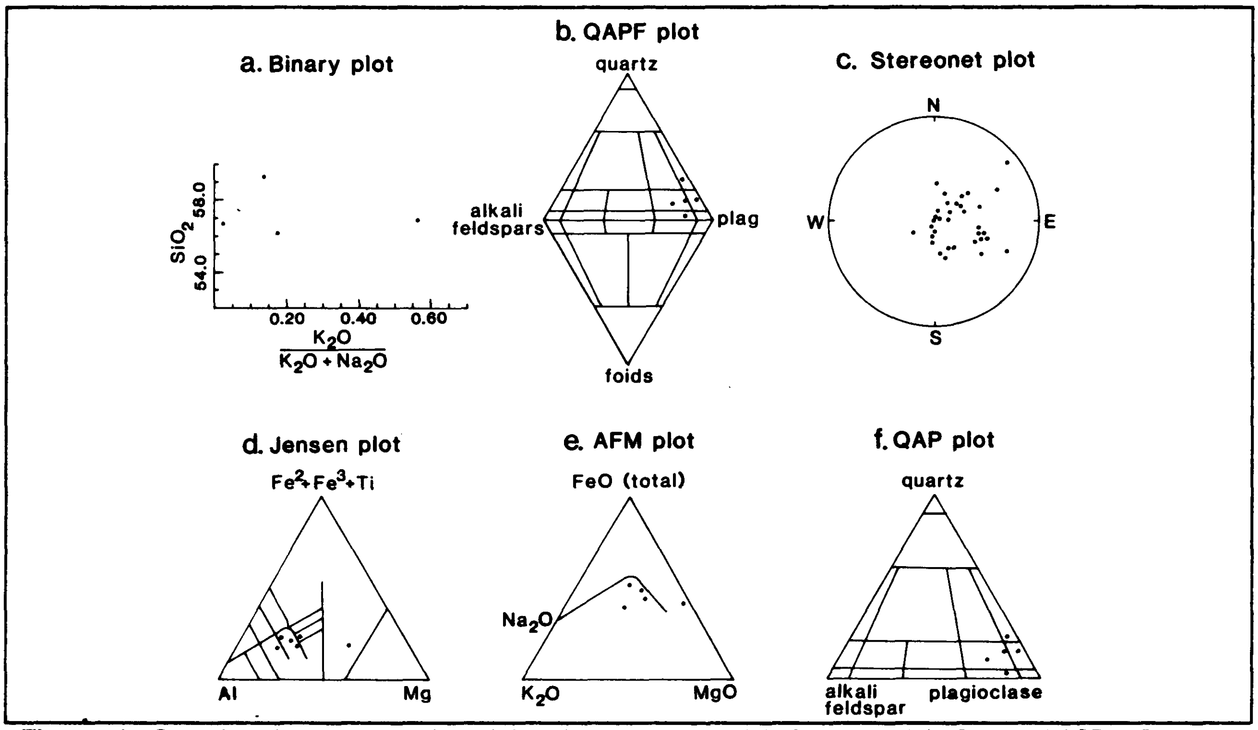

Figure 1. Sample diagrams produced by the programs: (a) BINARY, (b) QAPF, (c)STRNET, and (d,e,f) TERNARY. (Project 18.)

cal analyses (*after* Irvine and Baragar 1971).

C.I.P.W. Normative Mineral Calculations from chemical analyses (*after* Hutchinson 1965).

Barth-Niggli Normative Mineral Calculations from chemical analyses (*after* Barth 1959).

The documentation for these programs is currently not available, however Fortran IV source listings are available on request.

A field-note storage system was designed and implemented by G.M. Stott and E.C. Grunsky on the NEC PC-8201A computer. The field-note format combines standard codes for observed features with unlimited text description. The notes are entered in the field using a data entry program. These notes can be transferred at any time from the NEC to the PDP-11/34 via a direct link by telephone modem hookup. Programs are now under development for search and retrieval within these field-note files. A copy of the field-note format and the data entry program are also available with documentation.

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ENGINEERING AND TERRAIN GEOLOGY PROGRAMS

Summary of Activities 1984, Engineering and Terrain Geology Section.

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INTRODUCTION

The field activities of the Section were maintained at about the same level as last year, although several of the Quaternary geology field parties were staffed at levels lower than usual. Two of the Quaternary field projects were operated in conjunction with other sections in interdisciplinary programs. In northwestern Ontario, a crew operated out of the main base camp at Eyapamikama Lake as part of the integrated Opapimiskan Lake project on the North Caribou Lake belt, and a Quaternary geologist collaborated with staff from the Geophysics/Geochemistry Section in the geochemical investigation of the drift deposits in the Matheson area as part of the BRIM program.

The Paleozoic/Mesozoic Subsection staff continued their studies of the Hydrocarbon Energy Resources of the Province with funding support from the Board of Industrial Leadership and Development (BILD) Program. The staff of the Aggregate Assessment Office divided their time and field activities between completing aggregate inventories in designated townships in southern Ontario and undertaking specially requested aggregate studies in northern Ontario.

Aleksis Dreimanis and P.J. Barnett were mapping in the Port Stanley area, Elgin County (Project 20.), and concentrated their efforts in the eastern half of the map area to extend the mapping completed in the western half some years ago. The area concerned appears to be a complex interlobate region affected by lobes of ice from both the Huron and the Erie basins. Organic silts and clays were identified below the Catfish Creek Drift, and fluvial and deltaic gravels were identified below the Port Stanley till. These sands and gravels, which may be related to the Erie Interstadial, have, in this aggregate-deficient area, attracted the attention of the Ontario Ministry of Natural Resources field staff and further investigations are being planned. Beaches associated with glacial Lake Maumee (Maumee IV?) and glacial Lake Whittlesey have been identified in several localities.

P.F. Karrow commenced the mapping of the Brampton area (Project 21.) by concentrating on the western edge of the area, including the Niagara Escarpment. Small areas of Wentworth Till were identified above the escarpment but Halton Till, with significant inclusions of Queenston Formation red shale, was the most commonly encountered till in the area mapped.

Glaciofluvial deposits are extensive in the vicinity of the escarpment but were not worked extensively in the past, possibly because of the large size of clasts (which require excess crushing) and the high content of shale from the Georgian Bay and Queenston Formations.

Four of the 6 Quaternary geology field projects were located in northern Ontario in 1984, thus marking an evolving shift in emphasis of the activities of the Quaternary Geology Subsection.

R.S. Geddes commenced mapping of the Cedar Lake and White Lake map areas in the Hemlo area (Project 19.), not only to provide an account of the Quaternary geology of the area, but also to provide a stratigraphic framework for drift exploration studies in the area and to provide a geological framework for sand and gravel investigations.

The areas are characterised by drift, which varies in thickness from 0 to more than 100 m and by tills which vary in texture from a dense, calcareous, sandy silt with a high percentage of exotic Paleozoic clasts to a loose sand with clasts of local litholgy. Thick glaciolacustrine deposits, rich in shell and other organic materials, occur widely in the western half of the map areas. Aggregate resources in the vicinity of the mines being developed at Hemlo and may be affected by a high chert content but the fine-grained carbonate till may have a useful application in the construction of tailings dams.

In the Timmins-Matheson area the Section staff were involved in 2 Quaternary projects. J. Richard mapped the Porquois Junction and Watabeag River map areas (Project S51.) which adjoin map areas to the east, previously mapped under the KLIP and BRIM programs. This work will not only complete, at a scale of 1:50 000, a large area from west of Timmins to the Ontario-Quebec border, but will provide a Quaternary geology database for the BRIM till sampling programme.

Most of the area involved in this year's mapping project is covered by a thick mantle of lacustrine clays deposited in glacial Lakes Barlow-Ojibway. Where the original till surface stood up in relief, those areas remain today either bare of lacustrine clay or show evidence of having been winnowed and worked by the proglacial lake waters. Water-worked esker ridges and bedrock outcrops are also reported throughout the map areas. The Cochrane Till was not mapped in the Porquois Junction area, but the southern limit of the advance of the Cochrane ice is not far beyond the northern edge of the mapped area. The compilation of drillhole logs from the area and observations from beyond the map area indicate that its pre-Wisconsinan history may be more complex than hitherto understood.

Aggregate resources are not a problem in the area as plentiful supplies of aggregate should be available in the several esker systems present. Where the Barlow-Objiway clays form the river banks and lakeshore bluffs in the area, unstable slopes may cause problems, especially where toe erosion is possible from either river water or waves.

Baker *et al.* report the first stages of a joint Quaternary geology and geochemistry study of till in the BRIM area near Matheson through a backhoe sampling program (Project S54). The backhoe equipment was used to sample where till was known or suspected to be present close to the ground surface. More than 135 sites were investigated to depths of over 3 m, and 6 to 8 kg of material was taken for geochemical analysis at each of 93 sites. Pebble counts of the till clasts were made where appropriate.

In northwestern Ontario, P.F. Finamore was in charge of Quaternary geology mapping and bedrock dispersion studies with a interdisciplinary field party working on the North Caribou Lake belt (Project S49.), which runs both north and east from Opapamiskan Lake. The Quaternary studies were centred around the base camp established on Eyapamikama Lake at the western end of the belt.

The Quaternary geology is characterized by the presence of a stony, gritty lodgement till which occurs as drumlins, ground moraine, and end moraine. The waters of glacial Lake Agassiz are believed to have covered this area, as evidenced by the occurrence of glaciolacustrine sediments and wave-cut terraces and boulder lag concentrations on the drumlins. The examination and sampling of the boulders in the drift was predicated on the occurrence of gold-bearing iron formation in the vicinity of Opapimiskan Lake to the south. Similar boulders were located in the drift in the vicinity of the portage between Eyapamikama Lake and the North Caribou River, and in the general area south of Castor and Pollux Lakes. Other float of potential economic interest was found in the northern part of the Agutua Arm.

The Hydrocarbon Energy Resources Program (HERP) continued with field activity throughout northern Ontario and in the Algonquin and Eastern Ontario regions in the late Summer and Fall of 1983, and Winter of 1984. These activities are reported here for the first time (Telford and Russell, Project S23).

The second year (1983-84) of the peatland inventory saw peat inventory projects undertaken in 7 areas across the province (Rainy River, Ignace, Foleyet, New Liskeard, Parry Sound, Kingston-Belleville, and Ottawa-Brockville). Each project was undertaken by a consulting company using inventory specifications prepared by J. Riley of the Engineering and Terrain Geology Section who also supervised the 7 projects (Project S23.).

In the first 2 years of the program, 77 728 ha of peatland have been studied in detail and 68 759 ha have been investigated at the reconnaissance level. 1350 x 10^6 m^3 of peat have been identified to date, and samples were taken for laboratory analysis. Vegetation types occurring on peatlands have been mapped and satellite imagery obtained through the Ontario Centre for Remote Sensing, Ministry of Natural Resources, Toronto, has been used to evaluate the value of remote sensing techniques to the identification and characterization of peatlands.

Following the completion of the field investigation of the oil shales in southern Ontario, attention this past year was turned to the study of the Upper Devonian Long Rapids Formation of northern Ontario. Much less was known of this formation than about the Upper Devonian units of southern Ontario, but a concerted effort was made during the last field season to investigate the exposures of the Long Rapids Formation along the banks of the Abitibi River. Ontario Geological Survey staff were joined in this venture by representatives from the Geological Survey of Canada and McMaster University when 36 m of stratigraphic section along 2 km of river bank were examined. The uppermost 8 m of black fissile shale probably has the greatest economic significance but the apparent structural complexity of the exposure indicates that regional assessment extrapolated from this exposure could be fraught with difficulties.

The lignite resources of the Moose River Basin were further investigated through the drilling of a hole to the Precambrian basement at Schlievert Lake in the Fall of 1983 and by the drilling of 11 shallow holes in the western end of the basin in the Winter of 1984 (Telford, Project S25.). The winter drilling encountered lignite in only 1 hole, although Cretaceous sediments were encountered in 3 holes. The information obtained has provided much new information on the configuration and characteristics of the basin and an updating of the geological map of the area is indicated.

The inventory of the aggregate resources of the province continued with field studies and office compilations carried out on areas in both northern and southern Ontario (Project 22.). In southern Ontario, all of the activity was in southwestern Ontario except for 2 townships in Peterborough County.

Surficial deposits related to the action of glacial Lake Whittlesey are the usual source of aggregate in the aggregate-poor counties of Essex and Kent, but more extensive subsurface exploration may reveal an economically useful buried deposit near Leamington. Elgin County is another area which is short on good quality sand and gravel, but recent Quaternary geology mapping of the Port Stanley area (Dreimanis and Barnett, Project 20.) has revealed the potential of economically useful resources in a buried deposit.

Studies in Huron and Perth Counties were in townships in which there is an abundance of sand and gravel. Kame deposits are the major sources of sand and gravel in the area but terraced outwash deposits along the Maitland and Avon Rivers supply significant quantities of commercial aggregate.

St. Vincent Township in Grey County relies on glaciolacustrine beach deposits for most of its sand and gravel, but Amabel dolostone should be readily available if a quarry was to be opened up in the area.

The well known Norwood Esker, located in Peterborough County, is a major source of sand and gravel for the surrounding area. The area also enjoys an abundance of good quality Ordovician limestone which is quarried, in part, for the production of crushed stone. A basalt quarry east of Havelock is a major supplier of crushed stone for use as a wearing course on highways across the province.

In northern Ontario, aggregate studies were undertaken in the Helmo and Espanola areas following requests for assistance from local municipal and Ontario Ministry of Natural Resources district staff. An initial field visit to the Hemlo area in the Fall of 1983 was followed up by further work in the 1984 field season. All known pits in the Marathon, Manitouwadge, and White River areas were visited and sampled as were other localities which appeared to have an aggregate potential. Based on these studies, adequate short term supplies of coarse aggregate, suitable for most purposes, may be available in the vicinity of the developing mines, but top quality material (i.e. with an acceptably low chert content) may be more difficult to locate. There appears to be an abundant supply of fine sand to meet short term needs. Wise management of the resource is essential to ensure the availability of long term supplies. Coarse aggregate is readily available in the vicinity of White River, Marathon, and Manitouwadge.

In the Espanola area, 5 townships were assessed for their sand and gravel resources. In the past, most aggregate requirements have been supplied from small localized deposits flanking rock knobs. More extensive deposits have been located in McKinnon Township, along the shoreline of Lake Huron, and along the Spanish River in Hallan Township. Samples taken are currently being tested.

The aggregate resources in the Opapimiskan Lake area were also investigated as part of the interdisciplinary field party operations in that area (Breaks *et al.* Project S49. this volume). The area studied was along the winter road from the Pickle Lake Road to Opapamiskan Lake. Aggregate was shown to be available in the vicinity of the Pickle Lake Road but was sparse from there to a point about 10 km south of Opapamiskan Lake where adequate supplies from a number of eskers would be available. Overall quality is expected to be good with only a low percentage of fines and a minor percentage of chert present in the coarse gravel.

19. Quaternary Geology of the Hemlo Area

R.S. Geddes

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INTRODUCTION

Quaternary mapping of the Hemlo area (Figure 1) was undertaken during the summer of 1984 following preliminary investigation in the fall of 1983. The project area includes 2 1:50 000 scale map sheets, Cedar Lake (NTS 42 C/12) and White Lake (NTS 42 C/13). The area extends from Latitude 48°30'N to 49°00'N and from Longitude 85°30'W to 86°00'W. The Hemlo gold deposits lie in the west central part of the map area.

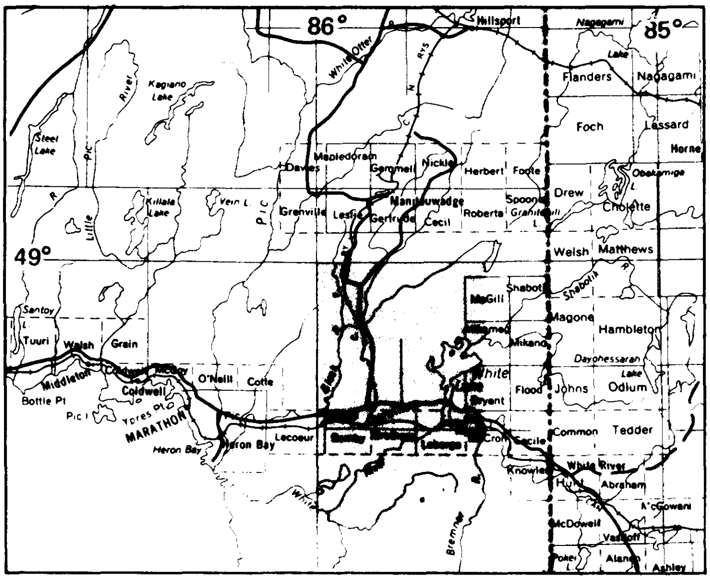
The area is traversed by Highway 17, which runs east-west through the centre of the map area, and by Highway 614 which extends northward from Highway 17 to the Town of Manitouwadge. Bush trails and forest access roads branch from these main corridors. Although boat and canoe access is good throughout much of the area, limited helicopter access was required to fully cover the area. Detailed studies and sampling were undertaken along the various access routes and supplemented by air photo interpretation.

Previous surficial investigations were primarily of a reconnaissance nature (Boissonneau 1965; Zoltai 1965). The area is also covered by an engineering geology terrain study (Gartner and McQuay 1980). Adjacent areas are currently being investigated by R. Kristjansson (Ontario Ministry of Natural Resources, Thunder Bay).

BEDROCK GEOLOGY

The Hemlo area has become well known because of the recently discovered "world-class" gold deposits. Exploration history and current status of activity are outlined by Patterson (1984). Detailed study of the bedrock geology specifically within this project area has been undertaken by Milne (1968) in the northern portion, and more recently by Muir (1982) in the western sector, and Siragusa (1984a, 1984b) in the eastern area.

The bedrock geology of the map area can be summarized as consisting of an east-trending belt of Archean metasedimentary and metavolcanic rocks, which are part of the Wawa Subprovince. The belt is synformal, with granitic intrusions along its axis, and is bounded on the north and south by gneiss complexes. The Pukaskwa Gneiss Complex occupies much of the southern part of the map area, the limits of which have not been mapped in detail.



LOCATION MAP Scale : 1 : 1 584 000 or 1 inch to 25 miles

QUATERNARY GEOLOGY

The direction of the last (Late Wisconsinan) glacial advance was moderately consistent over the northern half of the map area. Numerous glacial striae indicate an ice movement trending 210° (±10°). A more radial pattern is reflected in the southern part of the region, with a dominance of north-trending striae in the east, swinging to 240° in the west (the latter area includes the Hemlo gold deposits). In addition, in the central part of the map area, a weaker and apparently older striae direction is recognized, ranging from 170° to 190°.

The thickness of glacial drift in the region is extremely variable, ranging from less than 1 m to more than 100 m. Much of the area is covered with only a thin veneer of overburden, and bedrock outcrop is particularly common in the north central, and southern parts.

Deposits of till are extensive and quite variable in thickness and composition. In areas of high relief, and/or thin drift cover, the till is predominantly stoney, sandy, and generally of local derivation. Small pockets of this type of local till are also recognized directly over bedrock under thicker drift sequences.

Much of the till in the region, particularly in the central portion, is an unusual sandy silt till which contains a high percentage of exotic (e.g. Paleozoic carbonate) clasts. Matrix carbonate ranges from 15% to 30%. This till occurs as variations of 2 facies. One represents a dark grey, stone poor, massive, and extremely dense till and the other a looser, buff-grey, subcompact, and often substratified till. The latter variety is regionally the most extensive, while the more compact phase is periodically found at depth. In some areas, this exotic carbonate till appears capped by a stoney, sandy, and loose till containing more locally derived pebble lithologies.

Glaciolacustrine sediments form a thick and extensive cover, particularly over the northwestern sector of the map area. The deposits range from silt and clay varves to massive fine sands. They occupy a major lake basin, now centred on the Black River valley, which extends west to Lake Superior. The deposits appear to have a distribution confined by an elevation of about 320 m above sea level within the map area.

The lacustrine and terrace deposits contain an abundance

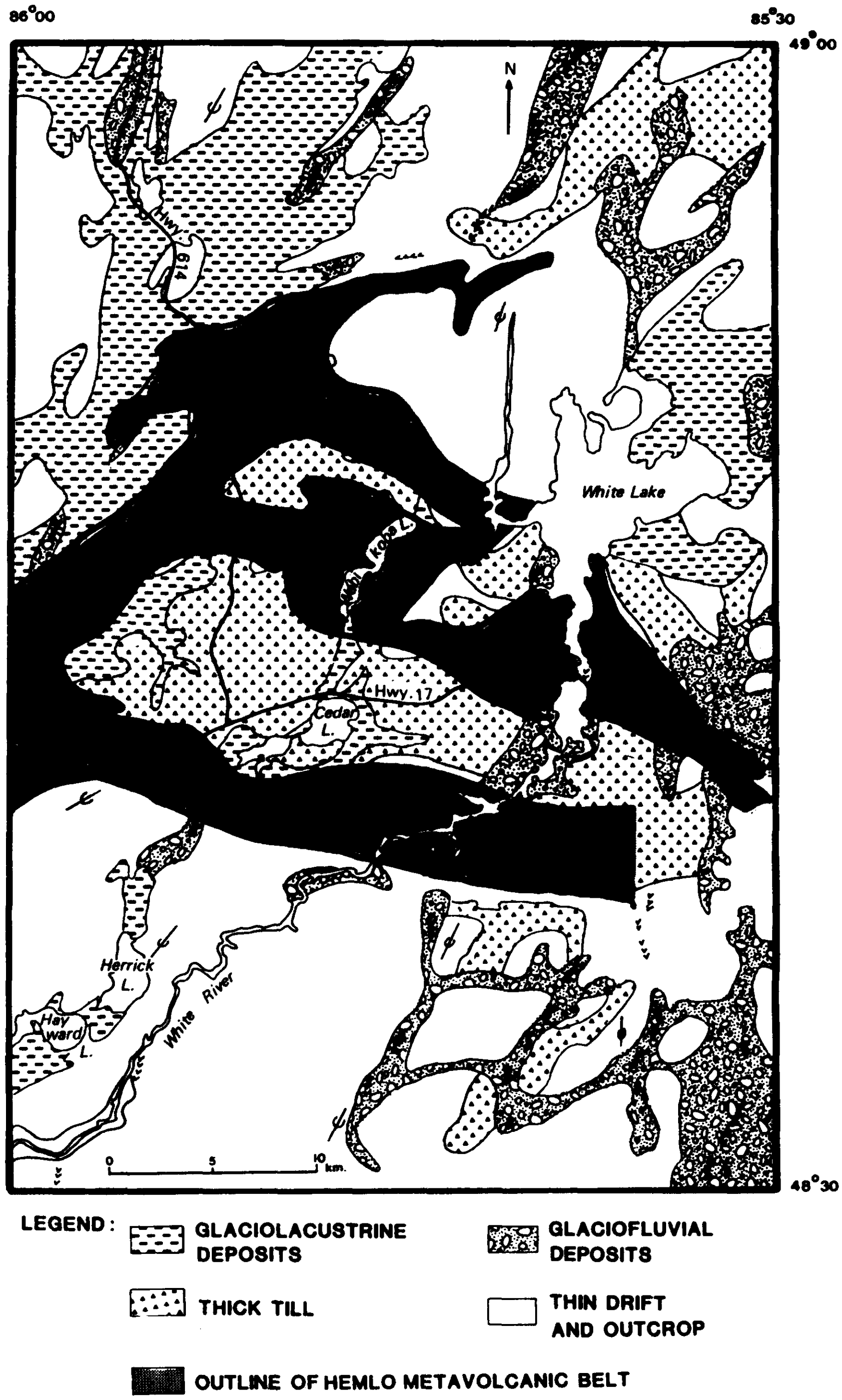


Figure 1. Generalized sketch map of Quaternary geology of the Hemlo area. (Project 19.)

of shell and organic material. Many good exposures were discovered and examined by A. Bajc (Senior Assistant), who will be investigating the material as part of an M.Sc. thesis at the University of Waterloo.

Other glaciolacustrine sequences are found in the central and northeastern parts of the region. They are particularly extensive northeast of White Lake.

Glaciofluvial deposits consisting of sand and gravel occur in the form of discontinuous eskers and kame complexes. They are commonly situated within regional topographic lows, and thus, in part are buried by the lacustrine sequences. Several narrow esker systems transect the south central and southeastern part of the region.

Outwash sands are also found in topographic lows and narrow drainage valleys. Two large outwash systems are associated with the White River and Bremner River valleys.

Alluvium is well developed along the Black River. Deposits of peat and organic muck are found in bogs and swamps throughout the area. Thickest accumulations of this material are found over some of the lacustrine plains. Scattered eolian dunes are also recognized in this same environment.

APPLIED QUATERNARY GEOLOGY

The Quaternary deposits of the Hemlo area provide both resources and constraints affecting the region's current development.

Areas of relatively thin drift cover appear amenable to a variety of exploration methods involving surface geochemistry and drift prospecting. This includes some of the region around the known deposits (Patterson 1984). This exploration technology, however, cannot necessarily be transferred or extended to other areas of the Hemlo belt. The glaciolacustrine deposits, particularly over the western part of the belt, can greatly inhibit the effective use of surface geochemistry. In other areas, the exotic carbonate till lacks a significant component characteristic of local glacial dispersion (Geddes 1984). While more research is required to investigate these problems, an initial understanding of the distribution and thickness of these surficial sediments is critical to exploration in the region.

Aggregate sources are scarce in the area, particularly in the vicinity of the mine developments. A limiting factor on gravel usage may be the high chert content which accompanies the exotic Paleozoic lithologies found in the surficial materials. Buried glaciofluvial deposits within the glaciolacustrine basins may warrant further investigation.

The exotic fine-grained till, while being an impediment to mineral exploration, has a number of characteristics which render it useful for certain applications. It has been extracted in the past for use in fill, and is currently being investigated for use as core material in tailings dams.

The general distribution of carbonate material in the area may have some important environmental applications. The relationship between the surficial materials and lake water acidity within the map area is being investigated as part of a B.Sc. thesis by E. Woods at the University of Western Ontario.

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20. Quaternary Geology and Stratigraphy of the Port Stanley Area, Elgin County

Aleksis Dreimanis[1] and P.J. Barnett[2]

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[2]Geologist, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto.

INTRODUCTION

Quaternary geological mapping and stratigraphic studies were undertaken in the Port Stanley (40 I/11) National Topographic Series map area during June and July. Mapping in this area was initiated by the senior author for the Ontario Department of Mines in 1964 and continued with support from the Geological Survey of Canada between 1968 and 1970 (Dreimanis 1969). A preliminary map of the western half of the area has been published previously (Dreimanis 1972).

The Port Stanley area is located along the north shore of Lake Erie and is bounded by Latitude 42°30'N and 42°45'N, and Longitude 81°W and 81°30'W. The entire map area is in Elgin County.

The assistance of both Southwestern Region and Aylmer District staff of the Ontario Ministry of Natural Resources during this survey was gratefully appreciated.

PHYSIOGRAPHY

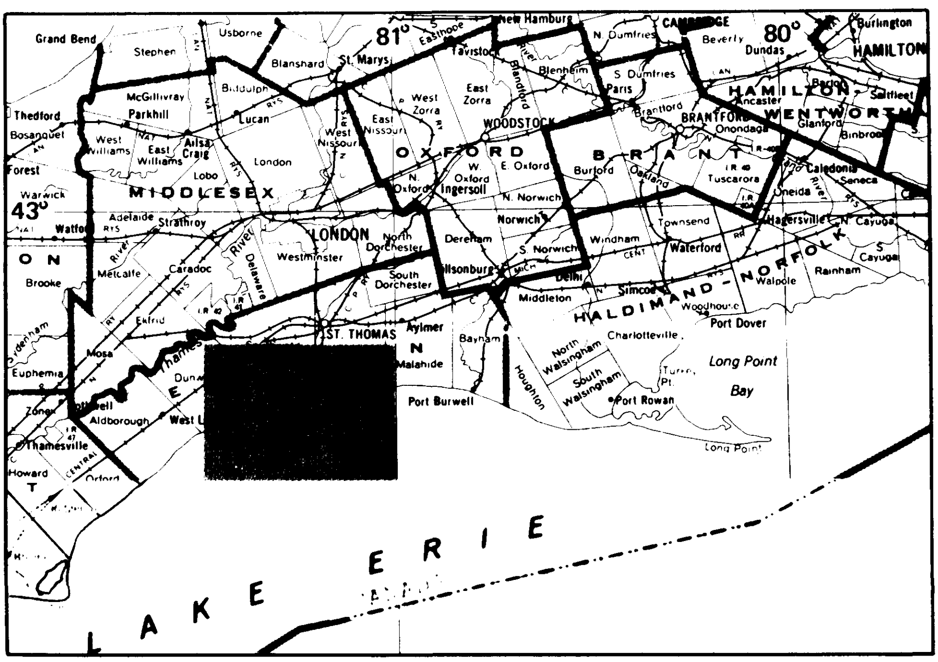
The Port Stanley area is essentially a gently undulating lake plain dipping southward towards Lake Erie. It is dissected to depths of 30 m by Talbot Creek, Kettle Creek, Catfish Creek, and several of their tributaries. Along Lake Erie, shorebluffs can exceed 30 m.

Positive relief is provided by the Sparta and St. Thomas Moraines. Northwest of Sparta, the Sparta Moraine rises over 30 m above the lake plain.

This lake plain has been subdivided into 2 physiographic regions by Chapman and Putnam (1966); the Norfolk Sand Plain (in the eastern part of the map) and the Ekfrid Clay Plain. The 2 moraines mentioned above are part of the Mt. Elgin Ridges physiographic region (Chapman and Putnam 1966).

QUATERNARY GEOLOGY

Mapping and stratigraphic studies were concentrated in the eastern half of the Port Stanley area. Here, surface sediments are predominantly



LOCATION MAP

Scale : 1 : 1 584 000 or 1 inch to 25 miles

of glaciolacustrine origin with the major exception of Port Stanley till which outcrops along the crests of several moraines which cross the area (Sparta, Tillsonburg, Courtland, and Mabee Moraines).

Noteworthy observations made during this summer include:

1. Several exposures of organic-bearing silts and clays occur beneath Catfish Creek Drift, along Catfish Creek.
2. Catfish Creek Drift is exposed primarily along Catfish Creek between Sparta and New Sarum. Studies here suggest that this area was a complex interlobate zone influenced by the Huron and Erie lobes as well as ice flowing from the northeast.
3. Several genetic varieties as well as textural facies were recognized in the Catfish Creek and Port Stanley tills, including excellent examples of lodgement, meltout, and flow sedimentary assemblages.
4. Catfish Creek Drift appears to be, in part, the core of the Sparta Moraine.
5. Fluvial and deltaic gravel and sands exposed along Catfish Creek northeast of Sparta. beneath Port Stanley till, may be deposits of the Erie Interstadial.
6. Port Stanley Drift is composed of at least 3 layers of subglacially deposited clayey silt till, separated by beds of rythmically bedded sand, and silt, and clay rythmites. Waterlain till was found to be associated with the subglacial till either above or below it, or as its continuation downglacier. Ice-contact stratified drift related to the Port Stanley till is present along the Sparta Moraine as well.
7. The Mabee Moraine was traced westward to the Lake Erie shorecliffs near Dexter, and the Courtland Moraine westward to Port Stanley.
8. High level shoreline features, occurring at elevations around 256 m (840 feet) above sea level, were formed during Lake Maumee, probably Maumee IV.
9. Two levels of glacial Lake Whittlesey were recognized between 3 and 5 m apart. The higher and apparently older beach probably predates the Mackinaw Interstadial, while the lower beach formed during the main Lake Whittlesey stage approximately 13 000 years ago.

ECONOMIC GEOLOGY

Sand and gravel is being extracted in the Port Stanley area from ice-contact stratified drift (associated with Port Stanley and Catfish Creek tills), beach deposits, fluvial deposits in abandoned terraces, and modern alluvium.

The major source of coarse aggregate presently is the fluvial and modern alluvial deposits along Catfish Creek, northeast of Sparta. Other deposits of significance are beach deposits of Lakes Arkona, Whittlesey, and Warren; however, these deposits tend to be mainly sources of fine aggregate.

Buried sources of sand and gravel along the Sparta Moraine and along the Catfish Creek valley are being extracted to a greater degree than in the past. At least 4 ages of buried aggregate were recognized: (1) ice-contact stratified drift related to Catfish Creek Drift; (2) possible Erie Interstadial fluvial and deltaic gravels; (3) ice-contact stratified drift related to Port Stanley till; and (4) buried gravel and sand of Lake Arkona.

Lake Arkona sediments are of limited extent, but are, however, areally associated with the two ages of ice-contact sediments. Ice-contact stratified drift related to the Port Stanley till appears to be predominantly a source for fine aggregate. Ice-contact stratified drift related to the Catfish Creek till and the Erie Interstadial deposits could be sources for coarse aggregate.

Further study into the nature and distribution of these buried sources of aggregate is recommended. This project has already stimulated an initial preliminary investigation of the buried aggregate potential by Regional and District staff of the Ontario Ministry of Natural Resources.

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21. Quaternary Geology of the Brampton Area, Southern Ontario

P.F. Karrow

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INTRODUCTION

The Brampton area is located northwest of Lake Ontario and includes the western part of Metropolitan Toronto. It extends from Longitude 79°30'W to 80°W and from Latitude 43°30'N to 43°45'N.

Part of the area within Metropolitan Toronto was previously mapped by Watt (1957, 1968). Additional mapping by Watt and D.R. Sharpe was not completed. Hewitt (1969) summarized the industrial minerals of the area. Adjacent areas have been mapped to the north (Bolton: White 1975), west (Guelph: Karrow 1968), and south (Hamilton-Galt: Karrow 1963).

Mapping was begun in June 1984 along the western edge of the area. The part of the area west of the Niagara Escarpment was completed, and the till plain east of the escarpment begun.

BEDROCK

Most of the area is underlain by shales of Ordovician age (Georgian Bay and Queenston Formations), while the Silurian clastic and carbonate rocks of the Niagara Escarpment underlie a belt a few kilometres wide, along the western edge of the area, (Bond, Liberty, and Telford 1976). Outliers of the Escarpment are present at Milton and Terra Cotta.

PHYSIOGRAPHY

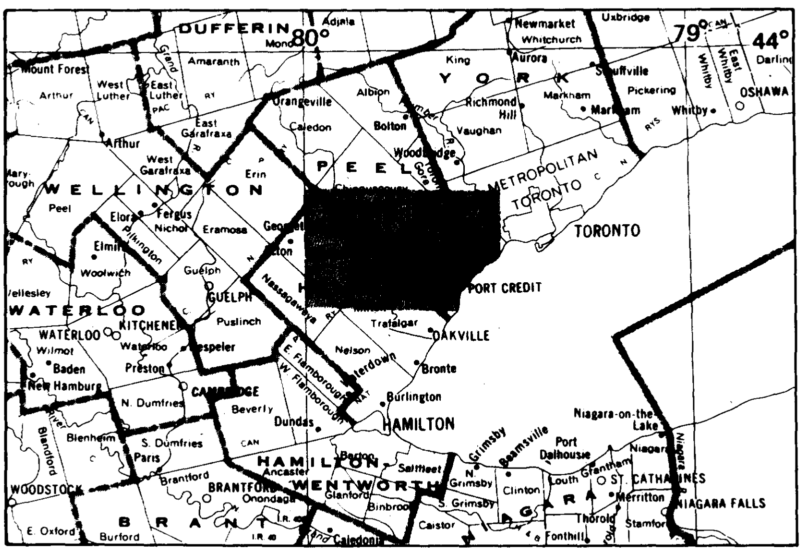
The area has an overall relief of about 300 m and all streams flow into Lake Ontario. The Niagara Escarpment is the major relief feature, with an extensive till plain east of the Escarpment sloping southeast to Lake Ontario. The glacial Lake Iroquois terrace extends along the northern shore of Lake Ontario as a belt several kilometres wide.

GLACIAL GEOLOGY

Small areas of sandy Wentworth Till occur along the western edge of the area, where they form part of a drumlin field east of the Paris Moraine, located just west of the present map area.

Most of the till so far encountered is considered part of the silty to clayey Halton Till. This till extends from near the western edge of the area eastward, and is believed to represent a readvance of the Lake Ontario lobe of Port Huron age. This till is commonly rich in clasts of red Queenston Shale, giving rise to its usual red brown or brown colour. The ice which deposited Halton Till surmounted the Escarpment, except at the reentrant west of Limehouse, and incorporation of Silurian dolostone caused a coarsening of the till. Several ridges of till and ice-contact faces in glaciofluvial sand and gravel mark the local trend of the ice front. A locally convex ice front, west of Milton, formed in the Escarpment reentrant north of the Milton Outlier.

North of Limehouse, ice-contact sands and gravels, often of cobble and boulder size, are abundant. These gravels, like the Halton Till, are rich in Ordovician clastics. Paleoflow directions of the depositing meltwaters are commonly westward and southward. Late meltwater erosion down to bedrock separated the deposit into residual "islands" and left extensive areas of outcrop.



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22. Aggregate Resources Inventory Program

Staff of the Aggregate Assessment Office

Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto.

INTRODUCTION

Field work was conducted in southern and northern Ontario during the 1983 and 1984 field season as part of the Aggregate Resources Inventory Program. The results of field activities undertaken will be published in Aggregate Resources Inventory Papers or released in Open File Reports, as applicable. The areas involved in field investigations were, in southern Ontario:

1. Essex and Kent Counties
2. Huron and Perth Counties
3. Elgin County
4. Grey County
5. Peterborough County

In northern Ontario:

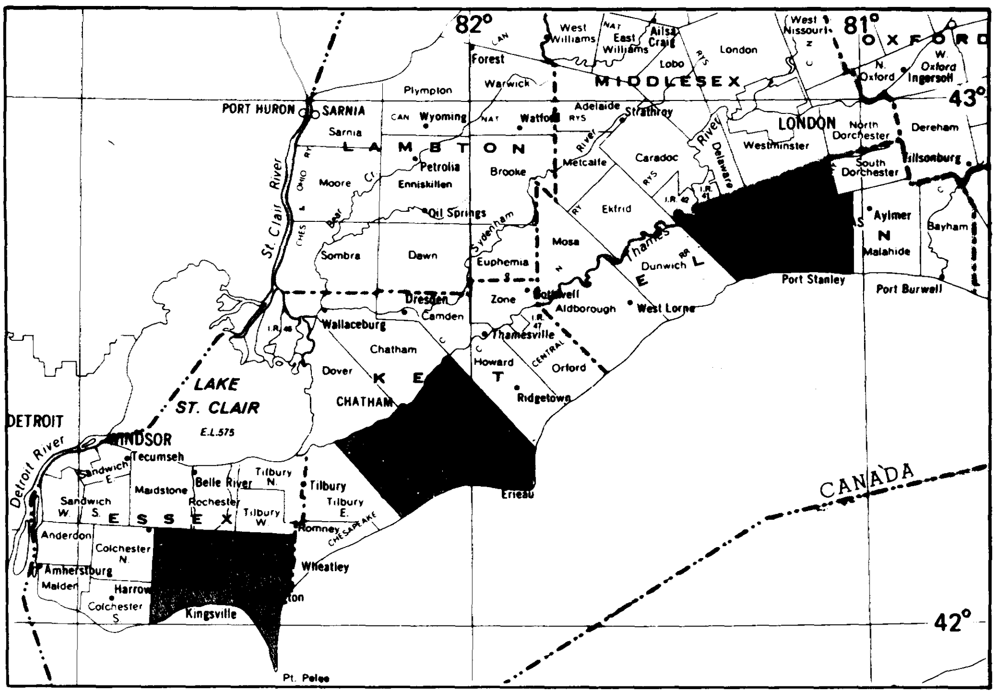
1. Hemlo area
2. Espanola area

Field investigations consisted of the following activities: examination of potential aggregate deposits, existing pits and quarries, natural and man-made exposures, as well as auger drilling. All active and abandoned pits were investigated and at each site several observations were made, including: face height, percentage of gravel and sand, and the presence of deleterious material such as chert, shale, clay, silt, and oversized boulders. Active and abandoned quarries were also visited. At these sites, the height of the face was noted, as well as bedrock geology, and the presence of deleterious materials.

The purpose of the field investigations was to confirm and add to information gathered from various sources such as existing geological reports and maps, data from files of the Ontario Ministry of Transportation and Communications, and water well data from the Ontario Ministry of the Environment. In areas where little pre-existing data were available, or where the presence of buried granular material was suspected, a small portable drill rig and geophysical equipment (conductivity and hammer seismic) were used to enhance the assessment of potentially significant deposits.

ESSEX AND KENT COUNTIES

The aggregate potential of Mersea, Gosfield South, and Gosfield North Townships in southern Essex County was investigated. The predominant aggregate-bearing glacial sediments in the study area are the gravels and gravelly sands related to the abandoned shorelines of glacial Lakes Whittlesey and Warren



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(Vagners 1972). The largest and most important sand and gravel deposit is located immediately west of Leamington. There has been substantial extraction from this beach deposit in the past and much of the material has been depleted. Extensive deposits of glaciolacustrine sand are abundant in the Leamington-Wheatley area. Continuous but thin deposits of glaciofluvial gravelly sand and fine to medium sand extend from the Essex-Kingsville area to Blytheswood. These deposits were laid down by meltwater discharging from the margin of the receding Wisconsinan glacier (Vagners 1972). Potential buried aggregate zones were also examined in the Leamington area, but more detailed subsurface investigations are required to identify areas of potential importance.

Field investigations were carried out in Raleigh and Harwich Townships in southern Kent County. The townships contain only limited deposits of fair to poor quality sand and gravel. Poorly sorted, fine aggregate is concentrated in the beaches and shoreline features that occur around the edges of the Blenheim Moraine. The fine aggregate found in these beach deposits is of limited use because of the high chert and shale contents.

Near Pinehurst a large, buried ice-contact-outwash deposit of well washed and sorted sands and gravels has been extracted to bedrock in 2 commercial operations. Aggregate is extracted by dragline because of a high water table. Shale and chert are removed through a heavy media separation process to upgrade the products for use as concrete aggregate.

ELGIN COUNTY

Field checking in Southwold Township revealed limited resources of high quality aggregate. Sand and gravel in the township is generally restricted to minor deposits of glaciolacustrine and glaciofluvial origin. Sand and gravel is extracted from alluvial deposits along the Thames River.

In Yarmouth Township, coarse crushable aggregate has been extracted from terraced outwash deposits and modern alluvial deposits along Catfish Creek, northeast of Sparta. Sources of fine aggregate include beach deposits of glacial Lakes Arkona, Whittlesey, and Warren.

The Sparta Moraine is located in the south central part of Yarmouth Township and is thought to contain several types of buried aggregate: (1) ice-contact stratified drift related to both the Catfish Creek and Port Stanley Tills; (2) potential Erie Interstadial fluvial and deltaic gravels; and (3) buried aggregate of Lake Arkona (*see* Dreimanis and Barnett, this volume). In cooperation with Ministry staff from Southwestern Region and Aylmer District, a subsurface investigation was initiated along the Sparta Moraine and along the Catfish Creek valley to examine the depth and extent of buried aggregate. A small portable drill rig and hammer seismic equipment were utilized to better understand the mode of deposition of these deposits.

HURON AND PERTH COUNTIES

Morris and McKillop Townships in Huron County were investigated. Both townships contain large resources of sand and gravel suitable for a wide range of products. Sand and gravel are found in eskers, ice-contact stratified drift and outwash deposits which were formed when the margins of the Georgian Bay and Huron lobes retreated from the area. Morris Township contains substantial deposits of good quality glaciofluvial outwash located along the Maitland River valley.

In southern Perth County, Downie, North Easthope, and South Easthope Townships were investigated. Pits have been established in the St. Marys Esker and in ice-contact deposits in all 3 townships. The main gravel-bearing areas are kames located south of Stratford and in the Easthope Moraine. Many of these kame deposits coarsen with depth and can produce a wide range of aggregate products. Minor resources of fine outwash gravel were deposited along the Avon River.

GREY COUNTY

Sand and gravel in St. Vincent Township is concentrated in glaciolacustrine beach deposits of Lakes Algonquin and Nipissing. The most significant deposit is a Lake Algonquin baymouth bar southwest of Meaford. This deposit contains medium to coarse gravel in a matrix of fine to medium sand.

Dolostones of the Amabel and Fossil Hill Formations form the cap of the Niagara Escarpment in the township. The formations are valuable sources of aggregate, and are capable of producing a wide range of high quality products. Shales of the Georgian Bay Formation are utilized for use as a raw material in clay products, such as drainage tile.

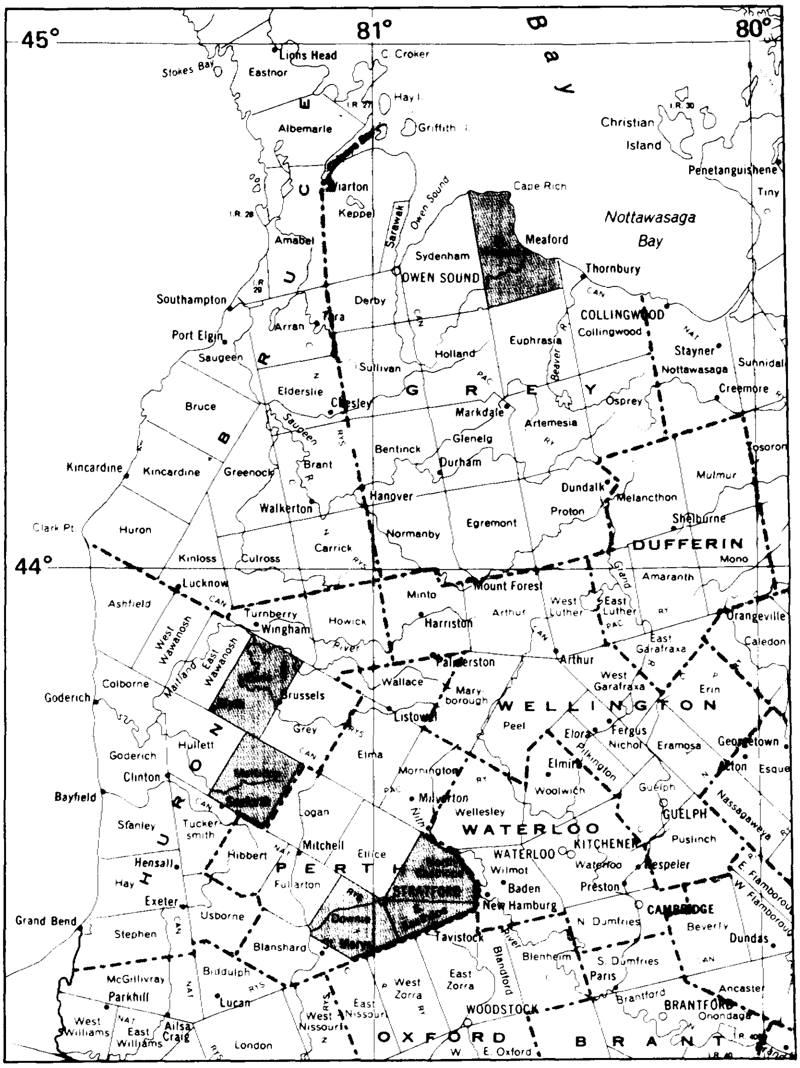
PETERBOROUGH COUNTY

Field investigations were conducted in Harvey and Belmont Townships. One of the most prominent deposits in the area is the Norwood Esker and its associated sediments, between Havelock and Crowe Lake. Other resources of sand and gravel were found in outwash deposits near Bobcaygeon and in glaciolacustrine beach deposits south of Havelock. An extensive area of glaciolacustrine sand is located in the southern and northeastern part of Belmont Township.

Bedrock in the townships consists of Precambrian granites, gneisses, metasedimentary rocks, and Middle Ordovician rocks of the Shadow Lake, Gull River, Bobcaygeon, and Verulam Formations. Limestones of the Gull River and Bobcaygeon Formations are well suited for use as crushed stone, and quarrying potential is high because the bedrock is covered by thin drift. A large quarry operated by 3M Canada Incorporated, east of Havelock, produces basalt ("trap rock") for use as skid-resistant aggregate for highway construction and coated roofing granules (Bartlett *et al.* 1982; Leyland and Mihychuk 1984). This rock is extremely hard and is ideally suited for high quality asphalt surface paving mixes.

HEMLO AREA

The Hemlo project area is located midway between Sault Ste. Marie and Thunder Bay near the northern shore of Lake Superior. Included within the area are parts of the municipalities of Marathon, Manitouwadge, and White River which form the western, northern, and eastern limits of



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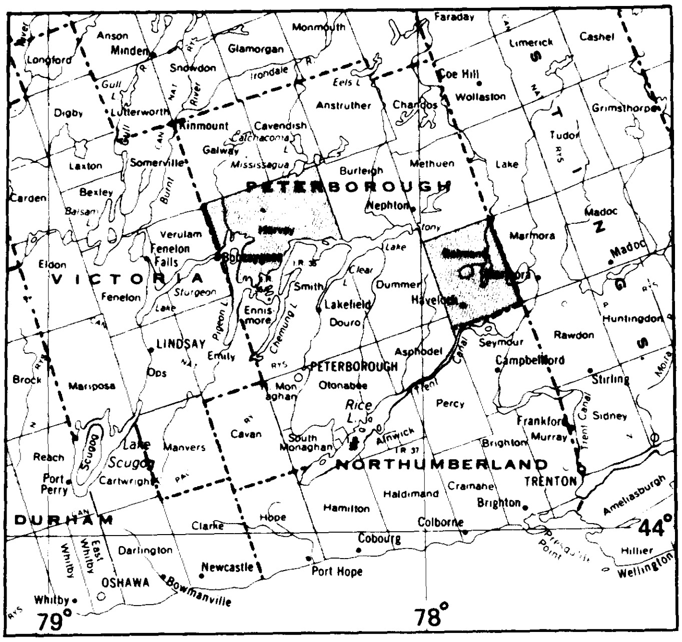

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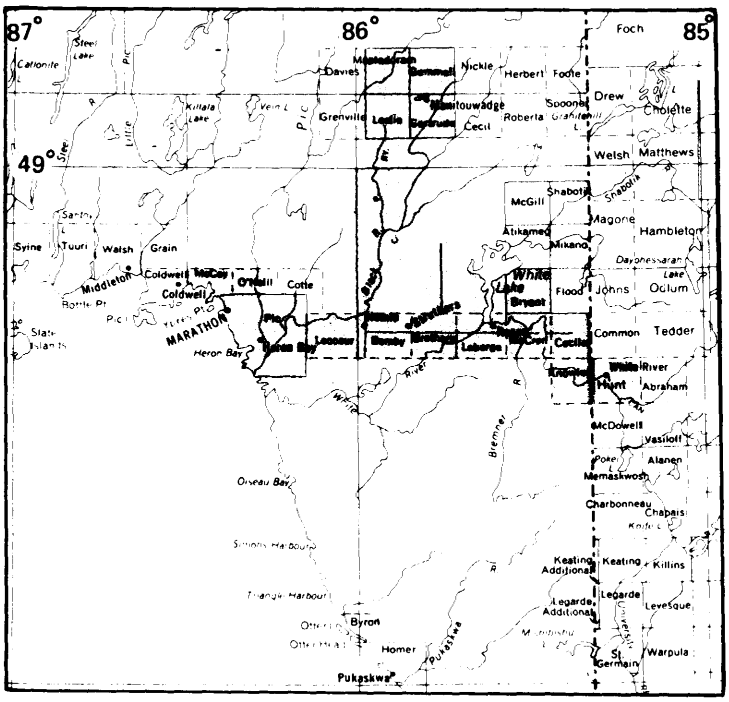

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the study area, respectively. The discovery of rich gold deposits near Hemlo in 1981 has led to the development of 3 mines. Construction of these mines and the resultant population growth in the surrounding communities has increased the demand on local aggregate resources and this project was initiated in response to this demand.

Field work was undertaken for this project by staff of the Aggregate Assessment Office during the fall of 1983 and spring of 1984. Quaternary mapping by R.S. Geddes, Engineering and Terrain Geology Section (this volume) and R. Kristjansson of the North Central Region, Ministry of Natural Resources in Thunder Bay provided the framework for the detailed aggregate study. During the spring, field assistance was kindly provided by the Wawa District Office.

Over 130 sand and gravel pits were visited during the field study. The material exposed in these pits was of varying quality and ranged in composition from fine sand with silt seams to coarse gravel. To better assess the quality of the aggregate, samples were taken for testing. In areas of limited subsurface exposure test holes were excavated using a backhoe. Geophysical testing was also undertaken.

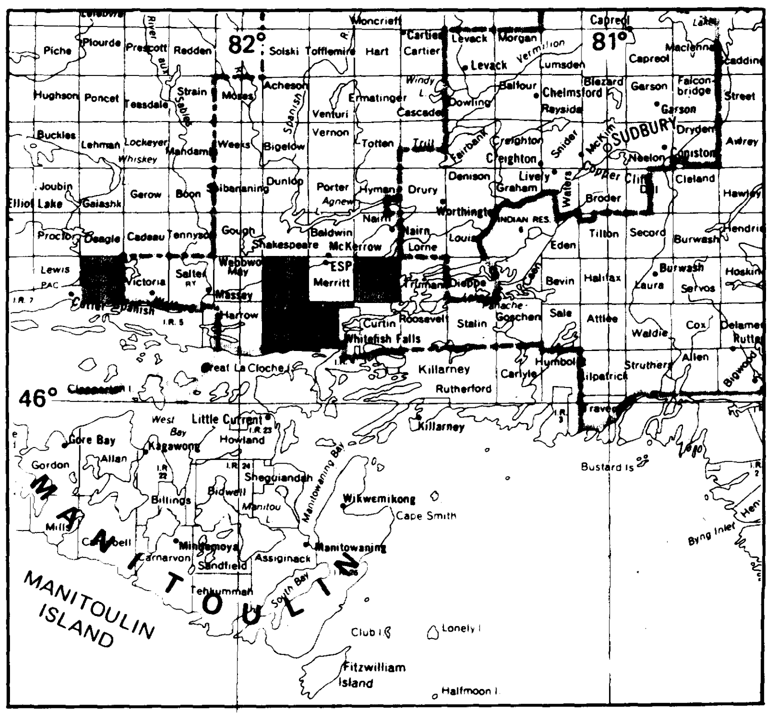
Much of the topography in the Hemlo area is controlled by bedrock and the aggregate deposits are often located in depressions between bedrock knobs. An exception to this is the existence of a broad glaciolacustrine delta near Marathon which was deposited on a bedrock high. This delta, together with the glaciolacustrine beach deposits developed along its flanks, are well suited for aggregate extraction and have been traditional sources of aggregate within Marathon Township Municipality.

In the vicinity of the main mining activity near Hemlo, sand and gravel exploration and extraction activities were intense and a number of pits have recently been opened. Major aggregate deposits located within 20 km of the Hemlo mine developments include:

1. a northeast- to southwest-trending glaciofluvial system in the eastern part of Bomby Township
2. esker and associated ice-contact deposits near Philips Creek
3. a lengthy esker system flanking the Black River
4. esker ridges located east of Highway 614 between Philip Lake and Barbara Creek
5. esker segments and ice-contact deposits along the eastern shore of White Lake

These deposits contain significant resources of sand and gravel suitable for such uses as mine backfill, road base, and crushed stone. Between Hemlo and Marathon, however, high quality aggregate resources are lacking and the predominant material is glaciolacustrine fine sand.

Several esker, ice-contact, and outwash deposits lie within Manitouwadge Township Muncipality. The most significant and readily accessible of these deposits are located west and south of the community of Manitouwadge and contain aggregate suitable for a variety of products. South of the municipality, aggregate resources are limited to glaciolacustrine reworked ice-contact deposits



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located along Highway 614 south of Dorothy Lake.

East of White Lake, large possible resources of sand and gravel are available from glaciofluvial deposits which trend northeast to southwest across Cecile and Knowles Townships. Additional quantities of aggregate may also be available from an ice-contact deposit in southwestern Bryant Township. Within the municipality of White River, a prominent esker has been a traditional aggregate source. The southern segments of this esker remain relatively undeveloped.

The aggregate in the study area is hard and durable, and suitable for the production of a variety of aggregate products. The presence of chert, however, may restrict usage of the aggregate for higher specification products such as concrete and hot-laid asphalt. Chert contents in samples from the deposits varied from 0 to 14% with the highest amounts having been observed in the vicinity of Manitouwadge. Despite the perceived lack of aggregate in the early stages of development of the Hemlo camp, the aggregate resources delineated during field investigation appear adequate to meet most mine construction and municipal demands within the project area.

ESPANOLA AREA

The Espanola project area consists of 5 townships: Foster, Hallam, McKinnon and Mongowin Townships in Sudbury District, and Shedden Township in Algoma District. The first 4 townships are located to the east, west, and south of Espanola. Shedden Township lies halfway between Espanola and Blind River.

During the last glacial advance, the ice deposited a veneer of till on some areas of bedrock. During the withdrawal of the glacier, ice-contact material was deposited locally against bedrock knobs. In addition, meltwaters from the receding ice front laid down quantities of outwash material in bedrock valleys, notably along the Spanish River. Large quantities of outwash sand are found along this valley in Hallam Township. As the ice front retreated farther northward, the area was covered by glacial lakes which occupied the Lake Huron basin. In the waters of these lakes, fine sands, silts, and clays were deposited. These materials generally occupy lower-lying areas between bedrock outcrops. In some areas wave action reworked pre-existing sediments, forming glaciolacustrine beaches.

The most common aggregate deposits within the report area are localized ice-contact features flanking bedrock knobs. The material exposed in these deposits ranges from sand to coarse crushable gravel. Many of these deposits have been exploited for local use. More extensive ice-contact deposits are located in central McKinnon Township near Evangeline Lake. These deposits have high potential for producing significant amounts of crushable gravel.

A number of relatively unexploited aggregate deposits are also located along the northern shore of Lake Huron in McKinnon and Mongowin Townships. These deposits consist of deltaic sand and gravel which have been reworked by wave action, forming glaciolacustrine beaches. Similarly, beach terraces have been developed on ice-contact sand and gravel in Shedden Township, near the community of Spanish.

Testing of samples taken from several exposures indicates that, in terms of gradation, the material is generally suitable for most road base products as well as asphaltic and concrete sand. The sand outwash in Hallam Township would be suitable for low-specification products such as fill. The main factor limiting aggregate development is deposit size, since the majority of the deposits in the study area are small in extent and depth. The deposits with the greatest potential for resource development are the ice-contact deposits near Evangeline Lake in central McKinnon Township and the glaciolacustrine deltas along the northern shore of Lake Huron.

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S23. Peatland Inventory Project, 1984.

J.L. Riley

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This Project is part of the Hydrocarbon Energy Resources Program (HERP) and was funded by the Ontario Ministry of Treasury and Economics under the Board of Industrial Leadership and Development (BILD) program.

INTRODUCTION

The principal objective of the Peatland Inventory Project is the evaluation of the resource potential of Ontario's numerous peat deposits, and the clarification of preliminary estimates of this resource (163 x 10^9 m^3 for Ontario south of the limit of permafrost; Monenco Ontario Limited 1981). In 1982-83, 4 areas were chosen for detailed and reconnaissance studies of some major peatlands (Figure 1; Riley 1983). In 1983-84, the following 7 study areas were selected: Rainy River, Ignace, Foleyet, New Liskeard, Parry Sound, Kingston-Belleville, and Ottawa-Brockville (Figure 1). These represent areas of considerable peat resources, within which there was expressed interest in the evaluation being conducted.

The 7 study areas encompassed 79 600 km^2. Satellite imagery supplied by the Ontario Centre for Remote Sensing was used to review the regional distribution of peatland types in all areas, and to select 63 peatlands (totalling 64 149 ha) for detailed study. Detailed study included elevation contour mapping, depth contour mapping, volume calculations, peatland classification mapping, peat type profiles, peat humification profiles, summary text, and site recommendations. Another 101 peatlands (43 236 ha) were selected for study at a reconnaissance level, to generate recommendations for possible future detailed investigations.

Other project objectives include the mapping of types of peatland vegetation occurring on peatlands, the investigation of remote sensing techniques for the identification and characterization of peatlands, and the laboratory analysis of representative peat cores from detailed study sites.

PROCEDURES

Field studies were undertaken by 7 consulting firms, 1 in each study area. Their procedures were directed by detailed project specifications outlining all field and reporting standards. This was augmented by field visits by the author. The procedures for 1983-84 were modified from those of the previous year as discussed in the 1983 Summary of Field Work (Riley 1983).

All site selection was undertaken in 1983-84 by the Ontario Geological Survey, in communication with Ministry of Natural Resources District Office staff and Regional Mineral Resources Co-ordinators.

Prospective sites for detailed study were selected on the basis of size, peatland type, proximity to population centres, and accessibility. On each detailed site, a grid was laid out made up of baselines and intersecting sidelines at 500 m intervals. Sample points at each 100 m along these transects were levelled, either by transit, electronic topochain, photogrammetry or airborne laser profiling. At each sample point, a core was characterized stratigraphically by change in peat type and peat humification, as well as fiber content and wetness. Field and reporting procedures, as well as laboratory procedures, are outlined elsewhere (Riley 1983).

PEATLAND CHARACTERISTICS OF STUDY AREAS

The Rainy River study area (south and west of 49°N Latitude and 93°W Longitude) is on the margin of the Canadian Shield, primarily in the lowland occupied post-glacially by Lake Agassiz. From northeast to southwest across this study area, the terrain shifts from a rolling upland of end moraines, washed bedrock, and silty/sandy tills, to gently undulating clayey till ground moraine, and then to low and flat clay lacustrine deposits and clay tills, with varved clays and silts in the southwest.

This major gradation is paralleled in the peatlands, shifting from large basin-type peatlands topographically contained by terrain relief in the east, to very large blanket peatlands that have expanded laterally over flat clay terrain in the west. The eastern sites are also older peat deposits which, especially in association with topographic confinement, have resulted in some of the deepest extensive peatlands surveyed in Ontario.

This east-west gradation is also apparent in the trophic level of the peatlands' vegetation and water chemistry. Ombrotrophic (bog) conditions, as domed bogs, tend to prevail in the east, but minerotrophic

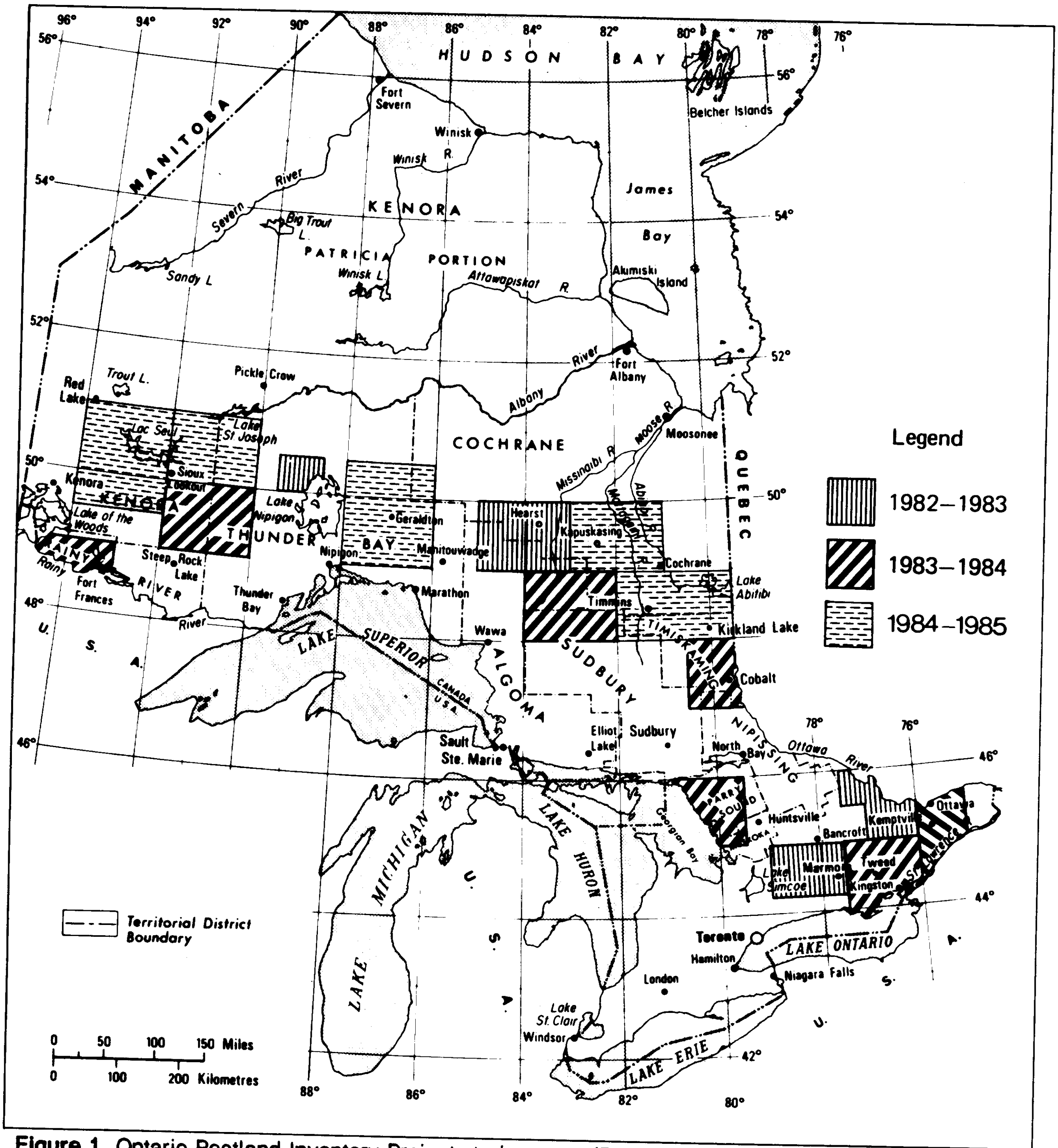

Figure 1. Ontario Peatland Inventory Project study areas. (Project S23.)

(fen, meadow marsh) conditions dominate the westernmost sites.

The Ignace study area (49°to 50°N Latitude, 90° to 92°W Longitude) is on the drainage divide between the Hudson Bay (English River) and Great Lakes basins. In the southwest the terrain has rugged Shield topography with thin, discontinuous loess deposits, and very few peatlands. To the northeast, the Shield terrain is also rugged, with discontinuous sandy till ground moraine, and few large peatlands. Across the central part of the study area are extensive glaciofluvial outwash deposits associated with the parallel Hartmann, Lac Seul, and Sioux Lookout recessional moraines. Almost all of the major peatlands of the study area are found on the fine sandy outwash channels draining southwest from these moraines, occupying channels which would have drained the ice front meltout waters westward towards glacial Lake Agassiz. These moraines define 3 age-sets of peatlands, with those immediately south of the Hartmann Moraine probably having drained 11 000 to 9900 years ago, those just south of the Lac Seul Moraine about 9900 to 9700 years ago, and those just south of the Sioux Lookout Moraine even later.

One of the major peatlands in the west occupies an embayment of the former Lake Agassiz, and several east of Upsala occupy glaciolacustrine basins and glaciofluvial channels flowing towards Lake Superior. However, most of the major peatlands share the characteristics of being underlain by fine sands (coarser towards the northeast, up the channels), draining channels from northeast to south-southwest, usually with distinctive central open fen drainways flanked by treed fens and bogs. These sloping peatlands are usually shallower than those in the Rainy River area.

The Foleyet study area (48° to 49°N Latitude, 82° to 84°W Longitude) is bordered on the north by clayey till ground moraines. Most of the south and west of the area is characterised by broad and discontinuous expanses of sandy till ground moraine overlying rough Shield topography. Peatlands in both these terrain types are small and scarce. Two studied in detail, on sandy sediments in the south, were rich slope fens with marginal swamps. The vast majority of peatlands in this study area are found in the intervening expanse of impermeable glaciolacustrine Lake Barlow-Ojibway deposits of varved clay and silt, with some increase in fine sands to the west. This flat low terrain supports extensive unconfined conifer swamp and treed bog, with the deeper peat basins characterized by more open bog and poor fen vegetation, in addition to low density treed bogs, fens, and poor fens.

The New Liskeard study area (47° to 48°N Latitude, 80°30'W Longitude eastward to Quebec border) lies within the Cobalt Plain of the Canadian Shield. The characteristic rugged Shield terrain of the southern, western, and northeastern parts of the area has few peatlands of significant size. All of the peatlands selected for study lie within the zone of glaciolacustrine Lake Barlow-Ojibway clay and silt deposits. Several study sites lie near the edge of the basin, where Lake Barlow-Ojibway was more shallow, and where sand deposits and bedrock outcrops are much more common. These sites were dominated by bog, 2 of them domed, and conifer swamp/treed bog. These sites tended to be ombrotrophic to mesotrophic.

The most extensive peatlands in the area are those in the central Lake Timiskaming Rift Valley, in the area of deep glaciolacustrine varved clays and silts deposited in the deeper sections of Lake Barlow-Ojibway. These extensive peatlands are dominated by mesotrophic-to-minerotrophic swamp, mostly conifer-dominated swamps and mixed thicket swamps. Several sites are actually underlain by Paleozoic bedrock at depth, but this appears to have less influence on the peat deposits than the overlying calcareous, flat, impermeable clay plain, and the regionally warmer climate of the Little Clay Belt.

Anthropogenic effects are widespread in these peatlands. Extensive fires on many peatlands early in this century, cutting of merchantable conifer swamp on the peatlands, and current draining and edge burning for agricultural purposes, have all increased the occurrence of dense thicket swamp and some shrub-rich fens. These are immature associations, which will succeed largely to conifer swamp with time. Peats tend to be shallow, with broad expanses of peat less than 1.5 m thick. In these lowland swamps, the peats consistently have higher stump contents than seen elsewhere in the inventory.

The Parry Sound study area (45° to 46°N Latitude, 79°30'W Longitude westward to Georgian Bay) is typically rock knob Shield upland, with the uplands mostly washed by the successive lowering of proglacial lakes occupying the study area, namely Lakes Algonquin, Hough, and Stanley. The lowlands are disjointed bedrock lows occupied mostly by small streams, lakes, and beaver floods, and the glaciolacustrine materials below them appear to be less important in defining the peatlands than is the topographic confinement of the basins themselves.

The peatlands tend to be small basin bogs and flat bogs, often flooded by beaver. Farther away from Georgian Bay, the peatlands appear to have expanded to occupy larger Shield bedrock basins, but even these have generally irregular basin morphologies, usually broken with bedrock islands. These small, irregular basins rarely have more than 100 ha areas of peat more than 1 m deep. Nevertheless, there are several small sites investigated which have peat concentrations of more than $2.5 \times 10^4 m^3/ha$ in the areas deeper than 1 m (Table 1). They are usually sphagnum-dominated (bog) peats which are well-humified.

The Kingston-Belleville study area (45°N Latitude southward to Lake Ontario, 76°W to 77°30'W Longitude) straddles the Frontenac Axis, with Paleozoic bedrock in the southwest and central parts of the study area, and again in the northeast near Perth. The Shield peatlands studied in detail were very much topographically defined by Precambrian terrain. Two were open bogs with sphagnum and sedge peats, and 2 were hardwood swamps with wood peats, but they shared certain features. They tended to be deep (average 3.2 m, 1.5 to 4.5 m), with low stump content (average 0.6%), and moderate humification (average H5).

The larger and more extensive peatlands on the flatter sloping Paleozoic lowlands, underlain by till moraines and glacial Lake Iroquois lacustrine deposits, were all dominated by forested swamp, mostly hardwood swamp, with much shallower woody peats (average 1.6 m deep, 0.7 to 2.6 m), with higher stump contents (average 1.8%), and greater humification (average H6).

The Ottawa-Brockville study area (75° to 76°W Longitude, Ottawa River to St. Lawrence River) lies almost entirely in the Ottawa-St. Lawrence Lowland underlain by flat lying and faulted Paleozoic bedrock. Glacial and recent deposits of till, marine and fluviolacustrine materials occur in the area, often as very shallow deposits on limestone plains. Many of the surficial deposits are of very fine grained, low permeability materials. Especially where the shallowness of soil over bedrock precludes agricultural drainage, such as on the Smith Falls Limestone Plain, peatlands are extensive and frequent. More than 60% of the peatlands larger than 100 ha in the study area are located on this limestone plain, which makes up only 27% of the study area. The 6 large detailed study sites on this plain averaged 1.7 m depth (1.1 to 2.1 m), and had relatively high stump contents (average 2.1%, 0.75 to 3.5%). The vegetation was not as predominantly hardwood swamp as the peatlands north of Kingston, but were more dominated by conifer swamp. Hardwood and thicket swamps were also common, and fens occurred on each site, probably reflecting the closer proximity to limestone bedrock. One slightly domed bog also occurred.

INVENTORY RESULTS

Reports on the 1983-84 Peatland Inventory have been or will be published as Open File Reports of the Ontario Geological Survey. Available to date are the reports on Rainy River (Northland Associates Limited 1984), Ignace (Proctor and Redfern Group Limited 1984), Ottawa-Brockville (Bird and Hale Limited 1984), Kingston-Belleville (Gartner Lee Associates Limited 1984), and Parry Sound (Monenco Ontario Limited 1984).

A summary (Table 1) of inventory estimates for 1982 to 1984 show a total peatland area of 77 728 ha studied in detail, 60% of which was more than 1 m in depth. Overall, the average peatland size was over 700 ha (with over 400 ha more than 1 m deep). However the size of areas varied tremendously, from 200-300 ha averages in the Parry Sound, Peterborough, Pembroke, and Hearst areas, to more than 1300 ha averages in the Rainy River, Ignace, and Ottawa-Brockville areas.

The total volume of peat delineated to date exceeds 1 350 000 000 m^3 in 108 detailed sites, at least 32 of which have areas with peat concentrations of more than 25 000 m^3/ha. Laboratory analysis of representative peat cores has been completed and analysis of these results will be presented in a future Open File Report.

The peatland classification of these detailed sites and 190 other reconnaissance sites has allowed some preliminary analysis of both the varying types of peatland vegetation in the study areas (Table 2), and the

TABLE 1. SUMMARY OF RESULTS OF 1982-84 PEATLAND INVENTORY PROJECT. (PROJECT S23.)

	1982-1983				1983-1984							
STUDY AREAS	Armstrong	Hearst	Pembroke	Peter-borough	Foleyet	Ignace	Kingston/ Belleville	New Liskeard	Ottawa-Brockville	Parry Sound	Rainy River	Totals
Total Study area (km^2)	3470	16 630	5770	10 000	19 800	19 800	13 000	8600	6300	7500	4600	115 470
DETAILED STUDY SITES												
Number of sites surveyed in detail	6	15	7	17	6	10	11	7	8	9	12	108
Total peatland area in detailed study sites (ha)	3230	3983	1836	4530	5417	13 851	5870	est. 8000	10 490	1900	18 621	77 728
Area of peatland >1m deep (ha)	3230	3120	1551	1900	4504	5781	2812	5149	5910	739	12 001	46 697
Total isopach volume of peat in detailed sites (x 10^6 m^3)	73.0	72.0	42.9	44.1	101.8	180.1	85.4	94.5	151.6	22.5	481.0	1349.1
% Potential fuel peat (% H4+ peat)	18%	70%	84%	57%	55%	36%	77%	39%	66%	61%	54%	
Average overall peat depth (m)	2.1	2.2	2.6	1.8	2.3	2.4	1.8	2.2	1.7	2.5	3.0	
Number of survey points	293	697	451	726	929	1385	724	862	980	384	1587	9018
Average volume/area of portions of detailed sites with >1 m peat (x10^4m^3/ha)	2.26	2.18	2.67	1.63	2.16	2.41	2.49	1.84	2.20	1.50	3.70	
No. of detailed sites with areas >1m deep having volume/area of more than 2.5 x 10^4m^3/ha	1	5	3	0	1	3	4	1	3	3	8	
Average stump content (range) for detail study sites	--	--	--	--	0.3 (.2-.5)	0.9 (.2-1.85)	1.3 (0-3.8)	2.7 (.7-3.8)	2.0 (.75-3.5)	1.9 (1-3)	0.2 (0-.5)	
RECONNAISSANCE STUDY SITES												
Number of sites studied by reconnaissance	8	39	9	33	10	18	19	8	15	12	19	190
Peatland area of reconnaissance study sites (ha)	675	8000	2525	14 323	2196	10 141	7910	1781	7900	2005	11 303	68 759

TABLE 2. MAJOR VEGETATION FORMATIONS ON PEATLANDS STUDIED AND THEIR AVERAGE PEAT DEPTHS. (PROJECT S23.)

	1982-1983				1983-1984							TOTALS	
STUDY AREAS	Armstrong	Hearst	Pembroke	Peterborough	Foleyet	Ignace	Kingston/ Belleville	New Liskeard	Ottawa-Brockville	Parry Sound	Rainy River	Northern Ontario	Southern Ontario
OPEN BOG (%)	8	5	2		9	17	3	6	0.5	44	18	14.57	5.96
Average Depth	2.7	2.2	3.7		2.9	2.4	3.3	4.3	2.3	2.5	3.6	3.09	2.66
(m) (n=)	(60)	(50)	(10)		(134)	(339)	(59)	(86)	(26)	(238)	(426)		
TREED BOG (%)	33	16	18		20	34	<0.5	5	2	49	16	20.42	7.07
Average Depth	2.5	2.4	3.1		2.3	2.4	3.4	3.4	2.0	2.6	4.0	2.91	2.57
(m) (n=)	(116)	(79)	(23)		(152)	(578)	(6)	(30)	(38)	(181)	(426)		
OPEN FEN (%)	9	13	1	8	17*	20	<0.5	4*	6		12	14.23	4.03
Average Depth	2.0	2.0	2.2	1.7	2.3	2.2	2.5	1.9	2.1		2.6	2.22	1.99
(m) (n=)	(93)	(129)	(14)	(56)	(282)	(437)	(5)	(37)	(91)		(128)		
TREED FEN (%)	49	62*		4	22*	12	<0.5	6*	4		9	15.48	2.69
Average Depth	2.1	2.3		2.1	2.2	2.6	2.5	2.4	1.7		2.7	2.36	1.76
(m) (n=)	(24)	(425)		(10)	(239)	(93)	(1)	(24)	(65)		(132)		
CONIFER-DOMINATED SWAMP (%)		1	42	56	30	12	25	48	37	4	18	19.20	32.31
Average Depth		1.0	2.7	2.0	2.0	1.8	2.3	1.9	1.8	2.4	3.2	2.28	2.10
(m) (n=)		(2)	(242)	(428)	(145)	(438)	(5)	(238)					
THICKET-DOMINATED SWAMP (%)		2	9	18	<0.5	1	9	30	29	3	14	1.44	18.08
Average Depth		1.2	2.8	1.9		2.0	1.6	1.9	1.5	0.6	2.02	1.92 1.75	
(m) (n=)		(12)	(46)	(128)		(2)	(42)	(460)	(240)	(2)	(204)		
HARDWOOD-DOMINATED SWAMP (%)			19	6			54	0.6	18	0.5		0.60	26.84
Average Depth			1.5	0.9			1.5	1.3	1.2	1.7		1.30	1.40
(m) (n=)			(60)	(55)			(535)	(5)	(150)	(5)			
MARSH AND MEADOW MARSH (%)			10	7	2	3			3		13	7.74	4.25
Average Depth			2.7	2.1	1.6	3.4			1.1		1.3	1.33	2.24
(m) (n=)			(46)	(49)	(2)	(3)			(13)		(204)		
Total Peatland Area (ha)	3230	3983	1836	4530	7613	23 992	13 780	6917	18 390	3905	29 924	75 659	42 442

(*Includes Poor Fen)

gross relationship between vegetation type and peat depth. The results to date parallel the scenarios of peat accumulation suggested by other peatland and palynological studies. This may provide an approximate predictive capability, on a regional level, which can be exploited in order to generate regional volume estimates by merging thematic satellite imagery with average depths of peat corresponding to theme units.

FURTHER STUDIES

For the 1984-85 Inventory Project, 5 study areas (Figure 1) were identified and field work is underway. These include Dryden-Lac Seul (24 000 km^2), Sioux Lookout (16 000 km^2), Longlac-Nakina (24 000 km^2), Cochrane-Kapuskasing (16 000 km^2), and Timmins-Kirkland Lake (21 000 km^2). Approximately 44 detailed study sites (22 000 ha) and 83 reconnaissance study sites (26 000 ha) have been selected for investigation.

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S24. Geology of the Long Rapids Formation, Moose River Basin

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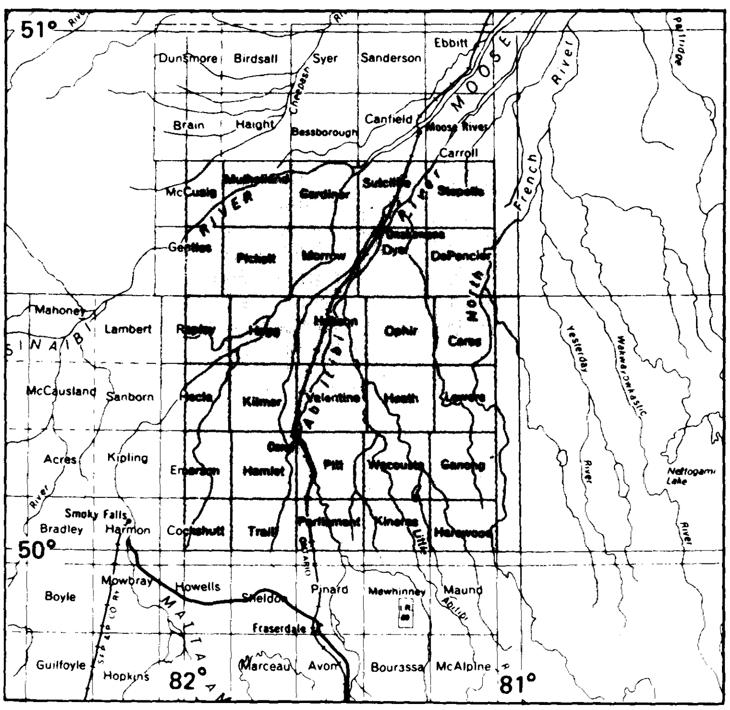
This Project is part of the Hydrocarbon Energy Resources Program (HERP), and was funded by the Ontario Ministry of Treasury and Economics under the Board of Industrial Leadership and Development (BILD) Program.

INTRODUCTION

As part of the Hydrocarbon Energy Resources Program, evaluations of the potential oil shale resources of Ontario are being carried out by the Ontario Geological Survey (OGS). The units of interest are the Collingwood Member (Upper Ordovician), and the Kettle Point and Marcellus Formations (Upper and Middle Devonian respectively) of southern Ontario and the Long Rapids Formation (Upper Devonian) of northern Ontario. In southern Ontario the oil shales have been investigated primarily by borehole sampling methods. In the Moose River Basin of northern Ontario (Location Map), the low level of knowledge of the distribution of the Long Rapids Formation, plus the logistical difficulties involved in working in this area resulted in a different approach to be taken. This approach has initially entailed a detailed structural, stratigraphic, and sedimentological study of an outcrop of the shale, from which the formation is named, along the Abitibi River at Long Rapids. This outcrop extends for about 2 km along the east bank of the river, about 25 km north of Coral Rapids, in Hobson Township.

A preliminary visit to the Abitibi River outcrop during 1983 yielded samples which contained >10% organic carbon. Samples of the Kettle Point Formation with this organic carbon content, yield >45 litres of oil per tonne of rock in the Fischer assay.

A short period of intensive fieldwork was spent examining the outcrop during mid-September 1984. Operations were based at a camp located at Smoky Falls with daily helicopter transport to the Abitibi River location. In addition to Ontario Geological Survey personnel, the field party included B.V. Sanford (Geological Survey of Canada) and R. Bezys and M. Risk (McMaster University), whose detailed sedimentological work is supported by an Ontario Geoscience Research Fund Grant. A small diamond drill was also used at the site. The core retrieved yielded valuable stratigraphic and structural information.



LOCATION MAP

Scale : 1 : 1 584 000 or 1 inch to 25 miles

STRATIGRAPHY

The Long Rapids Formation is the lithostratigraphic equivalent of the extensive Upper Devonian organic-rich black shale facies of North America, which is represented in southern Ontario by the Kettle Point Formation. Underlying the Long Rapids Formation is the Williams Island Formation (named from the large island in the Abitibi River in the middle section of Long Rapids), which bears considerable lithological and faunal similarities to the Hamilton Group of southern Ontario. Overlying the unit in the Moose River Basin is the Cretaceous, lignite-bearing, Mattagami Formation.

The thickest section of the Long Rapids Formation (>100 m) was reported by Dyer and Crozier (1933) from the Onakawana "A" borehole. Sanford and Norris (1975) reported a thickness of 37 m of stratigraphic section exposed on the Abitibi River. Current work involving compilation of all known drilling and outcrop data for the southeastern part of the Moose River Basin, has shown that the subsurface distribution of the Long Rapids Formation is restricted to a much smaller area than shown by Sanford and Norris (1975), in the southeastern part of the basin.

The lithologic sequence exposed along the Abitibi River at Long Rapids can be summarized as follows. The basal contact of the formation is disconformable, with >1 m of blue-grey plastic mud overlying the brecciated limestones of the Williams Island Formation. Fissile black shales, the type lithology of the Long Rapids Formation, overlie this basal unit. Above this are about 5 m of stratigraphic section, composed of green-grey mudstone and shale, alternating with fissile organic-rich black shale, that are poorly exposed due to faulting. The fully exposed section above this zone consists of 2 parts. The lower part (23 m thick) is characterised by numerous cycles of green-grey calcareous mudstone or shale, overlain by concretionary carbonate layers, sharply overlain by green or black shale. The upper section (~8 m thickness) is mainly black fissile shale, and is probably the zone of most economic significance. The discovery of an Upper Devonian goniatite fauna in the concretionary layers has considerable significance with regard to age determinations for both the Long Rapids and underlying Williams Island Formations (*see* discussion in Sanford and Norris 1975, p. 66-70).

The presence, thickness and general characteristics of the green grey lithologies in the exposed section suggest an environment of deposition with relatively shallow water. The interbedding of these facies with the black shales imply a similar water depth for these economically more important units. The detailed sedimentological and geochemical study of samples taken from the section will assist in interpreting the origin not only of the Long Rapids Formation but also of the Kettle Point Formation.

STRUCTURAL GEOLOGY

In addition to the faulting mentioned above, many other faults and dip reversals are present in the Abitibi River outcrop. This structural complexity creates problems in both local stratigraphic analysis and regional resource assessment. Brief inspection of other Devonian and Silurian units along the southern boundary of the Moose River Basin, carried out during the fieldwork period, showed that the structural geology of the area is much more complex than shown in presently available interpretations.

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S25. Lignite Assessment Project, Moose River Basin, James Bay Lowland

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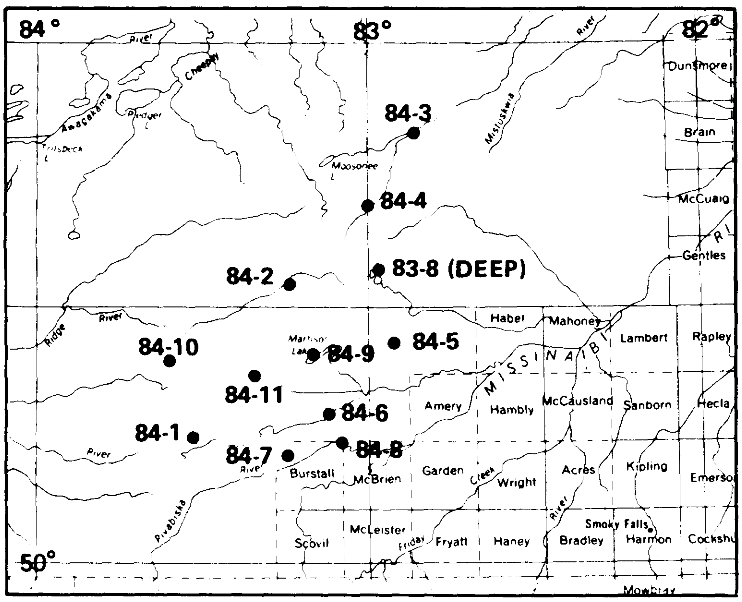
This Project is part of the Hydrocarbon Energy Resources Program (HERP), and was funded by the Ontario Ministry of Treasury and Economics under the Board of Industrial Leadership and Development (BILD) Program.

INTRODUCTION

During the second half of fiscal year 1983-84, 2 drilling programs were carried out in the Moose River Basin, James Bay Lowland, about 150 km southwest of Moosonee. The work was aimed not only at an evaluation of potential lignite resources of the area, but also to contribute to better delineation of potential oil shale resources and improved knowledge of the Mesozoic and Paleozoic stratigraphy of the basin. The drilling thus provided possible further stimulation of private sector interest in the mineral resources of the region.

The 2 drilling programs were of quite different character. The first, which was completed in October 1983, involved the drilling of a single deep fully-cored borehole to the Precambrian basement at Schlievert Lake, about 80 km northwest of Smoky Falls. Key Ontario Geological Survey (OGS) personnel on this program were D.J. Russell and J.W. Sanderson. The second program, conducted between January and March 1984, involved the drilling of 11 shallow boreholes, by coring or reverse circulation methods. in a large area centred on Martison Lake towards the western extent of known Mesozoic sediments (Location Map). This winter drilling program was managed for OGS by Watts, Griffis and McOuat Limited. OGS staff involved in the program included D.W. Sawicki, J.W. Sanderson, and G. Flach. Watts, Griffis and McOuat prepared a report describing all aspects of the winter drilling program and including lithological and geophysical logs of all the drillholes. This has been released as Ontario Geological Survey Open File Report 5511 (Watts, Griffis and McOuat Limited 1984b).



LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

GENERAL GEOLOGY

The Moose River Basin contains an approximately 600 m thick sequence of Paleozoic strata overlying Precambrian basement rocks. The southern margin of the basin is marked by a prominent east-trending fault-controlled escarpment that has truncated the Paleozoic sequence against basement rocks.

In the southeastern part of the basin the Paleozoic strata are overlain by up to several hundred metres thickness of unconsolidated Mesozoic sediments. The geographic limits of these Mesozoic sediments are imprecisely known, but they range in age from Middle Jurassic to Lower Cretaceous (Telford and Verma 1982). The lignite deposits at Onakawana, as well as other lignite occurrences in the region (Telford and Verma 1978), lie within the Lower Cretaceous portion of the sequence.

The entire region is overlain by a sometimes very thick cover (up to 200 m) of Pleistocene glacial and glaciolacustrine deposits and Recent marine clays (Skinner 1973).

SCHLIEVERT LAKE DRILLHOLE

Drilling of this borehole commenced in mid-September and was completed in late October 1983. It was located on the shore of Schlievert Lake, at Latitude 50°30'N and Longitude 82°45'W, about 80 km northwest of Smoky Falls, which lies at the northern end of the closest all-weather road. Equipment and personnel were transported from Smoky Falls to the site by helicopters of Ranger Helicopters Limited. The drilling was carried out for OGS by Longyear Canada Incorporated and geophysical logging of the borehole was undertaken by BPB Instruments Limited.

The borehole was intended to be continuously cored from surface to the Precambrian. Although this objective was accomplished in general, core recovery was poor in certain intervals, particularly in thick unconsolidated post-Paleozoic sand sequences. The borehole was terminated in Precambrian rock at a depth of 624.5 m. The generalised stratigraphy of the borehole is as follows (in descending order):

0-12.0 m — No recovery (probably Recent sediments, e.g. peat)

12.0-153.2 m — Pleistocene tills, sands, and lacustrine clays

153.2-154.0 m — Variecoloured oxidised clay, possibly of Cretaceous age

154.0-588.2 m — Devonian limestones, dolomitic limestones, dolostones, and mudstones

588.2-624.5 m — Precambrian gneissic granite

An Open File Report providing full details of the Schlievert Lake operation is to be released shortly. Additional detailed palynological, mineralogical, and sedimentological studies of the drillcore are also being undertaken by OGS staff and researchers at Laurentian University and the University of Toronto.

WINTER 1984 DRILLING PROGRAM

The Winter 1984 program continued and completed the lignite reconnaissance drilling program that was initiated during the winter of 1983. The report by Watts, Griffis and McOuat Limited (1984a) provides details of the 1983 phase of the program.

In 1984, 11 shallow boreholes were completed towards the western extent of known Mesozoic sediments in the southern Moose River Basin. The boreholes were spread over a broad strip between the Pivabiska River in the south and the Kwataboahegan River in the north (*see* Location Map). The base camp for the operation was established about 17 km southwest of Martison Lake, approximately 60 km north of Hearst. The project manager, Watts Griffis and McOuat Limited subcontracted the drilling services to Heath and Sherwood Drilling. North Star Helicopters Limited provided air support, and Century Geophysical Corporation carried out the downhole geophysical logging.

A total of 996 m of drilling was completed; 504 m were completed using reverse circulation methods and 492 m were cored. About 811 m of geophysical logging was completed in 10 of the 11 holes. Table 1 provides a summary of the stratigraphy encountered in the 11 holes.

Lignite was discovered in only 1 borehole (OGS 84-08), at the northwestern corner of McBrien Township, and only 3 of the boreholes intersected definite Cretaceous sediments. Also, 3 of the southern boreholes encountered Precambrian granitic rock at surprisingly shallow depths. Results of this program are therefore contributing to more accurate delineation of the distribution of potentially lignite-bearing Cretaceous sediments in the Moose River Basin, and major revisions to the geological maps of the area are indicated. For example, the OGS drilling results plus other recent data generated by private sector mineral exploration activity in the region indicates the presence of a previously unknown bedrock ridge extending northeastward into the basin from the Pivabiska River area. The position and character of this ridge have important consequences with regard to Paleozoic and Mesozoic depositional environments and the location of economically significant mineral and hydrocarbon deposits.

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Table 1: SUMMARY OF DRILLHOLE STRATIGRAPHY, WINTER 1984 DRILLING PROGRAM (FROM WATTS, GRIFFIS AND MCOUAT LIMITED 1984b). (PROJECT S25.)

	UNIT (thickness, in metres)					
Hole Number	Recent	Pleistocene	Cretaceous	Jurassic	Devonian	Precambrian
OGS-84-01	2.6?	9.3	-	-	-	6.1+
-02	1.5?	53.4	-	-	15.2+	
-03	2.4	92.7	-	-	5.5+	
-04	1.5	100.0	-	-	17.4+	
-05	1.2	82.3	18.3	4.2?	18.4+	
-06	4.0	58.8	62.5+			
-07	1.5	28.7	-	-	-	15.2+
-08	3.1	70.7	97.5?	21.0?	25.6+	
-09	1.5	49.1?	-	-	33.1+	
-10	9.5	35.1	-	-	31.2+	
-11	3.1	31.4	-	-	-	4.0+

+ Indicates that the hole "bottomed out" within this unit; total thickness is therefore unknown.
- Indicates that this unit is absent.
? Indicates a "tentative" designation and/or thickness.

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Watts, Griffis and McOuat Limited

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1984b: Lignite Assessment Project - 1984 Winter Drilling Program, James Bay Lowland: Ontario Geological Survey. Open File Report 5511, 120p.

GEOPHYSICS/GEOCHEMISTRY PROGRAMS

Summary of Activities 1984, Geophysics/Geochemistry Section

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GEOPHYSICAL PROGRAM

During the 1984 summer field season, survey and research activity continued on the Night Hawk geophysical test range near Timmins, Ontario. Results from 2 wide-band, time domain electromagnetic systems are presented. As well, 3 seismic reflection stacked profiles are shown from the central grid area (Barlow, Project 29.).

Section staff established approximately 2000 new gravity stations in the Kirkland Lake, Larder Lake and Matheson area. Density determinations were carried out on approximately 850 rock specimens collected during the survey work (Gupta *et al.* Project 26.). Interpretation techniques developed for previously surveyed areas are described and illustrate the utility of regional gravity surveys as an aid to mineral exploration (Gupta, Project 27.).

An airborne electromagnetic-magnetic survey was flown for the Ontario Geological Survey and released publicly in May of this year. The survey, which was carried out by Questor Surveys Limited, Toronto, covered an area of approximately 3550 km^2 (1371 $miles^2$) from the Black River-Matheson area to the Ontario-Quebec border (Barlow and Pitcher, Project S52.). This project is part of the interdisciplinary Black River-Matheson (BRIM) Program (Fortescue, this volume) which was equally funded by the Ontario Ministry of Northern Affairs and the Ontario Ministry of Natural Resources.

Two additional projects commenced this year utilizing the results of the electromagnetic data directly and indirectly. Firstly, reprocessing of the digital, airborne, time domain data produced a filtered difference (Channel 1-Channel 2) map which was, after interpretation, found to yield an accurate outline of the deeper sections of lacustrine clays in the BRIM area (Pitcher *et al.*, Project S55). Secondly, a ground electromagnetic technique was developed for the purpose of identifying small-scale buried valleys in clay covered areas (Barlow and Krentz, Project 28.). The 2 techniques can be used as an aid to develop an optimum strategy for conducting overburden drilling programs.

GEOCHEMISTRY PROGRAM

A reconnaissance till sampling project was carried out in cooperation with the Engineering and Terrain Geology Section and formed part of the Black River-Matheson (BRIM) Program. The project utilized backhoe sampling techniques to collect till samples for Quaternary and geochemical studies. This work preceeded a deep overburden drilling program which is scheduled to commence in the fall of 1984.

Remote sensing techniques were combined with lake water and sediment analysis to test a reconnaissance method for identifying lakes affected by acid precipitation in an area north of Sault Ste. Marie, Ontario, and immediately south of the Montreal River (Fortescue and Diamond, Project 30.). Lake water and sediment samples were collected from 100 lakes in the area of interest. During the sampling, aircraft equipped with an array of sensors were flown over the test area. The resulting database will be interpreted during the winter months and compared with the ground control to develop optimum techniques for identifying recently acidified lakes.

GEOCHRONOLOGY PROGRAM

During the 1984 summer field season, sampling programs were carried out in several areas of northern Ontario to complete earlier projects and initiate new ones.

Sampling in the Favourable Lake area will allow conclusion of dating of the volcanic sequences and refine the age of the molybdenite-mineralized Setting Net Lake stock.

A new project started this summer in the eastern Uchi subprovince will help establish a stratigraphic synthesis of the subprovince. Felsic volcanic units were sampled for this project in the Bamaji Lake-Fry Lake, Meen Lake, Lake St. Joseph-Pashkokogan Lake and Miminiska Lake areas.

Three other projects are focused on dating volcanic and plutonic rocks associated with gold-mineralization in order to put precise time constraints on the processes responsible for the formation of auriferous deposits. One of these projects was started in Red Lake in 1983. In the 1984 field season, porphyries which both predate and postdate the gold mineralization in the western part of the Red Lake belt, and granitoid units from the adjacent batholiths were sampled. Sampling for 2 similar projects was carried out in the Beardmore-Geraldton and Hemlo areas.

Two samples from the Cobalt region are being investigated in an attempt to obtain precise ages for both the intrusion of the Nipissing diabase and the timing of silver mineralization.

In addition to the above projects, analytical work is being continued on samples from the English River subprovince, the Shebandowan belt, and the Batchawana belt. The data for the Batchawana belt indicate that most of the volcanism and some early plutonism occurred between 2730 and 2700 Ma ago, whereas late plutonism and related metamorphic episodes occurred in the time span between 2680 and 2660 Ma ago (Grunsky, Project 13.). Preliminary data from the Shebandowan belt suggest ages in the range 2720 to 2660 Ma for intrusion of major plutons, porphyry dikes, and Temiskaming-type volcanism. Initial results from the southern part of the English River Subprovince indicate the formation of early tonalites about 2900 to 2800 Ma ago, and major plutonism and high grade metamorphism between about 2710 and 2660 Ma ago.

26. Gravity Mapping in the Kirkland Lake-Larder Lake-Matheson Area, Districts of Timiskaming and Cochrane

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INTRODUCTION

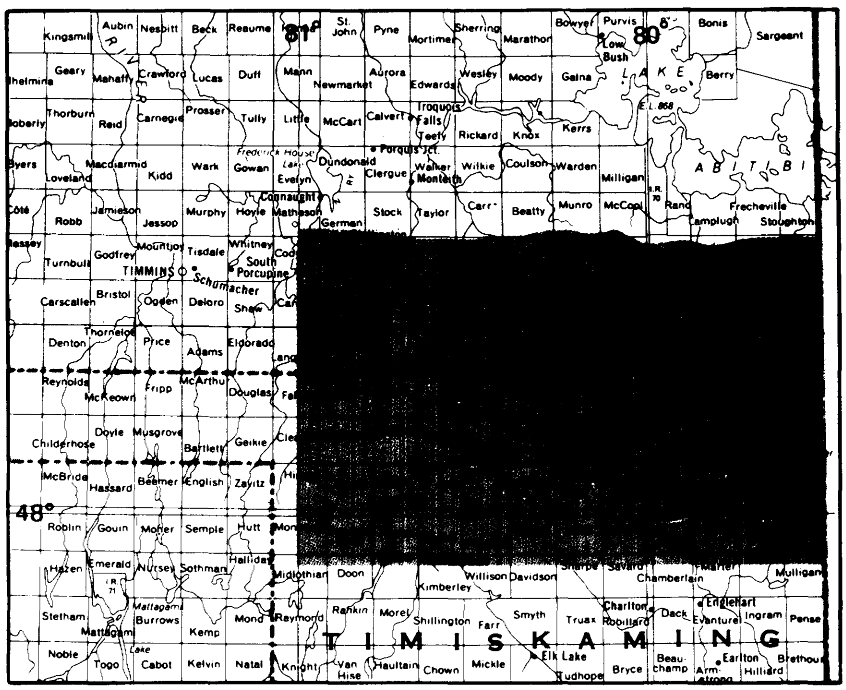
A gravity surveying program has been initiated by the Ontario Geological Survey to map the deeper geological and structural characteristics of the Abitibi "greenstone" belt for the purpose of arriving at a better understanding of its evolution and associated mineral deposits. The existing gravity coverage of most of the Abitibi belt is at a station spacing of about 12 km (Dominion Observatories Branch 1966) except for a small area near Matheson (Middleton 1976). Due to a large spacing of stations for existing gravity maps, many intrinsic details about the lithology, stratigraphy, and structures are difficult to interpret for regional mining exploration purposes. It is therefore planned to establish a network of gravity stations 2 to 3 km apart, and decreasing the spacing further to about 1/2 to 1 km in high mineral potential areas.

THE SURVEY

During the 1984 field season approximately 2000 gravity stations were established in an area in excess of 8000 km^2. Over 850 density measurements were also made on fresh rock samples collected from outcrops at or near gravity station sites. Rock identification in the field was provided by L.S. Jensen of the Precambrian Geology Section. The survey area is bounded by Latitudes 47°55'N and 48°32'N and Longitudes 79°30'W and 81°00'W. Kirkland Lake, Larder Lake, and Matheson lie within the map area, which is traversed by Highway 11. Several other Highways (e.g. Highways 101 and 66) and numerous lumbering, mining, and recreation roads provide access by motor vehicle. Access to remote areas was provided by a Hughes 500C helicopter, float equipped Bell Jet Ranger helicopter, and fixed wing Beaver aircraft.

Three Lacoste-Romberg gravimeters (serial numbers G-294, G-417, and G-626) used during the survey were monitored for drift at control stations at the beginning and end of each day's work. The gravity observations were tied to the control stations at Kirkland Lake, Matheson, Timmins, Cochrane, Sudbury, and Moosonee, forming part of the National Gravity Network which is tied to the International Gravity Standardization Net 1971.

Vertical control for the survey was provided mostly by Wallace and Tiernan altimeters in pair, which were tied regularly to known elevations within 1 to 1.5 hours. Geodetic Survey of Canada and Ontario Ministry of Transportation and Communications benchmarks were also used for elevation control. The elevations of many large lakes and river systems were established using



LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

data from Ontario Hydro dams.

The gravity stations were established at identifiable sites using 1:15 000 and 1:50 000 scale aerial photographs. The stations were then transferred onto 1:50 000 NTS maps having a 6° U.T.M. grid. The stations were digitized with a precision of ±25 m.

The gravity measurements were carried out to the specifications of the Gravity Division of the Earth Physics Branch, Ottawa, where the data will be processed this winter. A 1:100 000 map of Bouguer gravity contours superimposed upon the geology (provided by the Precambrian Geology Section) will soon be released with density data.

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27. Applications of Gravity Maps in Geological Mapping and Mineral Exploration

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INTRODUCTION

The Ontario Geological Survey has embarked on a systematic detailed gravity surveying program over mineral-rich Early Precambrian (Archean) "greenstone" belts of the Superior structural province and Proterozoic terrain of the Canadian Shield. To date, over 17 000 gravity stations have been established and 9500 density measurements have been made in Ontario. This paper illustrates the effectiveness of the second derivative of the gravity field as a supplement to geological mapping in the identification of lithological units and their contact relationships, stratigraphic correlation, and as an important tool in outlining mineral-prospective regions.

Examples are given from a gravity survey undertaken in the Red-Birch-Uchi Lakes area that demonstrate the application of gravity methods towards (1) developing exploration strategies to locate new deposits of base metals and precious metals, and (2) obtaining a better understanding of the evolution of the Canadian Shield, especially the supracrustal belts and their associated mineral deposits.

The examples clearly demonstrate that the derivative mapping provides a powerful approach to mapping the extent of bedrock lithological units, and to the problem of area selection for detailed exploration programs (Gupta and Ramani 1982).

RED LAKE AND BIRCH-UCHI LAKES SUPRACRUSTAL BELTS

The example is from a gravity survey of the Red Lake and Birch-Uchi Lakes supracrustal belts (Gupta and Wadge 1978; Barlow *et al.* 1976) which lie within the Uchi Subprovince of the Superior Province of the Canadian Shield, and contain mainly Early Precambrian (Archean) metavolcanic-metasedimentary and plutonic rocks. These rocks are covered for the most part by Pleistocene and Recent unconsolidated sediments. In general, the supracrustal belts are surrounded by granitoid rocks consisting mainly of plutonic granitoid gneisses. The 2 large supracrustal belts of the area, the Red Lake and the Birch-Uchi belts, consist of isoclinally folded, metavolcanic-metasedimentary sequences that are intruded by composite granitic batholiths and stocks (Figure 1). The northeast-trending Red Lake belt gives the appearance of an anticlinal structure, whereas the Birch-Uchi belt is folded about a north-trending central synclinorium.

Both the Red Lake and Birch-Uchi belts are composed of 3 basaltic-to-rhyolitic volcanic cycles. Based on U-Pb ages determined on zircons extracted from the rhyolites of each cycle, cycle I is 2.9 to 3.0 b.y., cycle II is 2.79 to 2.83 b.y., and cycle III is 2.74 to 2.75 b.y. (Wallace *et al.* 1983).

The study area is approximately 21 100 km^2 in size, and the gravity stations are spaced at an average interval of about 1 station every 1.5 km^2 in supracrustal areas which have been mapped. Over 2800 density measurements were made on fresh rock samples for use in the gravity interpretation. A Bouguer gravity map is shown in Figure 2.

APPLICATIONS IN MAPPING

Effectiveness of gravity maps in geological mapping and mineral exploration can be best demonstrated by a second vertical derivative map (Figure 3) produced from the Bouguer gravity map. Positive and negative second vertical derivative anomalies correspond remarkably well with the surface exposures of mafic and felsic rock units, respectively. The zero contours coincide, as expected, with the boundaries of lithological units. In particular, the greenstone-granite boundaries, which represent a large mean density contrast of approximately 0.2 g/cm^3, are quite accurately outlined by the zero contour throughout the Red Lake and Birch-Uchi greenstone belts.

On a regional scale, a 30 by 4 km northeast-trending negative anomaly zone near the south central edge of the second derivative map (Figure 3) coincides with fault zone A (Figure 1), which contains low-density migmatized metasedimentary rocks with cataclastic textures. This anomalous zone, containing uranium mineralization along the fault, is barely identifiable from the Bouguer gravity map (Figure 2) because the anomalies are very weak and superimposed on a large gravity gradient.

It is also possible to interpret poorly mapped or obscure folds from the second deriva-

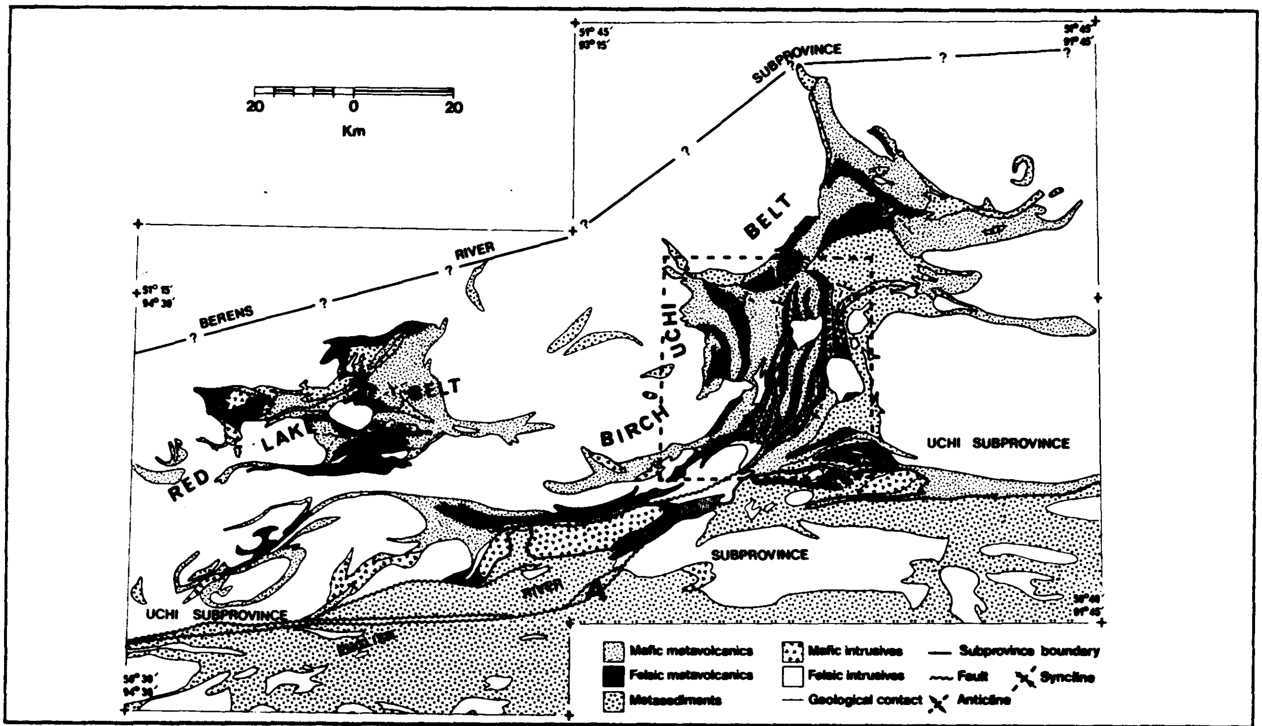

Figure 1. A generalized geological map. The central portion of the Birch-Uchi supracrustal belt is within the dotted boundary. Fault zone A is discussed in the text. (Project 27.)

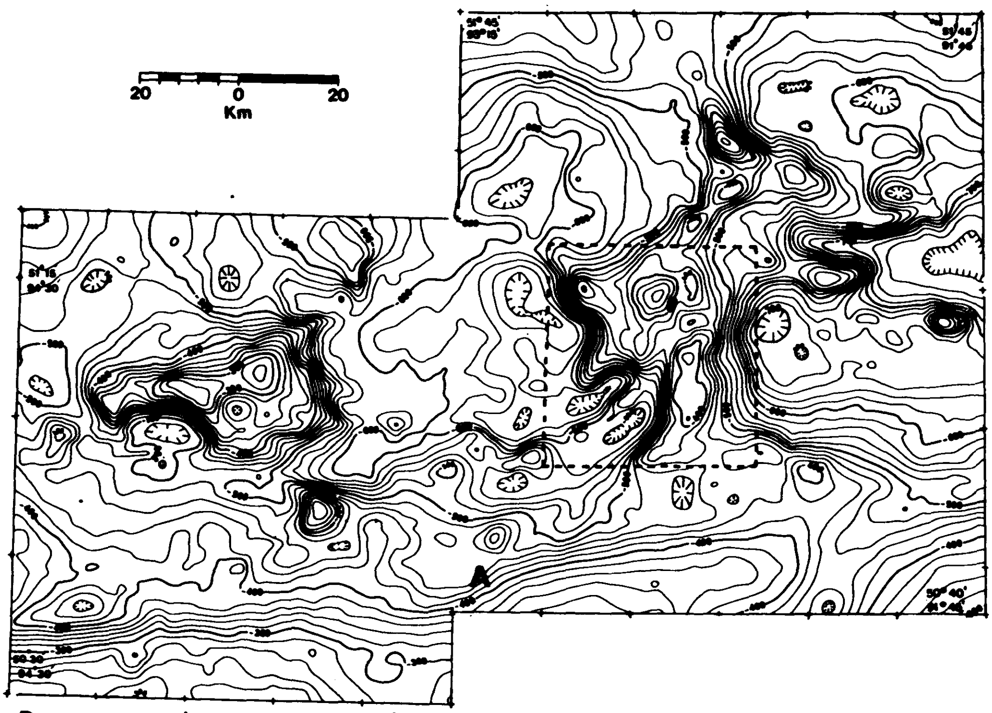

Figure 2. Bouguer gravity map, contour interval = 20 gravity units (2 mgal). The central portion of the Birch-Uchi supracrustal belt is within the dotted boundary, location of fault zone A is also shown. (Project 27.)

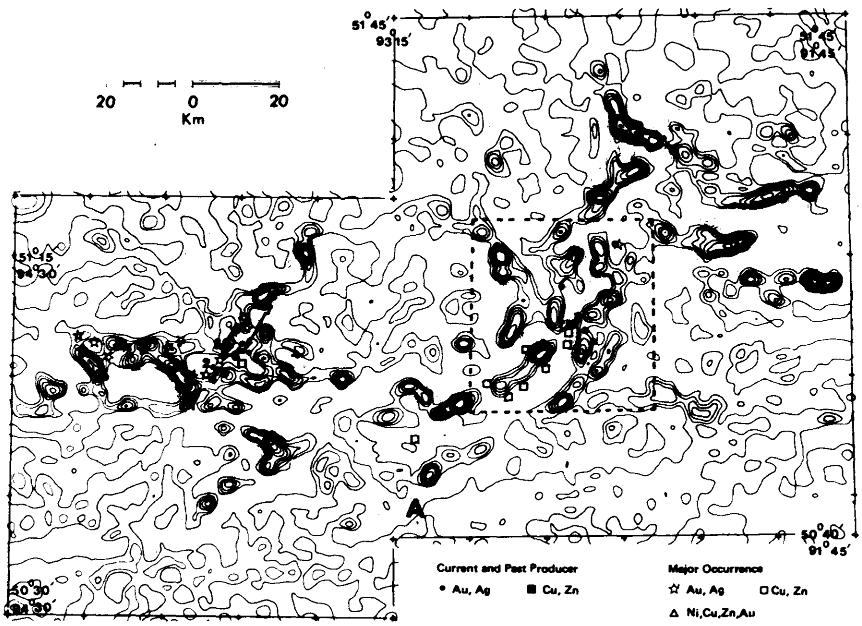

Figure 3. Second vertical derivative map, contour interval = 0.5 mgal/km^2. The positive contour regions are shaded dark, negative contours are shown by light lines, the zero contour by a thick dark line. Locations of current and past producing mines and major mineral occurrences are shown, 1 to 9 represent the location and names of selected mines referred to in the text. Fault zone A is characterized by a negative anomaly zone. The central portion of the Birch-Uchi supracrustal belt is shown within the dotted boundary. (Project 27.)

tive map. For example, some of the arcuate anomalies in the northern and western portions of the Birch-Uchi and Red Lake belts, respectively, appear to correspond with local or regional fold-like structures (Figures 1 and 3).

The second vertical derivative map can thus be of direct aid in regional geological mapping by identifying near-surface fold patterns, contacts, and other structures.

The application of the second vertical derivative of gravity in stratigraphic correlation is best illustrated in the central portion of the Birch-Uchi belt where the geology was mapped in detail by Thurston *et al.* (1978). The north-trending belt (Figure 4) is isoclinally folded about a central synclinorial axis and consists of 3 basalt-to-rhyolite volcanic cycles, numbered I, II, and III, each with mafic and felsic members

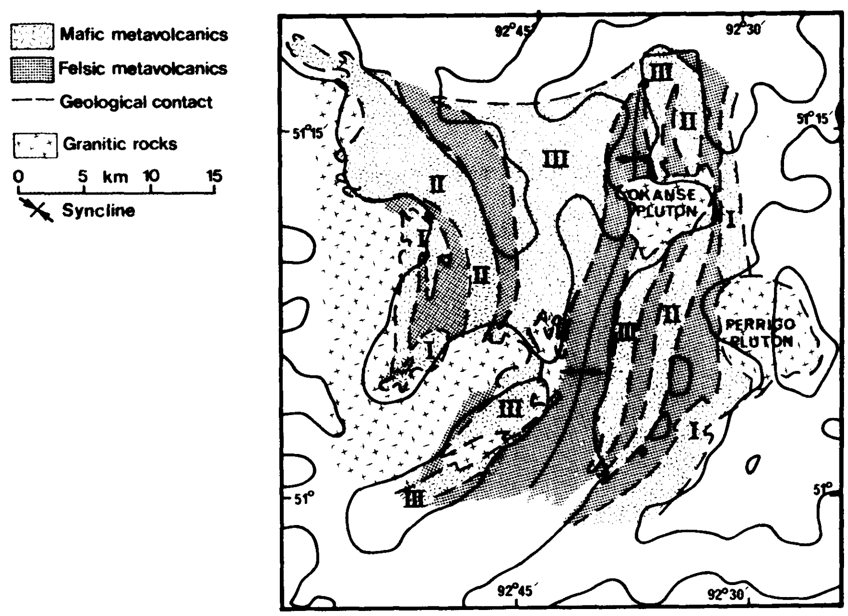

Figure 4. Second vertical derivative of gravity superimposed on geology in the central Birch-Uchi supracrustal belt, contour interval = 0.5 mgal/km^2, positive contours shown by dark lines, negative contours shown in broken lines, and the zero contour by a thick dark line. Locations of mafic volcanic cycles I, II, and III are shown. (Project 27.)

(Thurston *et al.* 1978). The trace of the axial plane of the north-trending syncline, poorly exposed at a few locations, lies in the upper felsic metavolcanic rocks of cycle III. The narrow, linear belts of positive and negative second vertical derivative anomalies correspond remarkably well with the mafic and felsic members of the volcanic cycles, respectively (Figure 4). Figure 5 shows the correlation between the mapped geological contacts and the zero contour of the second vertical drivative. The correlation is good over most of the area except just east of the synclinal axis. Here the boundary of the mapped cycle II felsic metavolcanic rocks, lying between the basalts of cycle III and cycle II mafic metavolcanic rocks, has not been demarcated by the zero contour. This discrepancy between the positive second vertical derivative anomalies and mapped felsic metavolcanic rocks is likely the result of the high proportion of intermediate metavolcanic rocks in the cycle II felsic metavolcanic unit. The bands of mafic and felsic metavolcanic rocks shown in Figures 4 and 5 represent zones in which mafic and felsic metavolcanic rocks predominate, but within which many rock compositions are interbedded. The second derivative map suggests that the proportion of cycle II felsic metavolcanic rocks lying between the mafic metavolcanic rocks of cycles III and II is small.

APPLICATION IN MINERAL EXPLORATION

The distribution of mineral deposit types depends greatly on their lithology and structure; this study finds a strong spatial correlation between these parameters and the second vertical derivative gravity anomalies. This correlation suggests that it should be possible to use the second vertical derivative map, in conjunction with geological mapping, as an indirect mineral exploration tool to identify and extrapolate various geological features associated with regional mineral exploration studies. It could be of particular value in extending mineral exploration to water- or drift-covered areas where geological mapping is restricted.

Figure 3 shows the location of major mineral occurrences, including inactive and active gold, silver, and base metal sulphide mines. It was suggested by Pirie (1981) that in the area under study the highest grade gold is located in mafic metavolcanic rocks. From Figure 3, it is evident that most of the major known occurrences and mines of gold and silver are associated with positive second derivative anomalies, for example, the Madsen Red Lake Gold Mine (1), Cochenour Willians Gold Mine (5), and New Jason Mine (9). This can be explained by the fact that the majority of the gold and silver-bearing quartz-carbonate veins occur in mafic metavolcanic rocks, which are in places altered and carbonatized, and which produce positive gravity anomalies. The Campbell Red Lake (6) and Dickenson Mines (7), Canada's 2 largest gold producing mines, are also located within zones of the positive second derivative anomalies (Figure 3).

In Figure 3, a good correlation has been shown to exist between the negative second derivative anomalies and the felsic metavolcanic rocks, which, according to Riley *et al.* (1971) have a direct relation-

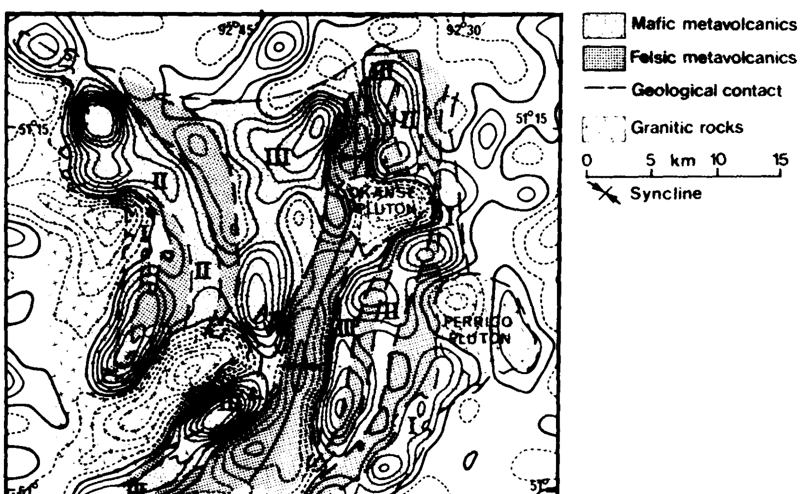

Figure 5. The zero contour (shown by thick dark line) of the second derivative of gravity and the mapped lithological contacts in the central Birch-Uchi supracrustal belt. Locations of mafic volcanic cycles I, II, and III are also shown. (Project 27.)

ship with the stratabound Zn-Cu-Ag sulphide occurrences in the area. A prime example is the central Birch-Uchi, north-trending, 50 km linear negative second derivative anomaly zone which coincides with ore bodies at the South Bay Mine (8). These are volcanogenic massive sulphides, yielding copper, zinc, and silver, hosted by the felsic pyroclastic rocks of cycle III. This relationship could be of benefit on a regional scale north of the mine, where the uncertainties of stratigraphic correlation due to sparse geologic mapping and scarcity of outcrop have prevented locating the extension of the metal-bearing felsic metavolcanic rocks belonging to cycle III. The second derivative map may, through the use of the negative anomaly signature, aid in locating the exact boundary of this felsic metavolcanic unit and thereby aid in the search for other metallic sulphides.

Minor gold and sulphide mineralization has also been reported along the borders of some of the felsic intrusions and in highly serpentinized, talcose, or carbonatized ultramafic sequences which are characterized by negative second derivative anomalies. On Figure 3, 3 past producing gold and silver mines, Gold Shore Mine (2), Howey Mine (3), and Hasaga Mine (4), coincide with a nearly circular negative second derivative anomaly caused by an intrusive diorite complex. Within the supracrustal belts, many such negative second derivative anomalies associated with felsic intrusions may thus merit closer attention for potential mineralization.

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28. Electromagnetic Depth Sounding of Quaternary Sequences in Parts of Walker and Taylor Townships, Black River-Matheson (BRIM) Area, District of Cochrane

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INTRODUCTION

Deep sections (~30 m) of massive and varved clay were outlined by processed airborne electromagnetic data as described by Pitcher *et al.* (this volume). A part of this area which parallels the present trend of the Black River was chosen as a test site to develop a ground transient electromagnetic technique for shallow sounding in clay covered areas. Clays are more electrically conductive than tills which are, in turn, much more conductive than sand, gravel, or bedrock. The Quaternary stratigraphy in the immediate area of the test site is mainly composed of sequences of clay over bedrock, clay over sand over bedrock, or clay over till over bedrock.

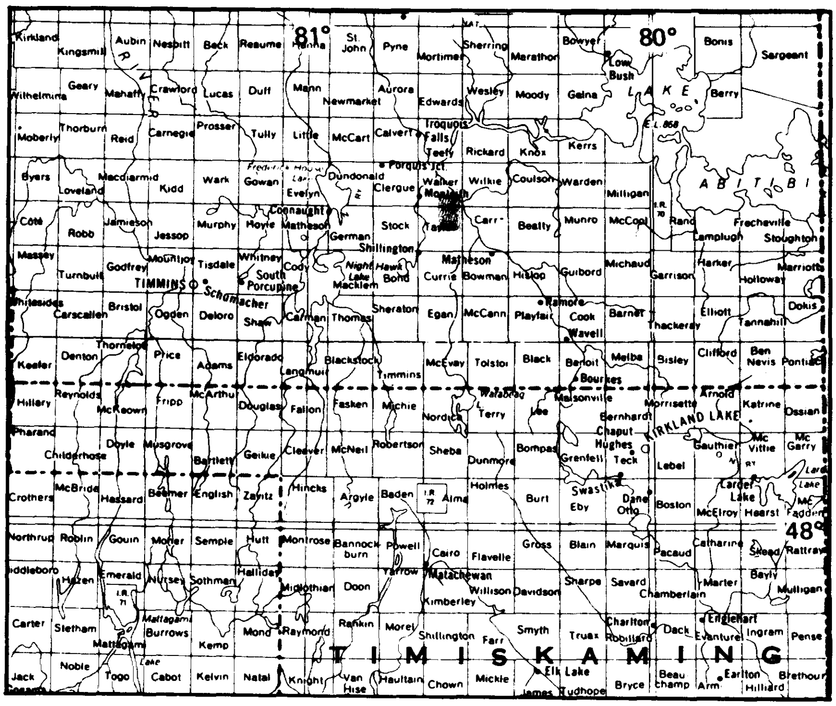
The purpose of the research project was to develop a rapid and accurate ground technique for determining the location of substantial thicknesses of till strata below the thick clay cover as an aid to overburden drilling projects in the area.

Such a technique would ensure a minimum loss of regional geochemical information derived from till analysis due to positioning drill sites where till sections are absent. The technique must be rapid in order to precede drill site selection during a drilling program and accurate enough to distinguish between thick till layers associated with bedrock valleys (>3 m), moderately thin layers of till (2 to 3 m), and areas where till is less than the minimum sample thickness required for regional overburden drilling programs (i.e. <1.5 m). Locations having a substantial till thickness would ensure a high probability that historic information such as multi-directional and multi-age till strata could be identified on a regional basis. The advantages of such information are obvious in the geochemical interpretation stage of till exploration programs.

LOCATION AND ACCESS

The test area is located approximately 6 km east of Val Gagne which is located approximately 16 km north of Matheson off Highway 11. The terrain is composed of open pasture and small woodlots west of the Black River and is accessible by north-south and east-west secondary roads.

The area, in general, is ideally suited for electromagnetic sounding as no major interference from power lines was encountered and variable thicknesses of clay were found to exhibit consistent conductivities. In addition, the generally flat-lying surface topography varies in relief only where the terrain has been interrupted by



LOCATION MAP

Scale : 1 : 1 548 000 or 1 inch to 25 miles

narrow gullies (up to 3 m deep) which provide a drainage network for the area. Several percussion drill holes were placed strategically in areas of variable clay thickness and provided quality control for a range of experiments used to formulate optimum survey parameters.

ORIENTATION

From inspection of the regionally derived first difference processed airborne results, it was interpreted that the axial direction of the deepest clay section is, in general, following a preglacial, regional bedrock valley. Although glacial striae, as indicated by reconnaissance mapping (Vagners 1983), have a range of directions, it is interesting to note that the axial direction of the deepest clay section closely follows the generalized axial direction of glacial striae (azimuth 165°). It seems reasonable to assume that local preglacial bedrock valleys orientated in this direction would be less likely to contain preserved till strata indicative of different ages of glaciation than would valleys orientated in an east-northeasterly direction (generalized strike direction of bedrock), which is nearly perpendicular to the latest ice movement.

With the above assumption in mind, several traverses approximately 3 km in length (station spacing 100 m) were positioned in a north-south direction in order to maximize the likelihood of intersecting a till-filled bedrock valley underlying the clay, as predicted from the airborne results. The results forthcoming from the ground study could then be compared with refined flight line data from the airborne program.

All assessment work drilling was located on regional working maps with a scale of 1:100 000 and overburden depths (vertically corrected for collar angles) were recorded. In most cases, drill logs were found to be of little help in determining the Quaternary stratigraphy, as it is common practice to only briefly identify overburden materials encountered. Although sparsely scattered and locally clustered, the depth information provided a perspective on the extreme bedrock relief in clustered areas.

METHODOLOGY

The electrical characteristics of the clay were investigated using Geonics EM-31 and EM-34 instruments. These frequency domain electromagnetic systems are calibrated to read directly the conductivity of the terrain in millisiemens/metre (mS/m). The EM-31 is a portable one-man rigid boom system which is useful for determining changes in horizontally stratified media to a depth of approximately 6 m. The EM-34, although identical in principle to the EM-31, offers the advantage of being able to expand the distance between transmitter and receiver from 10 m to 40 m, in order to allow one to determine the effective conductivity of the electrical section at increasing depths.

Weak eddy currents are induced in the ground by a time varying primary magnetic field resulting from an alternating current produced in the transmitter coil. Secondary magnetic fields arise from these induced currents and are sensed, in combination with the primary magnetic field, by the receiver coil. McNeill (1980b) has derived practical methods of interpretation for secondary field responses which are a complicated function of intercoil spacing, the operating frequency, and the ground conductivity. By changing system parameters (i.e. dipole orientation and intercoil spacing) it is possible to determine the relative conductivity with depth.

Electromagnetic soundings of the Quaternary section at each station were carried out using a Geonics EM-37 ground transient electromagnetic system. Although published case histories are few in number, the concept of sounding with time domain electromagnetic systems has a highly evolved theoretical base in the literature from both eastern and western block countries. Such research is amply developed in recent monographs (Kaufman and Morozova 1970, and Kaufman *et al.* 1983). An adequate introduction to the elementary principles of the transient sounding method is given by McNeill (1980a, 1980c).

In view of the shortage of case history information, considerable time was devoted to field experimentation, microcomputer programming for data reduction, and modelling algorithms, and alternate non-computer dependent interpretation diagrams.

SYSTEM DESIGN AND OPTIMIZATION

Experimentation included design and optimization of parameters such as transmitter loop size, loop resistance, current amplitude, and waveform, against system limitations such as predeterminable minimum turn-off time, sampling window locations, the accuracy and precision of the system measuring circuit, and the dynamic range of the 20 channels which display the receiver voltages.

It was found that using a square 20 x 20 m loop of insulated 19 strand #10 gauge wire with a series resistor of 0.8 ohms capable of handling 22.0 amperes of current at 40 volts, rendered a turn-off time of 34 μs. A quick turn-off time together with a current waveform having an appreciable amplitude before turn-off will offer two sought after commodities in shallow sounding. Firstly, a greater induced electromotive force over a shorter period of time will result, and secondly, a rapid turn-off time will enable more reliable deconvolution of the effect of finite delay caused by the source waveform. Correction for finite turn-off time will improve the accuracy of the transient response at the first few early-time channels. Deviation of the early-time channels, after correction for finite turn-off time (Levy 1984), from that predicted by theoretical thin sheet models is indicative of the later stages of the half-space response and the onset of the thin sheet response for the first conductive layer. As with most electrical methods, accurate determination of the first layer parameters is a necessary initial step in accomplishing complex multi-layer inversions.

In areas having a determined conductivity thickness product near 1 S, 11 channels ranging in time from 63 μs (1st channel) to 854 μs (11th channel) after turn-off could be reliably recorded. Repeated measurements were recorded to allow calculation of signal statistics and ensure reliability.

When measurements were recorded with the receiver positioned in the centre of the loop (central loop sounding), a consistent sign reversal was observed in the mid and later stages of the response. A similar effect has been observed and discussed by Lee (1981, 1984a, 1984b) and Buselli (1982). The effects have been, for the most part, observed over ground having superparamagnetic materials distributed in the near surface layer, causing the complex permeability of the medium to vary the frequency response of coincident loop systems. Although this effect will be the subject of further research we are not able at this time to offer reliable alternatives to the present hypothesis proposed. It was observed, however, that when measurements were taken with a larger loop the effect diminished.

Initially, measurements were recorded at 4 offsets which were determined by multiples of loop size. Hence, for a 20 x 20 m loop, offsets at 20. 40, 60, and 80 m were employed. Provided the thin sheet of conductive material does not vary in thickness over the offset distance, the low amplitude responses on an amplitude (A) versus conductivity-thickness (σt) nomogram do not vary with offset distance for any particular conductivity-thickness value. However, for increasing offset distances, larger amplitude responses effect an increasing curvature in the direction of increasing conductivity for all channels. This is in fact due to the position of the smoke ring (maximum current density) relative to the receiver at early time. For a 20 m receiver offset, the channel responses at late time will most closely approximate those calculated for the central loop configuration and will be of the form:

$$(1) \quad \frac{A_{S_1}^{CHX}}{A_{S_2}^{CHX}} \simeq \left(\frac{S_1}{S_2}\right)^3$$

where S = σt = conductivity-thickness product (siemens).

This relationship indicates the sensitivity of pulse transient responses to a conductive thin sheet. Selection of a transmitter-receiver configuration which is close to the ideal symmetry of the central loop configuration will eliminate as much as possible the effect of underlying topography. Hence, the 20 m offset and a 20 x 20 m loop were used as a standard sounding configuration during the later part of the study. The smaller loop size also provided savings in the time required for equipment set-up.

Transient soundings were carried out at 46 stations along 2 subparallel north-south traverses, 2.9 km in length, across the test area. Station spacing was 100 m except where adjustments were made to avoid metal fences and gullies.

CONDUCTIVITY (σ) MEASUREMENTS

Conductivity measurements for the clay layer as determined by the EM-31 (top 6 m) are summarized in Figure 1. The uniformly conductive nature of the top part of the clay layer throughout the test area is clearly illustrated. A mean conductivity of 37.3 mS/m corresponds to a resistivity of 26.8 ohm-m. Figure 2 and Figure 3 illustrate the behaviour of conductivity with depth as determined by the EM-34, using a transmitter-receiver separation of 10 m and 20 m respectively.

The small difference between the mean conductivity of the near surface clay and the 2 mean conductivities incorporating the successively deeper electrical section, 37.3 mS/m, 34.0 mS/m, and 32.6 mS/m respectively. may be indicative of either some thin sand layers at the base of the clay or the possibility that the water content in the near surface zone is slightly higher. From a modelling perspective, the small differences suggest a spatially homogeneous conductivity for the thin sheet.

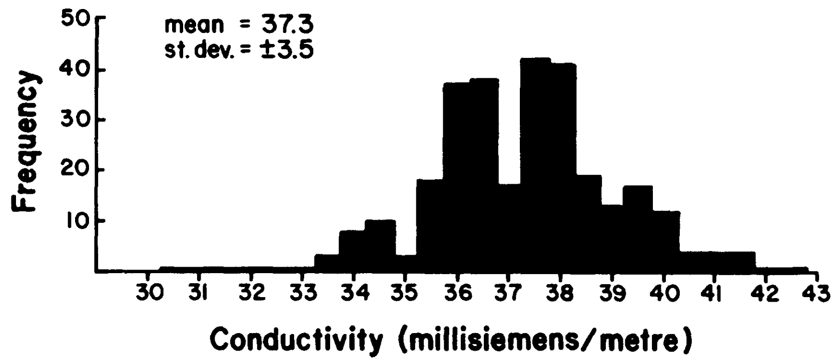


Figure 1. The distribution of clay conductivities near surface as determined by the EM-31 instrument. (Project 28.)

THIN SHEET MODEL

The time-derivative of the vertical magnetic field observed with coplanar transmitter and receiver dipoles located on the surface of a thin sheet can be derived mathematically (McNeill 1980c) as:

$$(2)\quad \dot{B}_z = \frac{-\mu M}{4\pi r^3} \cdot \frac{4\alpha(\alpha t + H)[9 - 24(\alpha t + H)^2]}{[1 + 4(\alpha t + H)^2]^{7/2}}$$

where $\alpha = 1/\mu Sr$, $H = h/r$, and

μ = magnetic permeability ($4\pi \times 10^{-7}$ H/m)

M = transmitter moment ($A \cdot m^2$)

r = transmitter-receiver dipole separation (m)

S = conductivity-thickness product (S)

t = time (s)

h = elevation of coplanar Tx and Rx above thin sheet (m)

At late-time where $t/\mu S >> r$ the equation for the time derivative reduces to:

$$(3)\quad \dot{B}_z \approx \frac{-9M}{16\pi} \cdot \frac{\mu^4 S^3}{t^4}$$

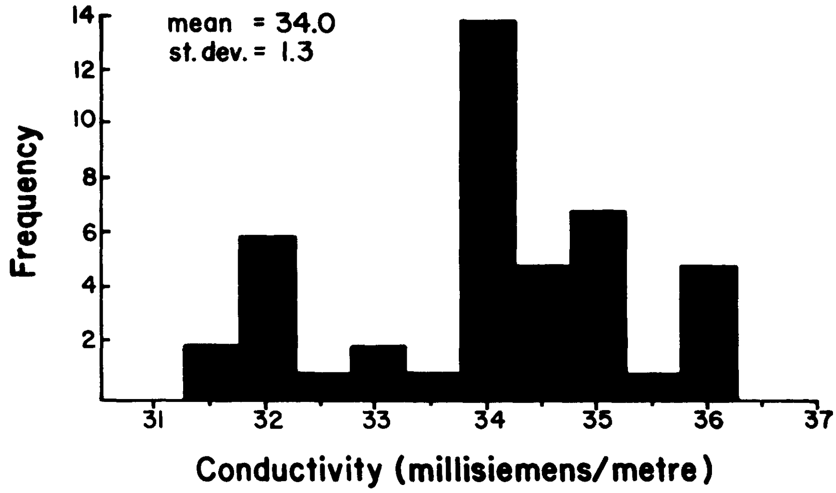


Figure 2. The distribution of clay conductivities using the EM-34 instrument with a 10 m coil spacing. (Project 28.)

An algorithm based on the above formula and incorporating the system response of the EM-37 was used to generate theoretical data for the thin

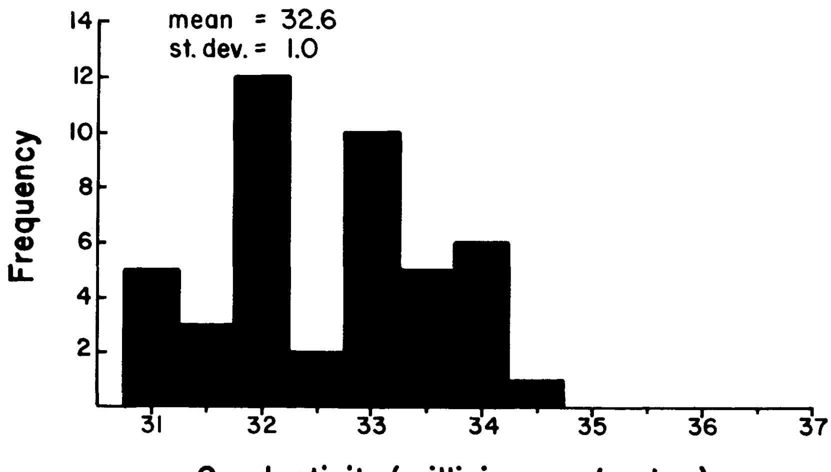


Figure 3. The distribution of clay conductivities using the EM-34 instrument with a 20 m coil spacing. (Project 28.)

sheet model. These data were used to produce a nomogram (Figure 4) consisting of transient decay voltages in millivolts (ordinate) for a range of thin sheet conductances (abscissa).

A preliminary interpretation of the sounding data can be done in the field to obtain an approximate σt value for the clay layer. The conductivity as measured by the EM-31 and EM-34 can then be used to calculate the thickness of the layer. Divergence of the channel amplitudes from the nomogram at successively later times is indicative of a 2 layer case for which a multi-layered earth model must be used to solve the conductivity and thickness of the second layer.

SUMMARY

This method was used successfully to locate several buried valleys where a second layer of lesser conductivity and thickness was present. Work is currently under way to refine the techniques used in order to improve the speed and accuracy of the method. We are satisfied with the progress made thus far and are convinced that the merit and relevance of this method will make it worthy of incorporation into future overburden drilling programs in the area.

In the future, we hope to investigate other methods such as shallow seismic reflection and refraction. Another potential method that has received some attention (Strangway *et al.* 1983) in recent years is the audiomagnetotelluric method. Because the method depends on a remote source, the resolution in areas of bedrock topographic relief may be suspect. More work on the above methods is certainly warranted.

ACKNOWLEDGMENTS

The authors express their deep appreciation to J.D. McNeill, M. Bosnar, and G. Levy for their stimulating discussions and useful suggestions. H. Northfield is thanked for his very capable and good-natured assistance in the field.

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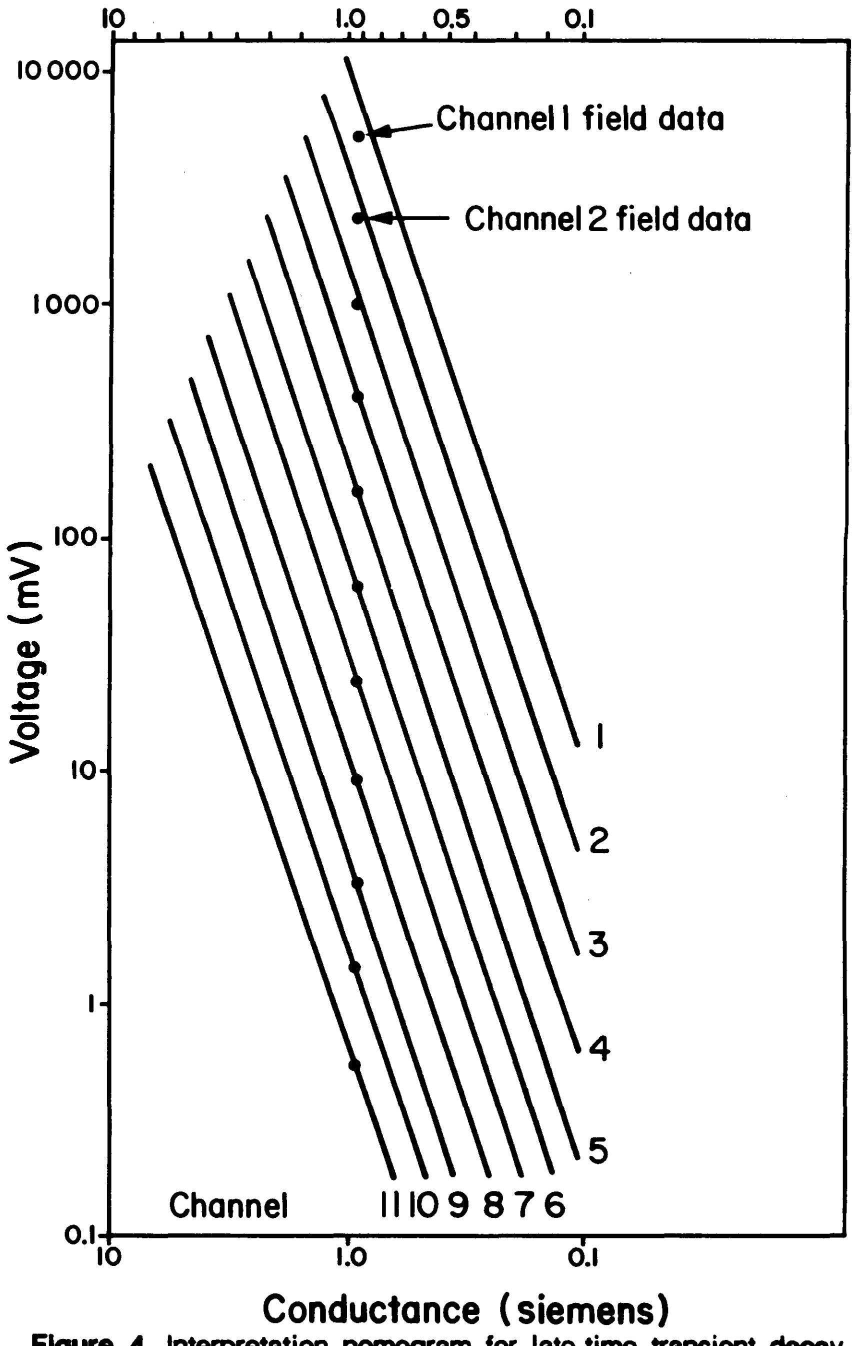

Figure 4. Interpretation nomogram for late-time transient decay of receiver voltages (ordinate) for a range of thin sheet conductances (abscissa). (Project 28.)

29. Night Hawk Geophysical Test Range Results, District of Cochrane

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INTRODUCTION

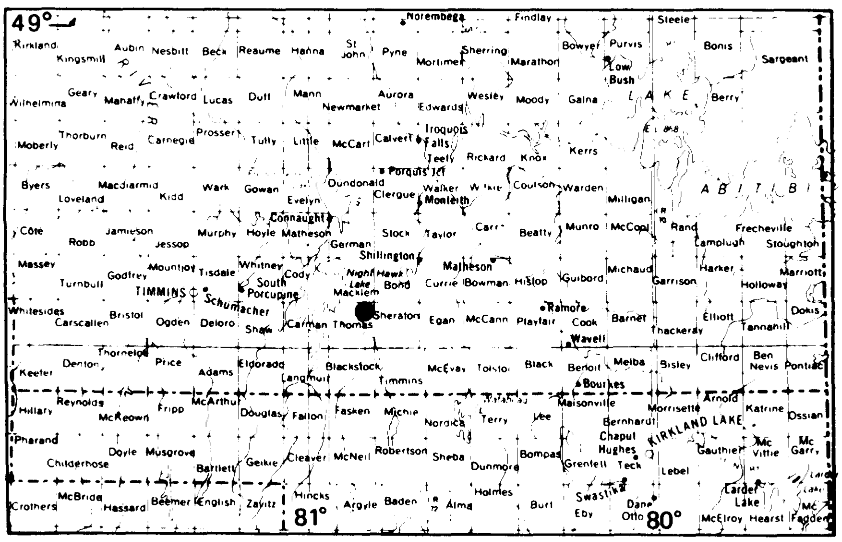
During the 1984 summer field season, studies were continued on the Night Hawk Geophysical Test Range and included interpretation work on data collected in recent years and new field work using the UTEM III system.

The test range program was initiated with the objective of developing certain areas, representative of exploration targets in Ontario, into sites for testing newly developed exploration technology. Sites that are selected for this purpose will be subject to ongoing research using new geophysical equipment by section staff and/or research scientists from university departments, industrial research and development companies, and other governmental agencies. The test ranges will therefore serve as field laboratories, thus aiding an important phase of exploration technology development. In addition, the sites will provide areas for instruction of field techniques in exploration geophysics.

A number of instrument manufacturing companies carried out independent testing programs this year. As well, the Geophysics Department of the University of Toronto used the site for their annual field school in September.

LOCATION AND ACCESS

The Night Hawk test range is located in the northeastern quadrant of Thomas Township, approximately 12 km south of Highway 101, on the Gibson Lake Road. The Gibson Lake Road turnoff is approximately 40 km east on Highway 101 from Timmins, Ontario. Figure 1, illustrating the grid, large transmitter loop positions, previous drillholes, the navigation control line, and access roads, shows that few areas of the grid are without ready access by vehicle.



LOCATION MAP

Scale : 1 : 1 548 000 or 1 inch to 25 miles

UTEM III SURVEY AND RESULTS

The UTEM III transient electromagnetic (EM) system, manufactured by Lamontagne Geophysics Limited of Toronto, is a large loop, wide band, time-domain EM system which incorporates recent modifications which are described by Macnae *et al.* (1983). A large loop is energized with an alternating current which has a precise triangular wave form at the selected fundamental frequency (for this survey, 30.974 Hz) and measurements are made in the presence of the primary field by the receiver on the transient response resulting from a step function. Frequency stability between the receiver and transmitter is accomplished by synchronizing the frequency and phase of 2, temperature compensated, crystal-controlled oscillators, and timing of the wave form is then controlled by a chain of counters programmed to produce the required base frequency.

For the survey described herein, the prom-programmable receiver sampling windows were set at 10 and arranged in a sequence where each successive earlier channel gate centre was positioned by division by 2 of the previous channel time, and arranged from 12.8 ms (latest channel) to 25 μs (earliest channel).

Both magnetic and electric fields can be measured, however E-fields were not recorded for this survey. A current of 3.7 amperes and a 63 ohm loop (1 by 1 km) of 18 gauge wire were used for transmission of a primary magnetic field. The northern side of the square loop was positioned 400 m south of the base line and centred on line 1+00 East on the grid system. Seven lines, 3 on each side of 1+00 East, were surveyed and 3 components of the secondary magnetic field were recorded at each station.

The results for lines 1+00 East, 0+00, and 1+00 West over the anomaly are presented in Figures 2, 3, and 4 respectively. In each set of diagrams, A, B, and D correspond to the H_z, H_x, and H_y components of the secondary magnetic field and are normalized to the primary magnetic field at each point of measurement. This procedure is usually referred to as "continuous normalization", whereas normalization to the primary field at a fixed point is the basis of an alternate presentation format called "point normalization". The point normalized presentation on C for each set is reserved for the H_x component only. The station closest to the positive peak was chosen as it reflects the approximate edge of the conductor closest to the transmitter loop in a wide spectra of geometries, provided the loop edge is offset a reasonable distance from the conductor.

EM-37 SURVEY AND RESULTS

The EM-37 transient electromagnetic system manufactured by Geonics Limited of Mississauga is a wide band, time-domain EM system which measures the transient response created by a finite impulse in the absence of the primary field. The transmitted current has a modified rectangular wave form with a rapid ramp-type turn-off. The transient decay of the secondary field is sampled using 20 logarithmically spaced gates by the receiver; timing between the transmitter and receiver is synchronized by adjusting the frequency and phase of 2 high frequency crystal-controlled oscillators.

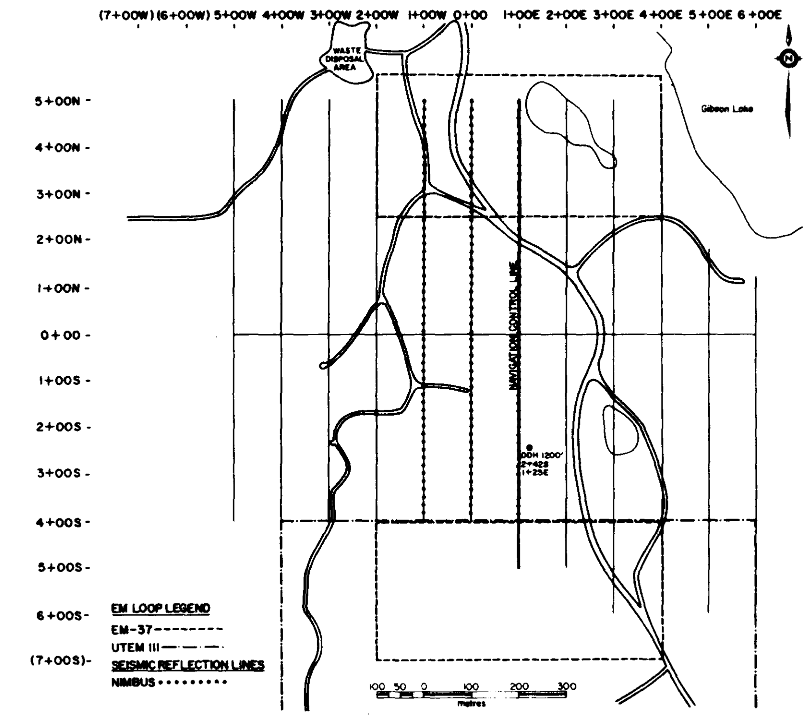


Figure 1. Grid map for the Night Hawk Geophysical Test Range showing the positions of transmitter loops and seismic lines. (Project 29.)

The survey specifications are listed for the data presented here in Pitcher *et al.* (1983). The data acquired over 7 lines last year with north and south transmitter loop positions have been contoured for all 20 channels. The late time responses acquired at 5554 μs after turn-off are portrayed for the northern and southern loops and illustrate the distribution of the secondary magnetic field as measured by 3 orthogonal orientations of the receiver coil (Figure 5).

NIMBUS REFLECTION SEISMIC SURVEY AND RESULTS

During the summer of 1982, seismic reflection profiling was carried out over lines 1+00 East, 0+00, and 1+00 West. The survey was carried out by staff of the Resource Geophysics and Geochemistry Division, Geological Survey of Canada, using a NIMBUS 1210F 12-channel digital enhancement engineering seismograph with filtering capability and auxillary computer and data reduction hardware (Hunter *et al.* 1982).

A 91.5 m 12-channel seismic cable with equispaced geophone take-outs, at 7.5 m spacing with 1 geophone per take-out, was used with 100 Hz geo-

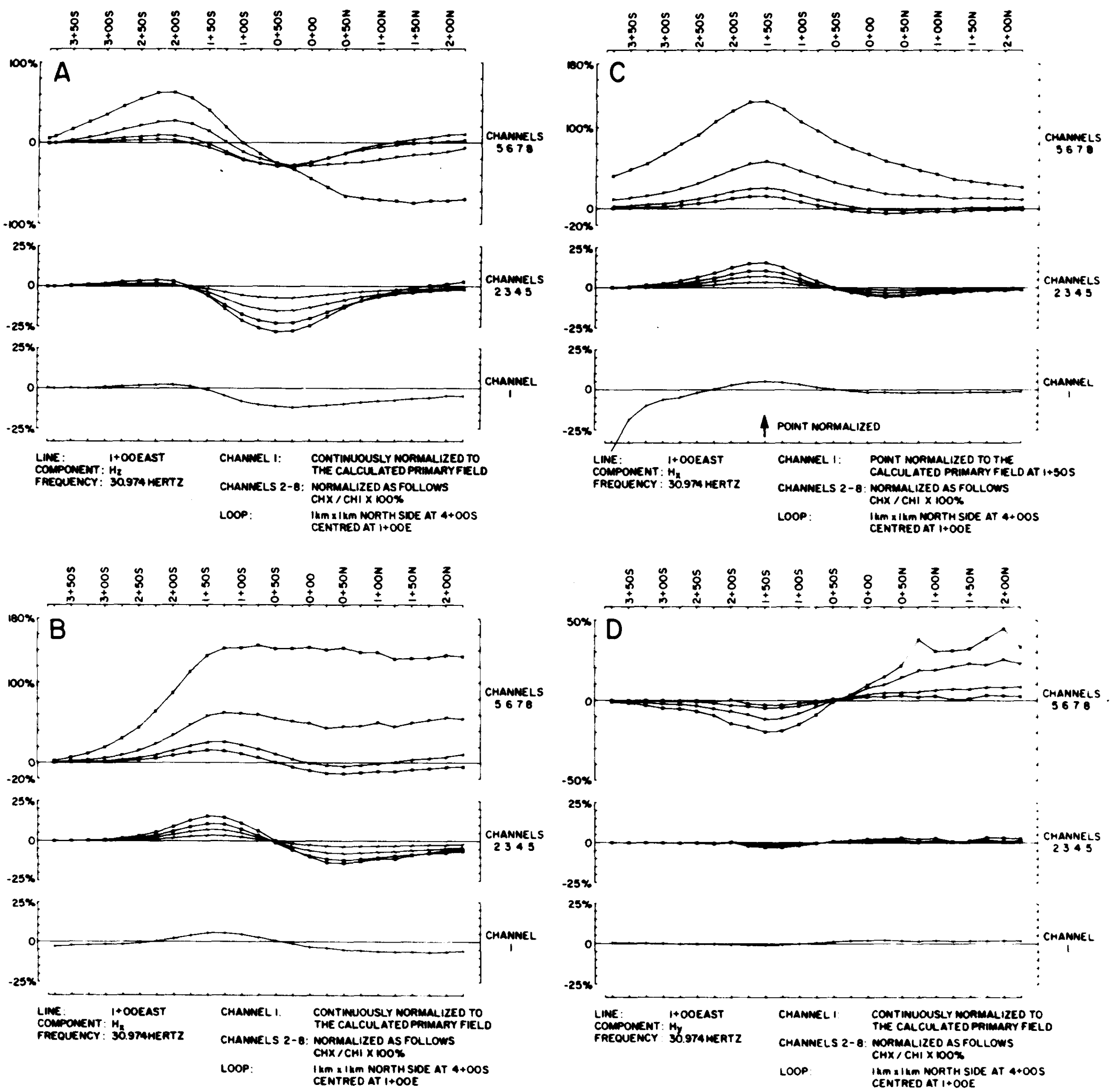


Figure 2. UTEM III results for 3 orthogonal components of the secondary field, line 1+00 East. (Project 29.)

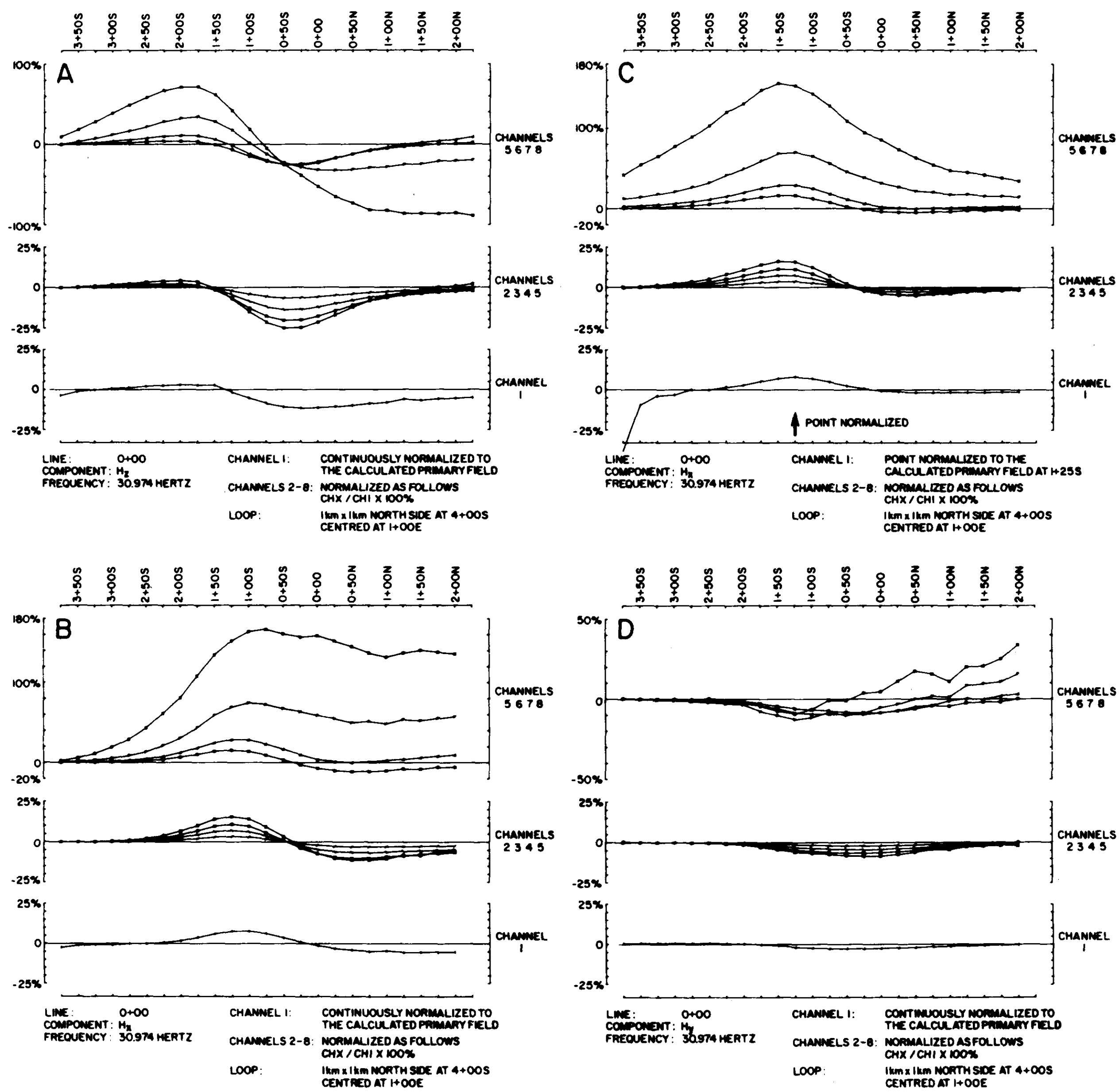


Figure 3. UTEM III results for 3 orthogonal components of the secondary field, line 0+00. (Project 29.)

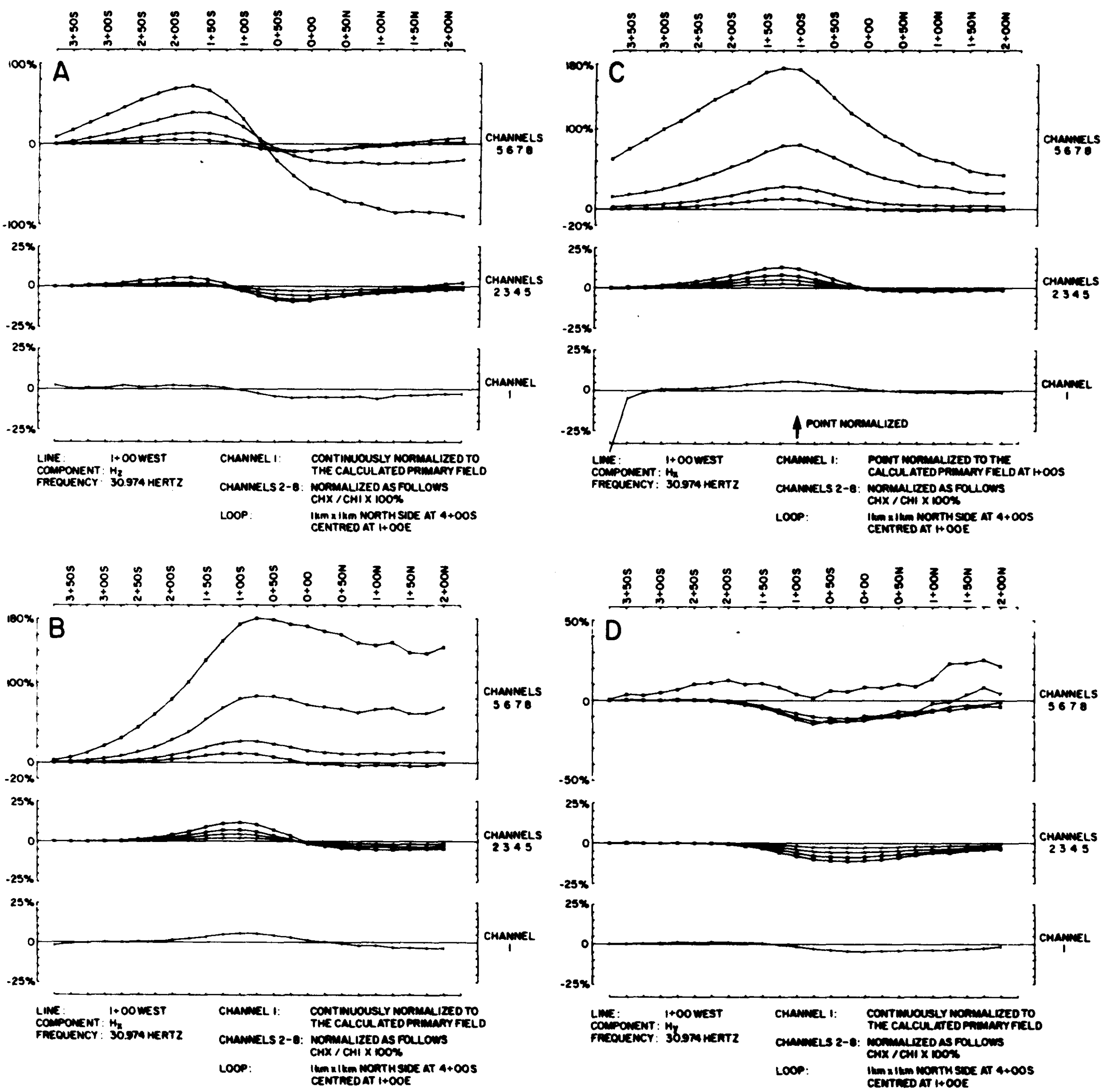


Figure 4. UTEM III results for 3 orthogonal components of the secondary field, line 1+00 West. (Project 29.)

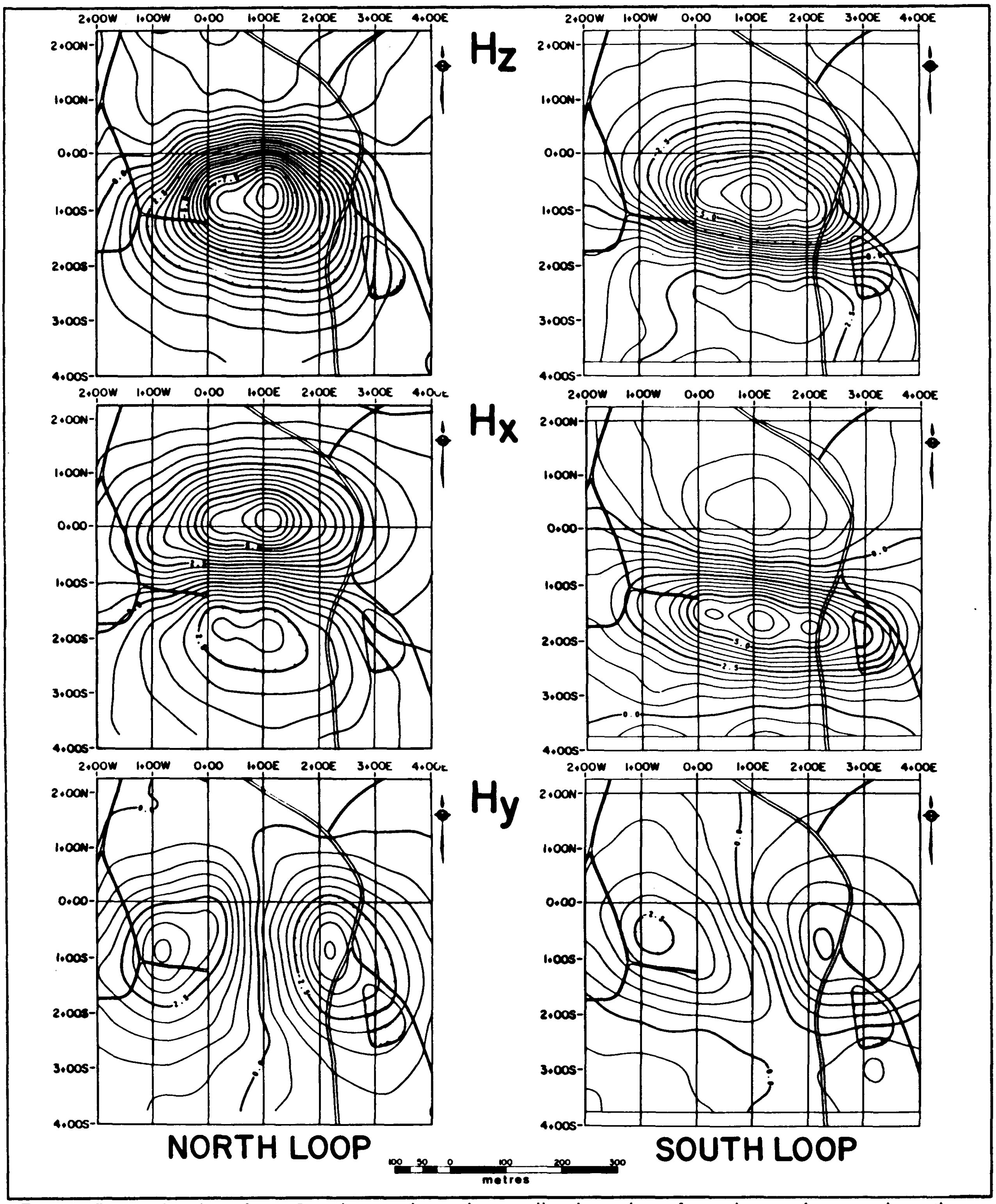


Figure 5. EM-37 data from 3 orthogonal receiver coil orientations from the northern and southern loops at late time (5554 μs). Contour interval is 0.5 millivolts. (Project 29.)

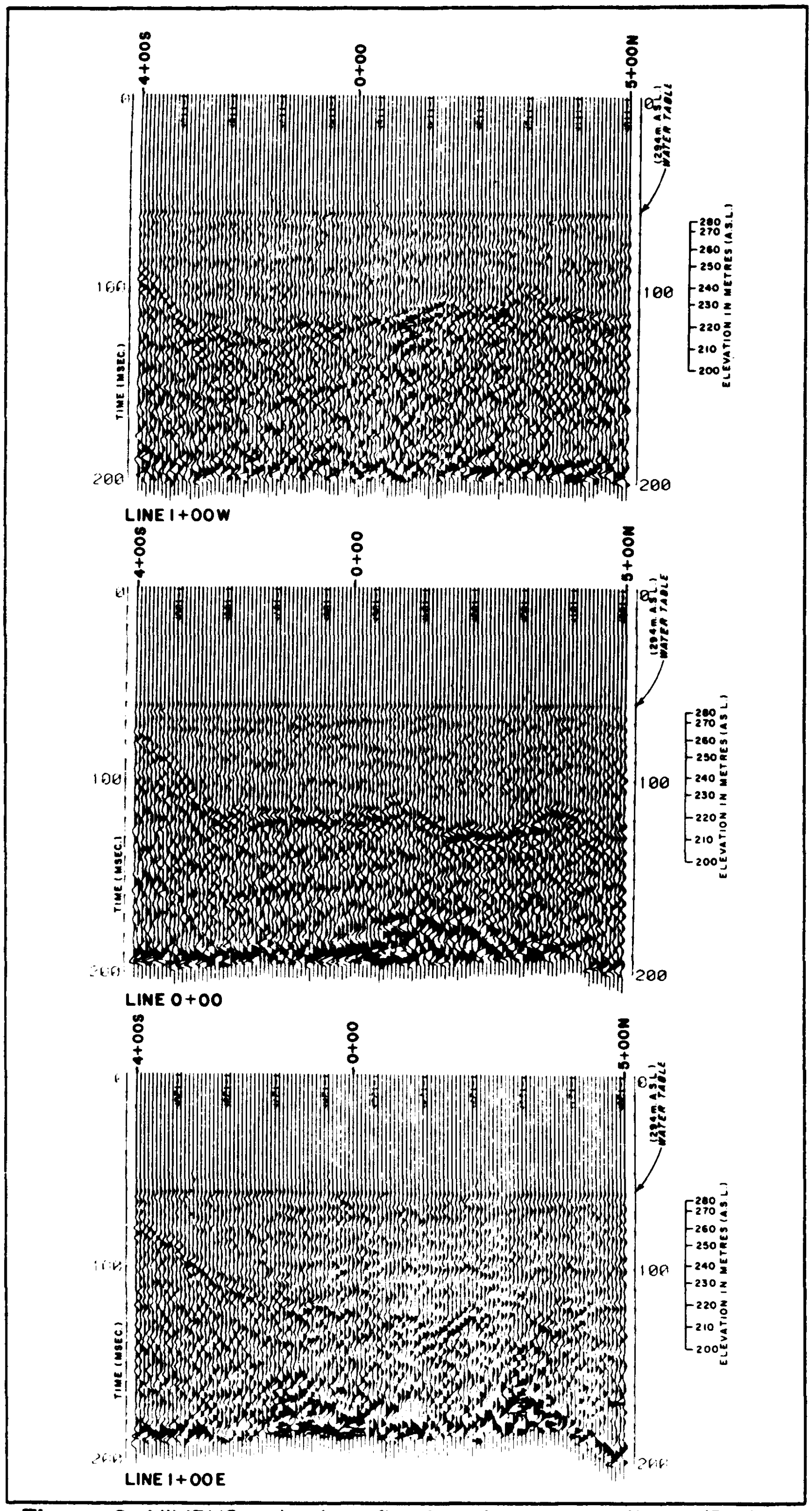


Figure 6. NIMBUS seismic reflection data over 3 lines. (Project 29.)

phones to minimize the low frequency content on the seismic record. Seismocaps were used as an energy source with an optimum offset spread; the shot point being displaced 60 m from the end of the spread.

The records were made using a 0 to 200 ms recording span with a 30 ms recording delay. The sections have been static corrected, band pass filtered from 100 to 300 Hz, and gain adjusted (Figure 6).

A sharp rise in the bedrock is evident to the south of the grid system on all 3 lines, whereas a gradual rise is apparent from east to west. Alternate sand and gravel layering is evident in the overburden section as well as undulations in the bedrock topography. Some evidence is also visable of possible zones of shearing in the bedrock particularly in the region of 1+00 N on line 1+00 West.

FUTURE ACTIVITIES

Some additional experiments are planned for the 1985 field season on the Night Hawk Test Range. As well, plans are underway to develop an integrated interpretation approach for time-domain electromagnetic methods, frequency-domain electromagnetic methods, potential field methods, and seismic results.

Work was temporarily postponed on the adjacent Sheraton Test Range but should commence during the 1985 field season.

ACKNOWLEDGMENTS

The author was ably assisted in the field by D.H. Krentz and H. Northfield. Staff from Lamontagne Geophysics Limited and Geonics Limited provided helpful suggestions with respect to field work and data presentation for UTEM III and EM-37 surveys and compilation. J.A. Hunter and staff from the Resource Geophysics and Geochemistry Division of the Geological Survey of Canada provided the excellent seismic reflection records shown in Figure 6. D.H. Pitcher provided computer contouring expertise for the EM-37 data.

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30. The Use of Remote Sensing for the Study of Acid Lakes, Raaflaub Township, District of Algoma

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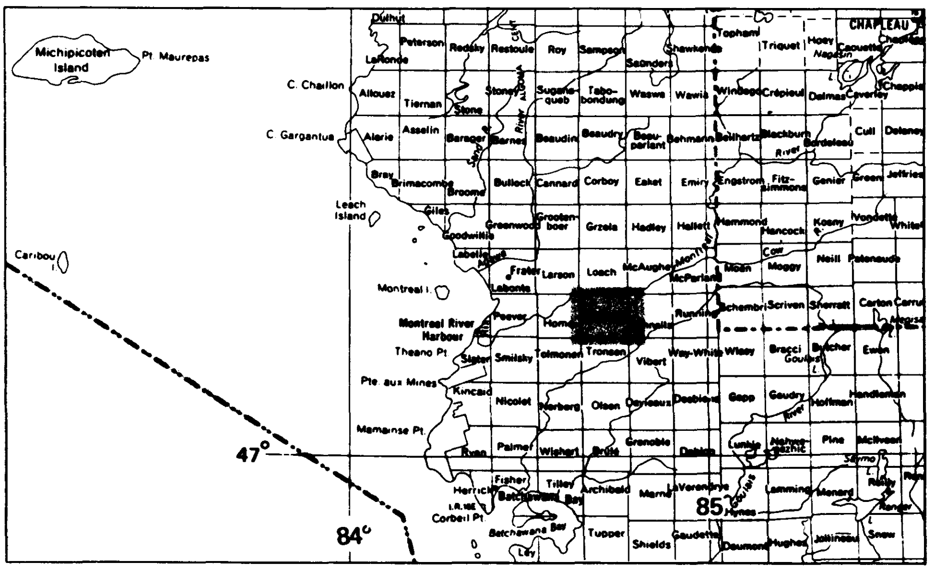
INTRODUCTION

Since 1980 an interdisciplinary team has conducted several studies concerning acid lakes in the vicinity of Wawa, Ontario. These studies form a part of the Ontario Geological Survey's activities that focus on the development of improved regional geochemical survey methods based on the analysis of lake waters and sediments. One aim of the studies has been to evolve a technique to identify lakes affected by acid precipitation, and to distinguish these acid lakes from naturally occurring acid and nonacid lakes. This technique is intended for incorporation in future regional geochemical surveys carried out by the Ontario Geological Survey for the purpose of mineral resource appraisal.

The information collected by the team has been described in 2 Open File Reports (Fortescue *et al.* 1981; Fortescue *et al.* 1984) and summarized in a broadsheet (Fortescue 1984). Briefly, this work has shown that a simple determination of pH of lake water is insufficient for assessing the effects of acid precipitation on a lake. Other factors, such as alkalinity, sulphate and calcium content, and the colour of the water must be considered when reconstructing the history of pH changes in a lake.

Work by M. Dickman and his coworkers at Brock University (as members of the team under contract to the Ontario Geological Survey), has shown that the pH changes in lake waters over the past 100 years can be described in detail using the technique of diatom inferred pH (Dickman *et al.* 1984; Dickman and Fortescue 1984). However, diatom inferred pH measurements are currently time consuming and require specialized expertise. For these reasons, the method is impractical for routine use in future regional geochemical surveys. Thus, a simpler method would be desirable for identifying recently acidified lakes.



LOCATION MAP

Scale : 1 : 1 584 000 or 1 inch to 25 miles

Results of research by the interdisciplinary team have shown that acid lakes in the Wawa area, particularly those not directly affected by smelter fumes, tend to occur in clusters. If these recently acidified lakes (in contrast to naturally occurring, brown-water, acid lakes) could be identified during the planning of geochemical surveys, then they could be included in the sampling program, and those of particular interest in relation to the acid rain problem, could be earmarked for further study. Therefore it is important to be able to identify clusters of these acid lakes within the Canadian Shield, in areas where lake sediments are used for regional geochemical surveys. This approach would increase the cost effectiveness of such mineral resource appraisal surveys. For this reason, we became interested in the possibility of using modern remote sensing techniques to identify geochemical and limnological characteristics of acid lakes.

REMOTE SENSING AS AN AID TO THE RECOGNITION OF ACID LAKES

Preliminary discussions with V.H. Singhroy of the Ontario Centre for Remote Sensing in the Spring of 1984, indicated that state-of-the-art remote sensing techniques could, in theory, provide information on the location of clusters of acid lakes. To test the use of remote sensing for locating acid lakes, it became clear that a feasibility study based on remote sensing data obtained at low levels would be necessary. The sensors used in the study would include some of those built into the current generation of satellites. This is an important point because, if this approach were to be widely followed in future, remote sensing data would be most accessible from this source, rather than from specially arranged flights.

In order to determine the applicability of remote sensing techniques to the identification of acid lakes, it was decided to conduct a combined ground and remote sensing survey in an area in which recently acidified lakes were known known to occur. The area east of Lake Superior and south of the Montreal River was studied previously by the interdisciplinary team and proved to be ideal as a prospective test site. The pH values of lakes in this area, centred on Raaflaub Township, were found to range from 4.8 to 5.6. Moreover, diatom inferred pH measurements of several of the lakes studied in this area verified that some of the lakes had been recently acidified, not as a result of direct smelter emissions, but presumably due to acid precipitation (Fortescue *et al.* 1984; Dickman and Fortescue 1984).

OBJECTIVES

The objectives of the study are:

1. to locate a test area some 10 by 10 km in which acid lakes are known to occur away from the direct influence of smelter activity
2. to collect water and sediment from 100 lakes in the area of interest in order to provide information on the limnology and geochemistry of the lakes pertinent to that to be obtained from remote sensing
3. to conduct simultaneous remote sensing surveys and field study of the area, in order to provide a comprehensive database which can be used to discover if acid lakes, or their catchment areas, can be identified on the basis of remote sensing alone
4. to complete a detailed interpretation of the remote sensing data using the field data as ground truth, and to draw conclusions regarding the feasibility of using remote sensing to detect clusters of acid lakes in the area to the east of Lake Superior.

METHODS

GEOCHEMICAL AND LIMNOLOGICAL

To determine if acid lakes can be located by remote sensing methods, a test area was required that would encompass lakes with a wide range of pH values. Also, in order to test the validity of remotely sensing lake characteristics, both clear-water lakes recently affected by acid rain, and brown-coloured, naturally acid lakes were needed in the test area. These considerations led to the selection of an area some 9 by 12 km centred on Raaflaub Township (*see* Location Map). Because most of the lakes in the area selected for study were expected to have a pH lower than 6.0, part of the reservoir formed by the Montreal River was included in the test area, as its waters were likely of a higher pH than that of the lakes. Another advantage of Raaflaub Township was its proximity to laboratory facilities in Sault Ste. Marie, which enabled us to perform chemical tests on water samples within 24 hours of collection. John Kelso and his staff at the Canada Department of Fisheries and Oceans, Sault Ste. Marie, are gratefully acknowl-

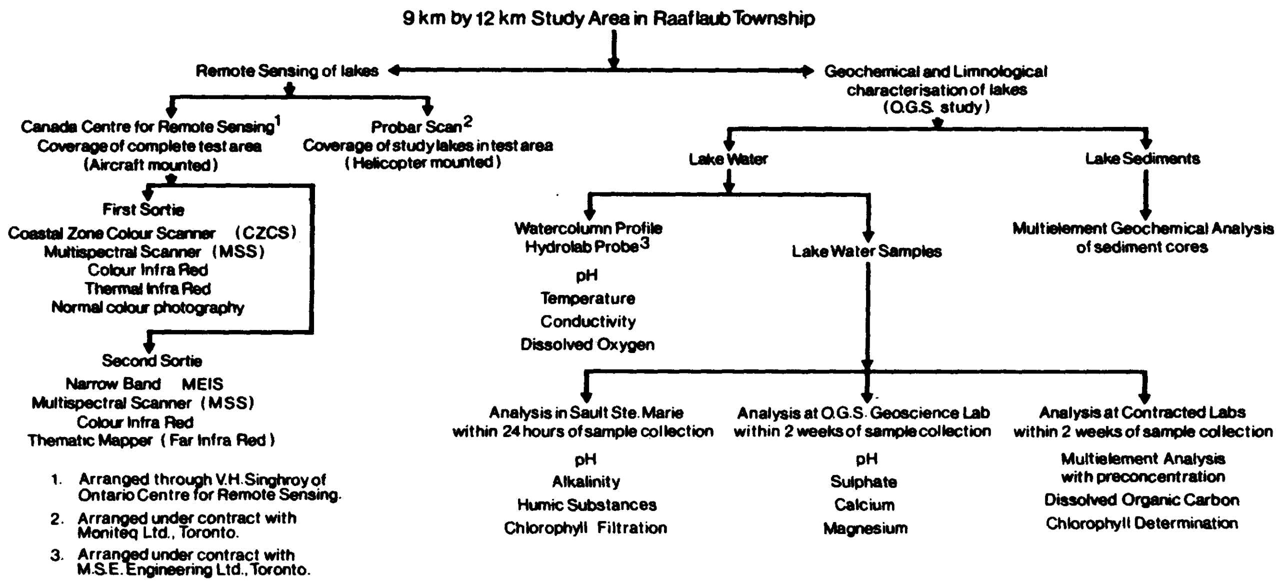


Figure 1. Field and remote sensing methods used in the Raaflaub Township study. (Project 30.)

edged for their assistance in the water analysis program.

An overview of the limnological and geochemical methods used to obtain ground truth data, together with a list of the types of remote sensors used in the study, is presented as a flow chart in Figure 1. A total of 79 lakes, plus 12 locations in the Montreal River reservoir, were sampled between August 20 and 24, with repeat sampling of 20 stations on August 26, 1984. Larger lakes in the area were sampled at several locations, bringing the total number of sampling locations to 113. At each location, vertical profiles of pH, temperature, conductivity, and dissolved oxygen were taken. In lakes deeper than 5 m, lakewater was sampled to this depth using a flexible plastic tube. Water samples from lakes less than 5 m deep, were collected just below the lake surface.

Within 24 hours of collection, the pH, alkalinity, and water colour (as an indicator of humic substances) of the water samples were determined at the laboratory in Sault Ste. Marie. As well, water samples from each lake were filtered for subsequent chlorophyll analysis. These filters were kept frozen until analysis in Toronto (at a contract laboratory) 2 weeks later. The remaining water from each site was analyzed for pH, and calcium, magnesium, and sulphate concentrations by the Geoscience Laboratories of the Ontario Geological Survey, Toronto, within 2 weeks of collection.

Additional tests were completed on samples of water and sediment collected from the 20 sites resampled on August 26. The abundance of elements in the sediment material was determined together with dissolved organic carbon and trace element levels in the water samples.

REMOTE SENSING

An aircraft from the Canada Centre for Remote Sensing, Ottawa, flew sorties over the test area twice on August 24, 1984; once in the morning and again several hours later. The sensors included on the first sortie were the Coastal Zone Colour Scanner (CZCS), thermal infra-red, and normal colour photography. On the second sortie the sensors were the Multi-Detector Electro-Optical Imaging Scanner (MEIS) and the Thematic Mapper. The Multispectral Scanner (MSS) and colour infra-red photography were included in both sorties.

Each of these techniques and scanners was designed to provide data pertinent to the lake acidity problem. The CZCS measures upwelling radiance in each of 4 spectral bands that are particularly sensitive to the concentration of chlorophyll in water bodies. Thermal infra-red imagery measures the latent heat given off by land and water. These infra-red images can be calibrated with ground truth, temperature data, to provide estimates of temperatures throughout the test area. Normal colour photography was included among the sensors as it allows detailed interpretation of ground features such as shoreline characteristics and bathymetry of shallow areas of lakes, which is unobtainable with black and white photography. MEIS is a multichannel imager that uses the "pushbroom" scanning approach. The narrow spectral bands and the design of the MEIS yield information with great sensitivity and spatial precision that can be used, for example, to quantify chlorophyll fluorescence of lakes and reflectance properties of vegetation. The Thematic Mapper measures upwelling radiance in the far infra-red portion of the electromagentic spectrum. The MSS collects upwelling reflectance data in 8 broad spectral bands. These bands cover the visual and infra-red portions of the electromagnetic spectrum, and thus allow assessment of water clarity and colour, and the spectral properties of terrestrial vegetation and rock outcrops. Colour infra-red photography records upwelling reflectance over a broad spectral range. The photographic images obtained with this sensor exaggerate the contrast between land and water, and levels of vigor in vegetation. Modern satellite scanners record similar images using the CZCS, MSS, and Thematic Mapper sensors, although the resolution is much coarser than with airborne sensors.

Information from the airborne remote sensors flown by the Canada Centre for Remote Sensing was augmented by data from a programmable band radiometer (PROBAR). The PROBAR was manufactured and installed in a helicopter under contract by MONITEQ Limited, Toronto, who were also responsible for collecting data from the Raaflaub Township test area. This device is a field radiometer that measures both downwelling irradiance and upwelling reflectance. The PROBAR is capable of high spectral resolution in the visual to far infra-red ranges of the spectrum, as well as excellent spatial resolution. It was mounted and operated

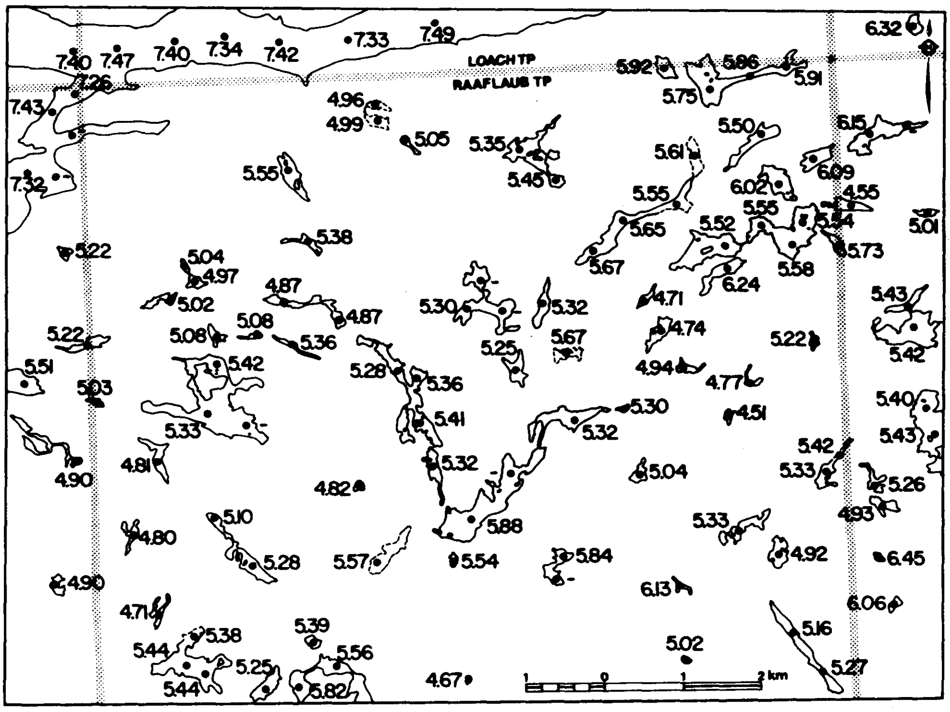


Figure 2. Map of lakes included in the Raaflaub Township study showing pH values of water samples determined within 24 hours of collection. No data are available for sites indicated by a dash. (Project 30.)

from a helicopter in order to maximize its spatial resolution. The test area was scanned with the PROBAR on August 21 and 22, 1984. The remote sensing data package, together with most of the laboratory observations on water and sediments, are currently being prepared for interpretation during the winter months.

PRELIMINARY RESULTS

A map showing the laboratory pH values of waters from the 113 sampling sites, as determined within 24 hours of collection, is illustrated in Figure 2. The values ranged from a low pH of 4.51 in a small pond, to a high of 7.49 in the Montreal River. As anticipated, lakes with low pH tended to occur in clusters. These ground truth data, and other sets like it, are expected to provide favourable targets for the interpretation of the data from the remote sensing surveys. Research is continuing to establish relationships between ground truth and remote sensing data that are suitable for incorporation in the planning stage of future regional geochemical surveys.

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MINERAL DEPOSITS PROGRAMS

Summary of Activities 1984, Mineral Deposits Section

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The "program" philosophy of research, outlined clearly in last year's summary (Colvine 1983), remains the basic approach to project work within the Mineral Deposits Section. While the smaller number of reports in comparison to 1983 is indicative of a reduced level of project activity due to constraints, they still represent a substantial body of work in which the products of the available resources have been maximized. The intention to diversify program emphasis has, however, not materialized to the extent desired. The predominance of Archean gold studies in the summaries that follow is indicative of this, although not fully representative of the true scope of the work underway; the majority of the work on topics other than Archean gold is at a preliminary stage and therefore not yet reported in individual summaries.

While the program focus is in part the result of current constraint conditions, it is also in part intentional or unavoidable. A major effort was mounted 3 years ago to provide new field-based data which would contribute to the understanding of Archean gold deposits as an aid to further exploration. Individual projects are now nearing completion, such that 3 staff geologists, A.J. Andrews, M.E. Cherry, and A.J. Macdonald, are devoting much of their efforts to comprehensive report preparation on their respective areas of investigation. As a continuation of these studies, S. Marmont initiated a 3-year study of the geological setting of the Detour Lake Mine, a major gold producer which is not documented in the geological literature, and J.S. Springer is investigating pyrite and carbon in gold environments. M.A. Vos is working outside of the gold program on aspects of industrial minerals, which are also receiving some input from J.S. Springer and M.E. Cherry.

The coordinated efforts of the gold study group have resulted in a comprehensive understanding of some fundamental regional controls on gold mineralization as well as providing some insight into the often characteristic local variability of individual deposits. Such "modeling" on a variety of scales provides a specific basis for targeting favourable areas as well as clues to the form of mineralization and expected wallrock alteration in individual areas. This advance has culminated in a recent documentation of new understanding of gold metallogeny (Colvine *et al.* 1984).

The next step is to develop projects specifically designed to apply this new understanding, gained from the study of known gold deposits, to areas where no major producers are present. Areas have been targeted on the basis of the apparent favourability of a combination of scaled geological parameters. The project approach is to add to the geological documentation of each area, providing a better basis for the assessment of the specific and "potential" information which would aid exploration. Obviously, limited resources at present preclude the use of staff geologists on this work, and it is being undertaken principally by contract geologists through supplementary funding (Ontario Ministry of Northern Affairs (MNA) and the Northern Ontario Rural Development Agreement (NORDA)). The principal areas being covered are Opapimiskan Lake (MNA) (H.

Shields and A.J. Macdonald), Shebandowan (NORDA)(L.B. Chorlton and G.H. Brown), Geraldton (NORDA)(S. Buck and H.R. Williams) and Black River-Matheson (BRIM)(P.J. Whittaker and J. Malczak). Some of these programs were initiated this year, while others are scheduled for completion in 1985. The Opapimiskan Lake and BRIM projects are components of Interdisciplinary Geoscience Programs and are reported in a separate section.

Individual summaries contain explanations of their focus and approach. The Red Lake area continues to receive a high level of study by both Ontario Ministry of Natural Resources and university geologists. The 6 summaries on the Red Lake area bring together much of that work, and a final publication by A.J. Andrews and M.J. Lavigne will provide a comprehensive understanding of the "anatomy" of the gold belt. Some areas of disagreement in interpretation are evident in these summaries; it is considered valid to present these alternative view points so that readers may be in a better position to assess the evidence.

The report on the structural setting of the Hemlo deposit was prepared by H. Hugon, a post doctoral fellow at the University of Toronto, under a grant from the Ontario Geoscience Research Fund to W.M. Schwerdtner. While a structural analysis alone cannot provide a complete interpretation, and the data presented may be controversial, it is included as a contribution, and to encourage discussion.

Geochronological investigation of gold associations is proving to be a very important component of the gold study program. The Section's work is being coordinated by S. Marmont who is conducting specific studies in the Abitibi belt. The Red Lake dating program is nearing completion and new sampling is taking place at Hemlo and Geraldton. Work at Shebandowan will also be a significant contribution. The Shield-wide bracketing of the mineralizing event(s) will become a powerful tool in targeting favourable areas.

The author's favourite program, Huronian paleoplacer gold potential, has suffered from lack of resources. We are, however, gradually building a data base on specific areas and formations. The Livingstone Creek and Matinenda Formations east of Elliot Lake, the Serpent and Mississagi Formations of the southern Cobalt Embayment, and the Gowganda Formation, north of the embayment, have all been covered in reports to be released shortly. Much of this work has been conducted by D.G.F. Long, who carried out a preliminary study of an area targeted by the author in the Lorrain Formation on the western margin of the embayment (Colvine 1981). Preliminary data substantiate the favourability of this area.

The intention to develop a more comprehensive effort in industrial minerals outlined last year (Springer and Vos 1983), as indicated above, has taken second place to the gold program. It remains an exciting new field, not only for mining but also for long term industrial development. A comprehensive program to investigate ceramics resources has been initiated by M.A. Vos. Ceramics commodities hold high potential for a variety of future developments.

The diversity of possibilities in industrial minerals outlined last year (Springer 1983a, 1983b, 1983c) has been supplemented by investigation of several other commodities.

Market information is an integral part of researching industrial minerals opportunities; thus markets, trade patterns, and specifications are being examined for talc, graphite, strontium, and micaceous hematites. Mineralogical data on graphite, dune sands, and refractory dolomite are also being compiled.

In the Grenville Province the erosional interval below the Paleozoic is being examined; it has been a site for mineral concentrations of hematite, gold, vermiculite, and quartz sand. It has influenced later fluid flow and the siting of post-Ordovician veins which contain lead and zinc and carbonates of calcium, barium, and strontium. Remote sensing (and data enhancement) are being combined with geobotanical techniques, and ground-based luminescence techniques to examine these veins.

Increased interaction with university specialists is also evident. Several outside research studies have been assisted by logistical support. In addition, Ontario Geological Survey geologists have provided field definitions for sampling in several research projects; most prominent are sulphur isotope studies with H. Schwarcz at Macmaster University, and direct dating of alteration minerals by the $^{40}Ar/^{39}Ar$ technique of D. York at University of Toronto.

The effort to improve communication and technology transfer has taken an increasing proportion of staff time. A large number of public presentations on a variety of topics were given at many meetings, including the Ontario Geoscience Research Seminar; GAC Cordilleran Section; GAC/MAC Annual Meeting; CIM, Chibougamau; CIM, Thunder Bay; P.D.A. Prospectors' Classes; CIM, Cobalt; CAME'84, Toronto; and the Timmins Geological Discussion Group. A special session on "Geological Fundamentals and Gold" was organized by the group. Interaction with industry geologists has increased substantially and their assistance has been most helpful in several projects.

Listed below are the publications, by the Mineral Deposits Section, which have been released by the Ontario Geological Survey over the past year; several others are nearing completion:

1. The Geology of Gold in Ontario; Miscellaneous Paper 110 (reprint)
2. Preliminary Report on the Timmins-Kirkland Lake Area Gold Deposits File; Open File Report 5467
3. Market Study for Stone in Northwestern Ontario; Open File Report 5493
4. Uranium and Thorium Deposits of Northern Ontario; Mineral Deposits Circular 25
5. The Application of Lake Sediment Geochemistry to Exploration for Lithium Pegmatites in Northern Ontario; Open File Report 5500
6. Gold Deposits of the Kenora-Fort Frances Area; Mineral Deposits Circular 16 (reprint)
7. Genesis of Archean, Volcanic-Hosted Gold Deposits; Miscellaneous Paper 97 (reprint)

8. Field Trip Guide to the Hemlo Area; Miscellaneous Paper 118
9. Market Study: Limestone Uses in Northern Ontario and Northwestern Quebec; Open File Report 5510
10. The Geological Setting of Mineralization in the Mine Centre-Fort Frances Area; Open File Report 5512
11. The Terrace Bay Batholith and Associated Mineralization; Open File Report 5514
12. Metallogeny of the Grenville Province; Open File Report 5515.

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31. Gold Studies in the Red Lake Area

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INTRODUCTION

This district-scale multidisciplinary study was initiated in 1982 on a background of previous Ontario Geological Survey project work in the area (Pirie 1981; Wallace 1982). The objective is to develop a comprehensive understanding of the processes involved in gold mineralization within the overall context of the geological evolution of a "greenstone" belt (Andrews and Durocher 1983).

The base program (Andrews 1982) continued this year with an emphasis on: (1) detailed petrographic studies, with special reference to metamorphic and alteration features characteristic of the eastern section of the belt (McDonough, Bateman, Balmer, and Dome Townships); and (2) geochronological sampling to complete the final stage of U-Pb radiometric dating of the gold deposits in the belt as a whole.

Early this year a brief reconnaissance was conducted in the underground workings of the A.W. White (formerly Dickenson) and Campbell Red Lake Mines, in anticipation of detailed alteration, metamorphic, and structural studies to be conducted in 1985.

Ontario Geoscience Research Fund (OGRF) and Ontario Geological Survey supported components of the project, initiated last year, continued during the 1984 field season. This year, the study by H. Hugon progressed under OGRF support (Schwerdtner, University of Toronto) and those affiliated studies by M.M. Sanborn, P.M. Berger, and B.C. Wilson continued. Together, these studies represent a coordinated effort to elucidate the history and style of deformation characteristic of the Red Lake "greenstone" belt and to define the relationships between the resulting structures and gold mineralization. The following studies were conducted during the 1984 field season:

1. H. Hugon (University of Toronto) (Project 33., this volume) conducted detailed structural studies in Heyson, Byshe, Balmer, and Dome Townships. A major objective this year was to define the northeastern extension of the Flat Lake-Howey Bay Deformation Zone and to examine its relationship to the inferred Cochenour-Gullrock Lake Deformation Zone (Figure 1).

2. Paula Berger (Queen's University) (Project 34.) completed a detailed study of a structurally complex area located in north central Dome Township. It has been suggested that this area represents the locus of convergence of 2 deformation zones (Andrews and Durocher 1983).

3. Mary Sanborn (University of Toronto) (Project 36.) continued detailed studies on the relationship between gold mineralization and local structures in the West Carbonate Zone of the former producing Cochenour-Willans Mine.

4. Bruce Wilson (Queen's University) (Project 35.) continued reconnaissance mapping of structures throughout the belt, and conducted detailed work on the Jamie-Frontier (formerly Keeley-Frontier) and Lake Rowan Properties, the Buffalo Deposit, and selected areas in the underground workings of the A.W. White and Campbell Red Lake Mines.

Details concerning these studies are described in the individual reports in this volume.

DISCUSSION

The application of the term "deformation zone" in the Red Lake area is new and still somewhat controversial, and thus requires clarification. The adoption of this structural concept was a direct result of detailed structural analysis by H. Hugon in the vicinity of Madsen (Durocher and Hugon 1983; Hugon and Schwerdtner, in press). These authors interpret the existence of a large, left-lateral shear system, of regional extent, in this area (the Flat Lake-Howey Bay Deformation Zone). As a result of this work, combined with the observations of Durocher and Burchell (1983), Andrews (1983), and Hugon (Project 33., this volume), it has been suggested that a system of deformaton zones exists which cross-cut the Red Lake belt on a regional scale (Figure 1). It should be noted that with the exception of the deformation zones illustrated by hatching in Figure 1, the existence of the other large scale structures illustrated is inferred on the basis of preliminary observations only. They will be the subject of detailed structural analysis as the project continues.

The deformation zones in the Red Lake area are manifested as linear belts of de-

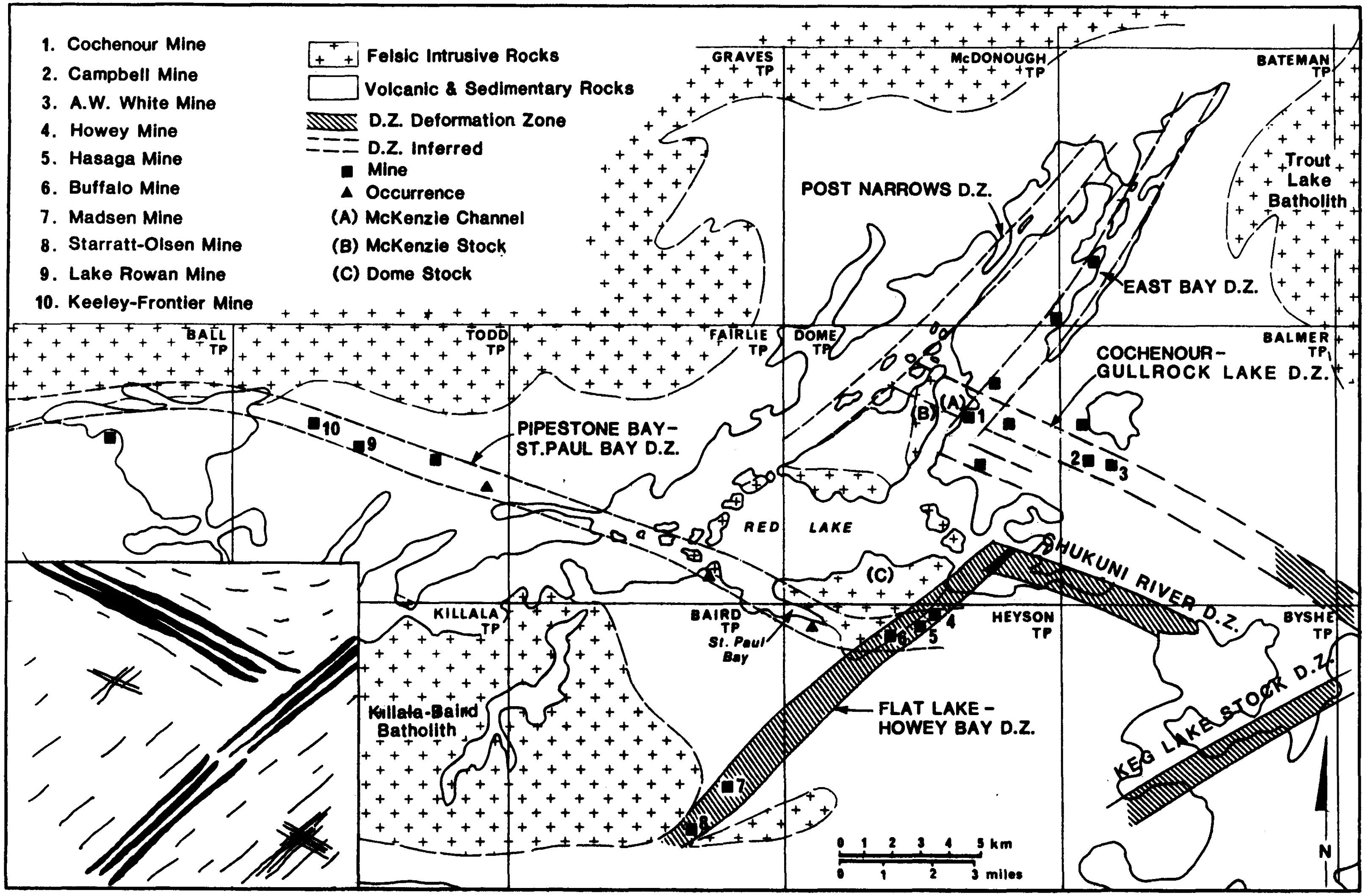

Figure 1. The large map (*after* Andrews and Durocher 1983; Hugon, this volume) highlights the location and approximate boundaries of deformation zones defined or inferred in the Red Lake belt at this point in the study. The inset map illustrates that deformation also occurs in the surrounding rocks but is generally less intense, thus the deformation zones represent areas of focused, increased strain. In general the structural elements within and outside the boundaries of the deformation zones are compatible and most likely reflect the reaction of the supracrustal rocks to batholith emplacement. (Project 31.)

formed rocks, up to 1 to 3 km in width, and tens of kilometres in strike length. While deformation is persistent and widespread in the Red Lake belt as cleavage, foliation, lineation, small scale shears, fracture sets, etc. (for example, *see* Berger and Helmstaedt, this volume, Figure 1), the nature and intensity of fabric development within the deformation zones sets them apart from the surrounding country rocks as discrete zones of higher strain (Figure 1, inset). The deformation zones have been identified by employing a combination of structural elements which include: (1) linear arrays of closely spaced, parallel shear and mylonite zones (centimetres to metres in width); (2) mineral lineations, and planar fabrics distinct from regional fabrics in the surrounding country rocks; and (3) kinematic indications of a significant rotational component of strain. The recognition and delineation of deformation zones in the Red Lake area is complicated by the often subtle and sometimes equivocal nature of the structural indicators and the generally poor outcrop exposure. This situation has contributed to the present lack of consensus as to the dominant structural style. Note, for example, the alternate emphasis of structural interpretation presented by Berger and Helmstaedt (this volume) and Wilson *et al.* (this volume).

As discussed by Andrews (1983, and this volume), the inferred deformation zones appear to exercise a fundamental control on the spatial distribution of intense alteration and major gold deposition in the Red Lake area. As such, discrete sections of these zones must have acted to focus massive fluid flow through the Archean crust. The detailed structural work by Hugon and Schwerdtner (in press) and Hugon (this volume) indicates that the dominant structural elements within and outside the boundaries of the deformation zones are generally compatible, and together represent a response of the supracrustal rocks to diapiric emplacement of the surrounding granitic batholiths. It is significant that deformation zones of similar scale, nature, and geometry have been observed to occur in the Pickle Lake supracrustal belt located to the east (Stott, this volume). The Red Lake and the Pickle Lake supracrustal belts form components of the Uchi Subprovince. As such, the patterns of deformation observed in individual supracrustal belts may reflect large scale tectonic processes acting over significant areas of the Canadian Shield.

FUTURE WORK

The interdisciplinary district-scale approach to this study will continue, along with detailed comprehensive work in critical areas. A coordinated, metamorphic, alteration, and structural analysis of the A.W. White and Campbell Red Lake Mines is tentatively set to be conducted early in 1985.

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32. Alteration, Metamorphism, and Structure Associated with Archean Volcanic-Hosted Gold Deposits, Red Lake District

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INTRODUCTION

The purpose of this component of the Red Lake Gold Project is to examine the distribution, nature, and history of alteration and metamorphism to determine how these processes relate, both spatially and temporally, to gold mineralization (Andrews 1982, 1983). The following studies were conducted in 1984:

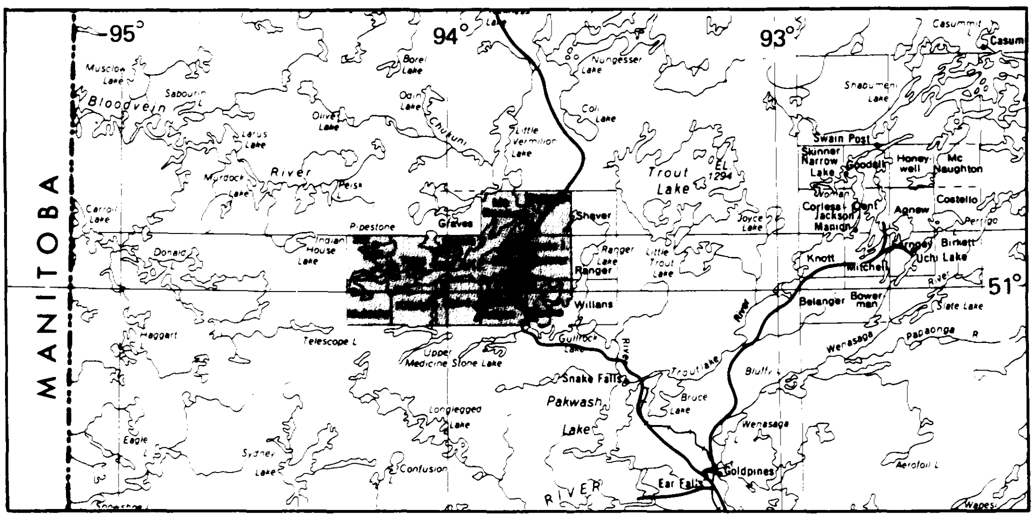
1. Petrographic examination of alteration and metamorphic features in samples collected from McDonough, Bateman, Balmer, and Dome Townships
2. Sampling for the final stage of U-Pb radiometric dating of gold deposits and related geological features in the Red Lake area
3. Reconnaissance of the A.W. White and Campbell Red Lake Mine underground workings in anticipation of detailed work to commence in 1985.

PETROGRAPHIC STUDIES

Petrographic studies provide a detailed and refined level of observation essential to the interpretation of field relationships. Petrographic work completed to date, together with field interpretation, are briefly summarized below. This work refers specifically to the detailed study being carried out at the eastern section of the Red Lake supracrustal belt including McDonough, Bateman, Balmer, and Dome Townships.

METAMORPHISM

A very extensive contact thermal aureole is developed in the supracrustal rocks surrounding the Trout Lake Batholith (Figure 1). The supracrustal rocks exhibit variable lithology, but consist predominantly of tholeiitic, mafic to ultramafic volcanic and intrusive rocks. The lateral extent of the thermal aureole was not obvious from field observations and was difficult to discern in thin section. The general paucity of epidote and chlorite, and rather erratic plagioclase compositions, left amphibole as the only useful metamorphic indicator mineral. At dis-



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

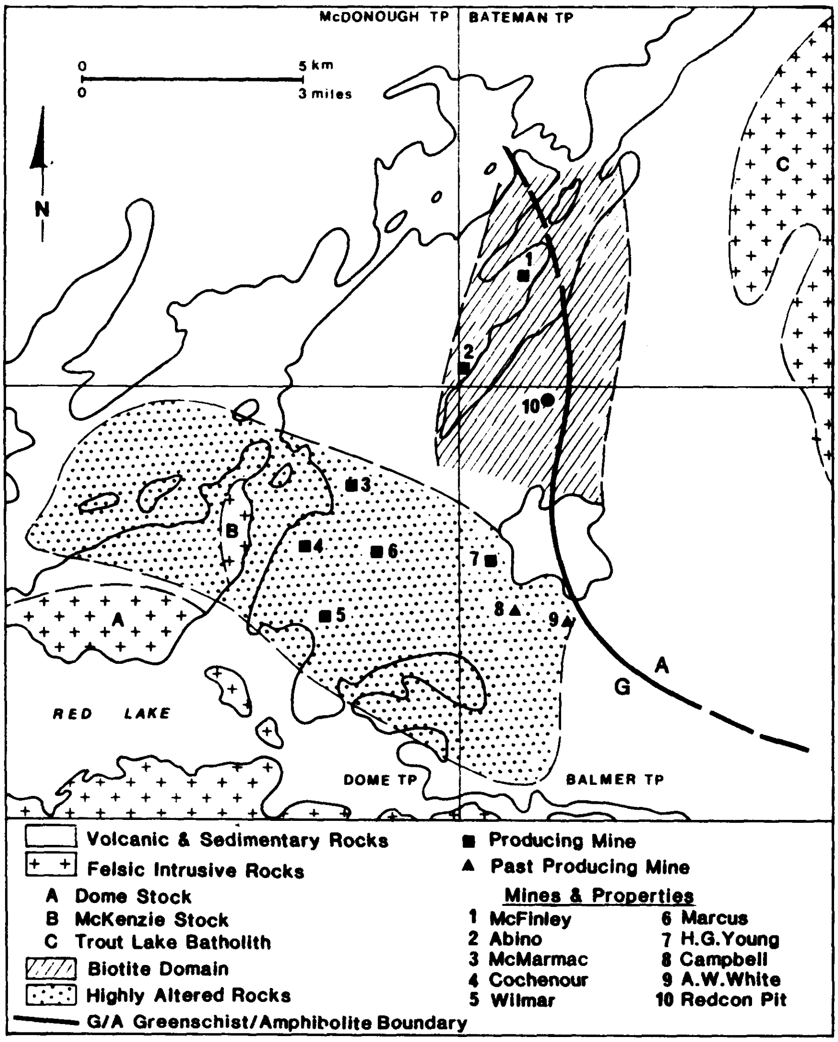


Figure 1. Simplified geology of McDonough, Bateman, Dome, and Balmer Townships, emphasizing regional metamorphic and alteration patterns. The distribution of highly altered rocks is a function, in part, of structurally enhanced permeability in this area (*see* Andrews 1983, Figure 1). (Project S32.)

tances of greater than 0.5 km from the granite contact, hornblende develops a felty, fibrous habit very similar to that of actinolite, and these amphiboles become virtually indistinguishable in thin section. As a result, amphibole compositions were examined by electron microprobe analysis, and the occurrence of hornblende and actinolite thus identified was used to define the location of the isograd marking the greenschist-amphibolite grade transition (Figure 1). The fibrous habit of hornblende and the erratic plagioclase compositions (An_{28-72}) combine to suggest that the contact thermal aureole manifested as a thermal perturbation of relatively short duration, thus not allowing enough time for total rock re-equilibration to occur.

REGIONAL CARBONATIZATION

The eastern section of the belt as a whole has been affected by regional carbonatization in the form of calcite. For the most part calcite is a minor (<5%) but persistent phase occurring exclusively in structurally generated elements of permeability, including small scale fracture systems, foliation surfaces, and less commonly as the major component of small scale (~1 m wide) shear zones. In the amphibolite grade domain of the thermal aureole, calcite and quartz occur in veinlets exhibiting relatively coarse-grained hornblende selvages. Fine-grained hornblende of similar composition occurs as the main component of the adjacent metamorphosed rock.

Calcite - actinolite - quartz veinlets with actinolite and/or biotite selvages occur with increasing distance from the granite contact. The structural siting of calcite, and the accompanying mineral assemblages as described above, suggest that regional carbonatization was coeval with thermal metamorphism and represents a hydrothermal expression of this event.

BIOTITE

A large domain of biotite-bearing metabasalts occurs in a position generally straddling the greenschist-amphibolite grade boundary (Figure 1). This domain is defined by the presence of biotite in modal abundances of >10% and the persistence of amphibole as a stable phase. In some parts of this domain (e.g. the Redcon and McFinley Properties), it is not uncommon to observe modal abundances of biotite up to 60%. Biotite is usually pervasively distributed throughout the massive crystalline rock, but is often concentrated along pillow selvages, and forms coarse-grained haloes to calcite veins. The regional location of the biotite domain suggests that it is a metamorphic component of the contact thermal aureole (biotite has a wide range of thermal stability extending from upper greenschist to upper amphibolite grade). However, the high modal abundances of this mineral as developed within dominantly mafic precursors requires metasomatic input of components, the most obvious being K_2O. As such, the biotite domain is viewed as a hydrothermal-metasomatic expression of the contact thermal aureole. Biotite occurs as a significant secondary phase in close association with gold mineralization in the underground workings of the A.W. White and Campbell Red Lake Mines. The relationship between this biotite and that in the regional biotite domain remains uncertain at this time.

HIGHLY ALTERED ROCKS

The highly altered zone (Figure 1) is characterized mineralogically by total replacement of albite and actinolite precursors, with an assemblage dominated by Fe-dolomite, quartz, white mica, chlorite, and subordinate calcite. Fe-dolomite and quartz also occur as the main components of veins. The chemistry of this mineralogical transformation is generally reflected by variable but significant additions of Si, CO_2, K, and S, and the removal of Ca, Mg, and Na. Significant anomalies of As and B occur in the highly altered rocks but show no systematic correlation with Au values. Within the highly altered zone, pervasive generation of Fe-dolomite is the most characteristic feature and occurs on the scale of kilometres. Within the large area of Fe-dolomitization, large patches of silicification occur on the scale of 100s of metres containing altered pillowed basalts now recording 55 to 60% SiO_2 by weight. As discussed by Andrews and Wallace (1983), significant removal of CaO, MgO, and Na_2O is more characteristic of silicified basalts as opposed to Fe-dolomitized ones. From this one can infer that the patchy, localized silicification occurred subsequent to the more widespread Fe-dolomitization.

GOLD MINERALIZATION

As a general observation, ore grade mineralization exhibits a persistent (though not exclusive) association with 3 specific types of alteration environments:

1. Massive Fe-dolomite veins: These veins, while intrinsically barren of gold, become important hosts where they have been deformed. Gold mineralization occurs in cross-cutting quartz veins and fine-grained breccias internal to the Fe-dolomite veins (*see* Sanborn, this volume).

2. Small patches of moderate to intense silicification: These patches, occurring on the scale of 10s of metres, are randomly distributed within the highly altered zone and are characterized by a pervasive replacement of the rock by quartz. Quartz veining is usually, though not always, present. Gold occurs as disseminations within the silica-replaced rock, and as high grade pockets in the quartz veins.

3. Sulphide disseminations: This environment constitutes zones of rock containing anomalous concentrations of disseminated secondary sulphides, dominated by pyrite, pyrrhotite, and arsenopyrite. Sulphide abundances are highly variable, with arsenopyrite sometimes constituting up to 50% of the rock. On the average, modal abundances of sulphide in these zones are about 5% combined (M.J. Lavigne, Regional Geologist, Ontario Ministry of Natural Resources, Red Lake, personal communication, 1984). These zones occur in dimensions of ones to tens of metres and are often accompanied by significant development of biotite. Gold ore occurs in intimate association with the disseminated sulphides.

Generally speaking, structurally induced permeability exercises a fundamental control on the location and distribution of these environments of mineralization. The systematics of structural control are complex and as yet not well understood; however, as a general observation, the variable mechanical properties of different lithologies play a very important role. For example, favourable structures are often found along or near the contact of 2 different rock types which have undergone deformation.

Good examples of environments 1, 2, and 3 can be observed in the Cochenour-Willans, Campbell Red Lake, and A.W. White Mines. Environment type 3 is most typically developed in the A.W. White Mine. Preliminary observations suggest that systematic changes occur in the nature of ore zones proceeding from southeast to northwest, from the A.W. White to the Campbell Red Lake workings respectively. The author believes that this may reflect a westerly decreasing metamorphic grade of the host rocks (amphibolite to greenschist), concomittant with a transition from a dominantly ductile to a brittle-ductile structural regime. This area will be the subject of a detailed study to commence in 1985.

TIMING OF ALTERATION AND MINERALIZATION

The following geological relationships place constraints on the relative timing of alteration and mineralization:

1. Fe-dolomite replaced rock and Fe-dolomite veins are intrinsically barren of gold.
2. Fe-dolomite veins are characteristically deformed. As such they have been rendered favourable ore hosts due to structurally induced permeability in the form of cross-cutting quartz veins and zones of brecciation.
3. Gold ore favours areas of silica and sulphide addition, usually accompanied by potassic alteration in the form of either white mica or biotite. This locally developed alteration-mineralization is superimposed on the large scale alteration pattern characterized by the occurrence of pervasive Fe-dolomite. As described above, the chemical characteristics of silicified versus Fe-dolomitized basalts is in agreement with silicification occurring subsequent to dolomitization.
4. Preliminary fluid inclusion studies of mineralized quartz veins (Lakind and Brown 1984) indicate that the gold-bearing fluids, while rich in CO_2, were characteristically dominated by H_2O.

From these observations one can infer that the hydrothermal regime responsible for alteration and mineralization was characterized by an initial massive insurge of CO_2-dominated fluid which caused widespread and intense Fe-dolomitization, with little or no attendant Au precipitation. With time, the system evolved to produce an H_2O-dominated fluid which precipitated much of the gold together with large amounts of quartz and K-bearing phases. Structurally induced permeability was maintained during alteration and mineralization by continuous deformation.

The emerging patterns of metamorphism, alteration, structure, and mineralization in the Red Lake belt (Andrews 1983; Andrews and Lavigne, this volume; Hugon, this volume; Hugon and Schwerdtner, in press) imply that gold mineralization occurred significantly later than volcanic activity and was directly related to the diapiric emplacement of nearby granite batholiths.

GEOCHRONOLOGY

This year, geochronological sampling was finalized for U-Pb dating of gold deposits and major rock units in the Red Lake belt. This component of the program (*see* Andrews 1983) is being conducted in cooperation with F. Corfu (Geochronologist, Royal Ontario Museum, Toronto). Rock units were sampled which predate and postdate gold mineralization at the Keeley Frontier and Lake Rowan Properties located in Todd Township towards the western end of the belt. This will complement sampling conducted previously at the eastern end of the belt (Andrews 1983). Sampling was also conducted near Little Vermilion and Hammel Lakes in order to date granitic batholiths located to the north of the belt. The Trout Lake Batholith located to the east is being dated as part of an Ontario Geoscience Research Fund (OGRF) supported study (N. Evenson and S. Noble, University of Toronto) and the Killala-Baird Batholith to the southwest was sampled in the previous year. With completion this year of the U-Pb stage of the geochronological program, the second stage, involving application of the ^{40}Ar-^{39}Ar technique, will now commence (OGRF Project, D. York, University of Toronto). The focus will be to obtain quantitative data on metamorphic and alteration events di-

rectly related to gold mineralization.

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33. Ductile Deformation Zones and their Significance in the Tectonic and Mineralization History of the Red Lake Belt

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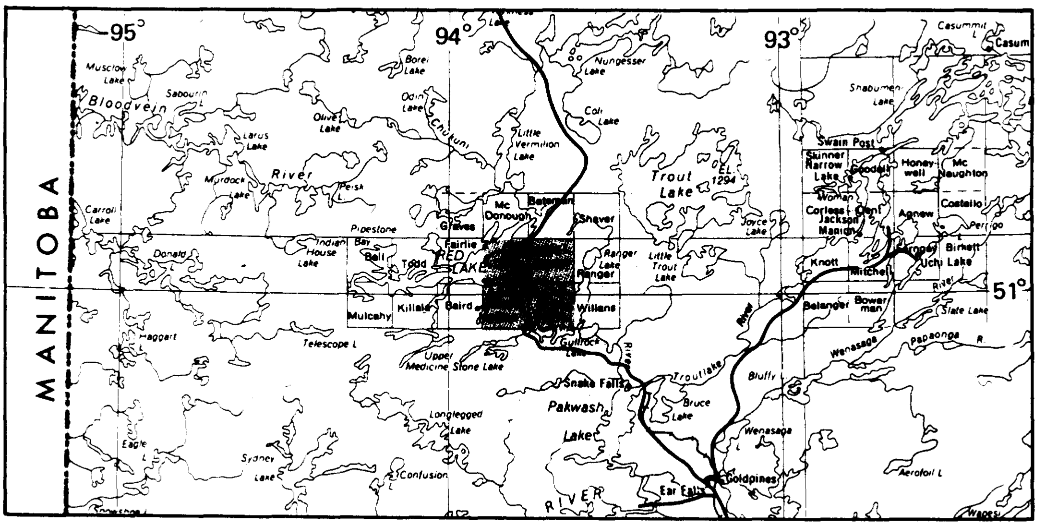
INTRODUCTION

The aim of this project is to gain a better understanding of the structural signature, geological setting, and tectonic history of gold-bearing units and their host rocks in the Red Lake area. As the brittle to brittle-ductile features of rock deformation have been studied extensively at a mine scale (Rigg and Helmstaedt 1981; MacGeehan and Hodgson 1981; Lavigne and Crocket 1983), the author's attention has been focused on the ductile response of rocks to deformation and its significance relative to gold mineralization. Judging from the Madsen example (*see* Durocher and Hugon 1983), this approach helps one to define zones of more intense deformation, i.e. ductile shear zones. In 1984, structural mapping has been extended to the northeast, from the Madsen area towards the Chukuni River as well as in the Keg Lake area and in the northern part of the Gullrock Lake area. Careful measurements of ductile features such as foliation, schistosity, stretch lineation, and small-scale ductile shear zones led to the recognition and definition of a network of large-scale conjugate ductile shear zones in Heyson, Byshe, Dome, Balmer, and Willans Townships. Structural investigations have also been made in areas northeast and north of McKenzie Island and at the Lake Rowan and Jamie-Frontier (formerly Keeley-Frontier) properties at the eastern end of the belt (*see* Figure 1, Andrews and Lavigne, this volume).

FIELD OBSERVATIONS

DOME STOCK AREA

At the Buffalo Mine, the mineralized veins are displaced along sinistral brittle-ductile shears. In this mine, small-scale shear zones are subparallel to the main Flat Lake-Howey Bay Deformation Zone. The southeastern margin of the Dome stock shows evidence of mylonitization from the Buffalo Mine to White Horse Island (Figure 1).



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

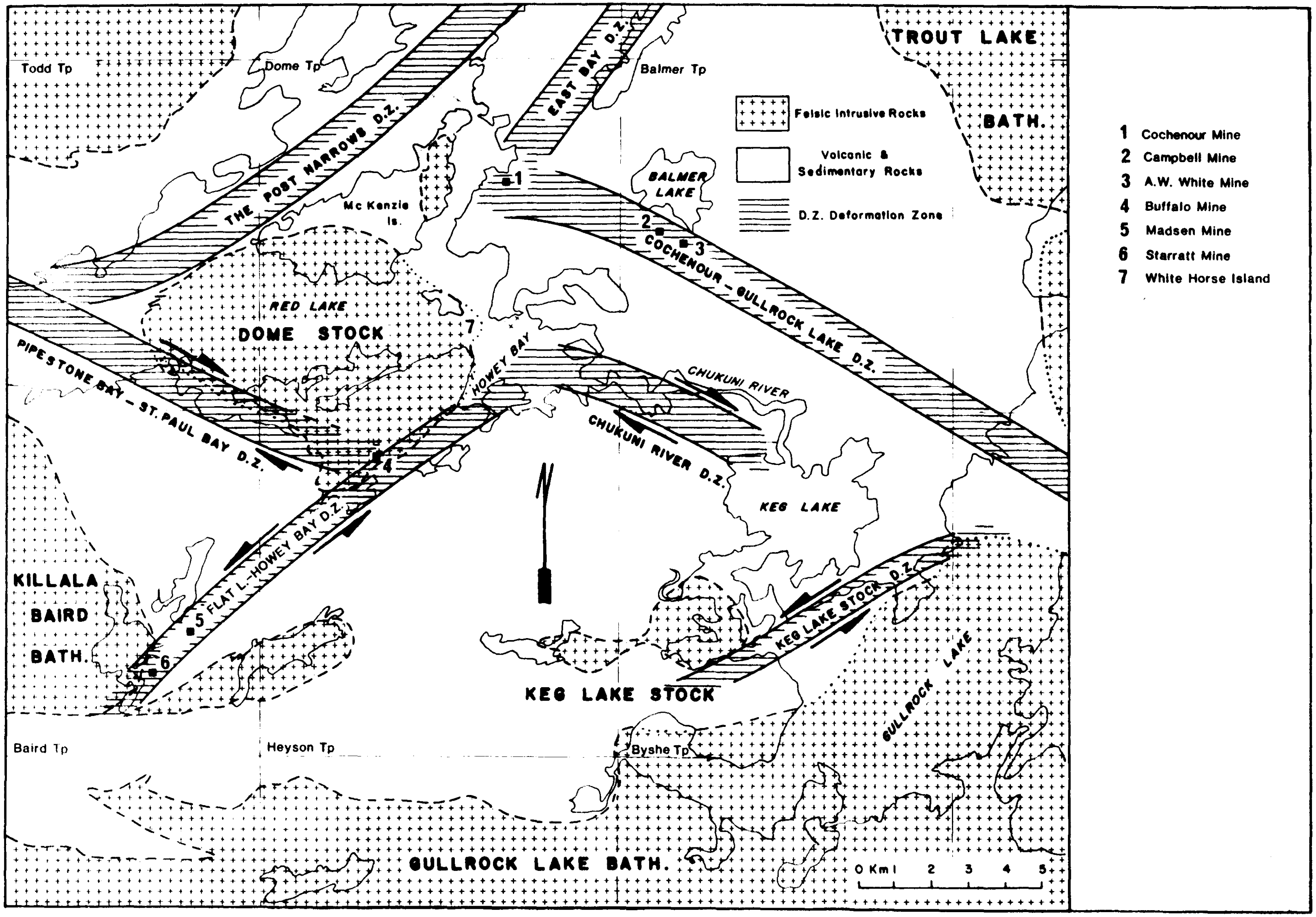


Figure 1. Structural framework of the Red Lake belt, eastern section. The patterned areas represent zones of most intense deformation. Deformation in the surrounding areas is pervasive but generally less intense. (Project 33.)

HOWEY BAY–CHUKUNI RIVER AREA

In this area, conjugate sets of ductile shear zones and shear fractures occur. The sinistral set of ductile shear zones is dominant in the western part of the area (Howey Bay) while the dextral one predominates in the eastern part (Chukuni River). In the intermediate area, conjugate sets of shear fractures define a cataclastic network that is a few centimetres wide in places. Where the shear fractures are closely spaced, pseudotachylite seems to be developed, e.g. southeast of the Red Lake Hospital. Southward from the Howey Bay area, the density of shear fractures decreases. Displacement along the sets of conjugate shear zones indicates that motions along these shear zones were more or less coeval. The L-S fabric of the rock material is approximately coplanar with the plane that bisects the acute angle formed by these conjugate ductile shear zones and shear fractures. As pointed out by Wilson *et al.* (this volume), who observed similar structures in other parts of the Red Lake belt, the maximum shortening direction parallel to the bisectrix of the obtuse angle formed by these shear fractures poses a problem. Moving northward within the Howie Bay diorite, a decrease in fracture spacing as well as a gradual increase of the number of small-scale conjugate ductile shear zones can be observed. The small-scale, conjugate shear zones developed from the shear fractures. This is, therefore, an example of progressive transition between cataclastic and mylonitic deformation of the Howey diorite.

CHUKUNI RIVER AREA

Numerous dextral, ductile shear zones on the scale of metres have been observed within the Howey diorite in this area. Sinistral shear zones are rare or absent. Collectively they define a dextral deformation zone trending parallel to the small-scale shear zones. This dextral deformation zone, the Chukuni River Deformation Zone, trends west-northwest. Subvertical shear plane/schistosity plane intersections, associated with a subhorizontal to shallowly northwest-plunging stretch lineation, are characteristic of this area, indicating that the right-lateral movement has been distributed over a width of approximately 1 km along this deformation zone.

KEG LAKE AREA

In this area, the Howey diorite shows little deformation while felsic volcanic rocks show a very well developed fabric, especially north of the Keg Lake stock. Sinistral, northwest-trending shearing seems to have occurred north of the Keg Lake stock. This trend is peculiar for sinistral shear zones in the Red Lake belt and the sense of shearing will be further investigated in thin sections. Conjugate fracture sets with foliation coplanar to the bisecting plane of their acute angle are also present in the area north of the Keg Lake stock.

GULLROCK LAKE AREA

Field observations confirm the occurrence of a sinistral shear zone following the northeastern shore of Gullrock Lake (Hugon and Schwerdtner, in press). The narrow zone between the Trout Lake and Gullrock Lake batholiths is marked by the presence of strongly deformed and gneissose metavolcanic and metasedimentary rocks. The schistosity/gneissosity dips shallowly to the south and trends northwest. On the western shore of Gullrock Lake, on strike with the gneissic foliation on the eastern shore, is a zone of strongly deformed metavolcanic rocks. Also on strike is a marked linear topographic low as well as the A.W. White, Campbell Red Lake, and Cochenour Mines. Also on strike and trending parallel to the lineament is a zone of strongly deformed rhyolite situated on the southeastern part of the A.W. White Mine property (Mike Chowaniec, Geologist, A.W. White Mine, personal communication, 1984).

NORTHEASTERN MCKENZIE ISLAND – POST NARROWS AREA

A gradual variation of the stretch lineation plunge has been observed in this area. The plunge changes from steeply northeast, northeast of McKenzie Island, to subvertical north of McKenzie Island, to steeply southwest in the Post Narrows area. The stretch lineation is associated with 1 cm to 1 m wide shear zones characterized by oblique movement. These shear zones have a sinistral component of movement northeast of McKenzie Island, and a dextral component of movement in the Post Narrows area. The presence of mylonitic to ultramylonitic fabric associated with inferred pseudotachylite northeast of the Post Narrows area is indicative of a very high magnitude, high strain rate deformation along the Post Narrows Deformation Zone.

LAKE ROWAN PROPERTY AREA

This property is located within the Pipestone Bay-St. Paul Bay Deformation Zone (Durocher and Burchell 1983). Ductile features such as asymmetric folds indicate a dextral component of shearing along this shear zone. This confirms the previous observations made by Durocher and Burchell (1983). Late conjugate sets of shear fractures studied in detail by Wilson *et al.* (this volume) affect an unmineralized, post-ore gabbro dike. Therefore, shear fractures in that area are late in the tectonic history.

PRELIMINARY INTERPRETATION OF THE OBSERVED STRUCTURES

Qualitative appreciation of strain intensity helps define large scale zones in which the rock material is more intensely deformed than in the surrounding rocks. The intense deformation is mostly due to ductile shearing but cataclastic deformation is also present. These large scale deformation zones define a network which is part of the structural signature of the Red Lake belt (Figure 1).

Concerning the Post Narrows Deformation Zone, the gradual variation in the plunge of the stretch lineations and the associated oblique shear zones seem to indicate a major component of vertical tectonics. The presence of a diapiric triple junction of foliation trajectories northeast of McKenzie Island is inferred from the foliation pattern in that area (Hugon and Schwerdtner, in press), and is compatible with such vertical movements. The oblique shearing is indicative of a downthrow movement of the block east of the Post Narrows Deformation Zone as well as a convergence of the supracrustal material flowlines toward this triple junction.

The Chukuni River Deformation Zone is a mirror image of the Flat Lake-Howey Bay Deformation Zone about a subvertical symmetry plane trending north-northwest. Subhorizontal to shallowly northwest-plunging stretch lineations of the Chukuni River Deformation Zone correspond to subhorizontal to shallowly northeast-plunging stretch lineations of the Flat Lake-Howey Bay Deformation Zone. The sense of movement along these zones indicates that they are conjugate and that the direction of maximum shortening of the *finite* state of deformation is colinear with the bisectrix of their obtuse angle which trends north-northwest. The junction of these 2 deformation zones is marked by conjugate sets of shear fractures and shear zones. The displacement along these sets indicates that the Flat Lake-Howey Bay and the Chukuni River Deformation Zones were active during the same period of time. From the Madsen study (Durocher and Hugon 1983; Hugon and Schwerdtner, in press), it follows that the Chukuni River Deformation Zone is coeval with the emplacement of the Killala-Baird batholith. As the Flat Lake-Howey Bay Deformation Zone affects the Dome stock, which gives a zircon U-Pb age of 2718 Ma (F. Corfu, Geochronologist, Royal Ontario Museum, Toronto, personal communication, 1984), the Flat Lake-Howey Bay and Chukuni River Deformation Zones are younger than 2718 Ma. The gradual appearance and increase in number of conjugate sets of small scale ductile shear zones towards the main domains of shear indicate either a progressive widening of the main deformation zones or that ductile shearing, due to circulation of hot fluids and associated alteration, occurred after an initial brittle behaviour of the rock material. Nevertheless, the junction area of these 2 deformation zones, marked with a strong cataclastic to mylonitic deformation (and therefore high permeability), is a high potential area for gold exploration.

Although more work needs to be done in the area of the Campbell Red Lake and A.W. White Mines, it appears that these mines are located along a zone of intense deformation extending from the contact between the Trout Lake and Gullrock Lake batholiths, northwesterly to the vicinity of Cochenour (Figure 1). Recent zircon U-Pb age dating (F. Corfu, personal communication, 1984) indicates that intense ductile deformation in that area is syn- or post-2757 Ma as it affects an isoclinally folded dike of that age. In comparison, the mineralization / alteration and deformation history of the Madsen area is syn- or post-2718 Ma (the age of the Dome stock). As summarized in this report and Hugon and Schwerdtner (in press), the combined structural evidence relates the deformation in this area to the emplacement of the surrounding batholiths. As such, the Flat Lake-Howey Bay, Pipestone Bay-St. Paul Bay and Chukuni River Deformation Zones were most likely coeval and broadly synchronous to the emplacement of the surrounding granites.

A similar history to that of the Madsen area may be applicable to the Campbell Red

Lake-A.W. White Mines area but in relation to the emplacement of the Trout Lake batholith. Down-dip stretch lineations observed in the A.W. White Mine suggest mostly a vertical tectonism as recorded within the Gullrock Lake-Cochenour Deformation Zone. The above inferred relationship between the emplacement of the Trout Lake batholith and the mineralization / alteration in the Campbell Red Lake - A.W. White Mines area will be further investigated during 1985.

DISCUSSION

Conjugate shear zones with similar trends as those described in the Red Lake belt have been observed elsewhere in the Pickle Lake belt to the east (Stott and Wallace, this volume). As the Flat Lake-Howey Bay and Chukuni River Deformation Zones are conjugate shear systems of the same age, the above observation in the Pickle Lake belt suggests that the structural pattern of the Red Lake belt is due to regional tectonics involving large parts of the shield. The study conducted in the Madsen area (Hugon and Schwerdtner, in press) indicates therefore that batholith emplacement and regional deformation were approximately coeval.

The large scale structures delineated in the Red Lake belt reflect both regional and diapiric tectonics. The geometry of the shear fractures and shear zones at all scales, as well as their sense of displacement, indicates a northerly direction of maximum shortening. Concerning the latter point, it has to be pointed out that this maximum shortening direction describes only the *final* state of deformation and therefore does not indicate if the observed maximum shortening direction is the result of a regional coaxial or noncoaxial deformation mechanism. Owing to the presence of the major dextral Quetico and Sidney Lake shear zones further south, the author suggests that the Red Lake belt, and the Uchi Subprovince in general, has been involved in an overall right-lateral deformation process. Such a large scale dextral shearing has been suggested by K.H. Poulsen (Research Scientist, Economic Geology Division, Geological Survey of Canada, personal communication, 1983) to explain a similar geometry of conjugate shear zones within the Quetico Subprovince.

CONCLUSIONS

The present state of the structural study of the Red Lake "greenstone" belt warrants the following observations and conclusions:

1. Past and present gold producers are located either along linear zones where deformation is more intense than in the surrounding rocks or at their intersection. This intense deformation took the form of brecciation, strong veining, or strong ductile shearing depending on competency contrast and rock behaviour at the grade of metamorphism reached.
2. Exploration for potential economical targets can be restricted to areas of intense deformation and associated structures.
3. The zones of more intense deformation resulted from the coeval interaction of diapiric and regional tectonics which took place syn- or post-intrusion of the Dome Stock, dated at 2718 Ma.

ACKNOWLEDGMENTS

The author wishes to thank Steve Manz (Fourth year student, University of Toronto) for assistance in the field, M. J. Lavigne (Resident Geologist, Ontario Ministry of Natural Resources, Red Lake) for constructive discussions and logistical support, Ed Everly (District Manager, Ontario Ministry of Natural Resources, Red Lake) and the personnel of the fire centre for accommodation facilities and logistical support. The author wishes also to thank Keith Peden (Project Geologist, Rowan property) and Mike Chowaniec (Geologist, A.W. White Mine) for field guidance. Special thanks are due to A.C. Colvine and A.J. Andrews (Ontario Geological Survey, Mineral Deposits Section) for logistical support and stimulating discussions, and to W.M. Schwerdtner (Professor, University of Toronto) for helpful discussions and assistance with the manuscript.

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34. Structural Studies in Northern Dome and Southern McDonough Townships, Red Lake District, Ontario

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INTRODUCTION

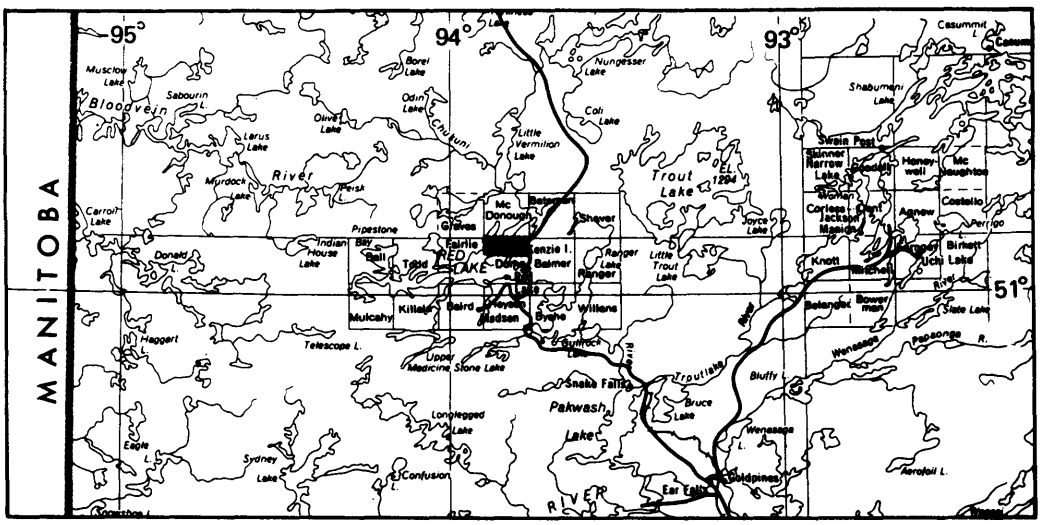
The nature, distribution, and significance of the deformation structures within the Archean supracrustal rocks were studied in order to gain a more complete understanding of the geological history in the eastern Red Lake area.

During 1983, the lithology and structure of parts of northern Dome and southern McDonough Townships (Figure 1) were mapped at a scale of 1:1000 (Berger and Summers 1983). At least 70% of the area is covered by water and most outcrops are flat, wave washed exposures along the edges of islands. The area was chosen because mapping by Pirie (1981) and Andrews and Wallace (1983) suggested the intersection of 2 regionally dominant structural trends.

During the 1984 field season, outcrops surrounding the previously mapped area were examined in order to correlate the map area within the regional structural framework of Dome, McDonough, and Balmer Townships. Emphasis was placed on exposures near Cochenour to determine the nature of the southeast-trending fabric which dominates this area, and its relationship to the east- and northeast-trending fabrics to the north.

GENERAL GEOLOGY

All of the supracrustal rocks within the map area are of Archean age and have been metamorphosed to greenschist grade. The northeastern part of the area is underlain mainly by fine- to very fine-grained massive or pillowed/variolitic tholeiitic to basaltic komatiitic metavolcanic rocks. Interlayered with and overlying the mafic metavolcanic pile are 2 cm to several metres thick bands of ferruginous sedimentary rocks and layered chert. Within the metavolcanic unit, layers of ironstone are discontinuous, however, the unit directly overlying the flows can



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

be traced throughout most of the map area.

The mafic sequence is overlain by a sedimentary package of reworked felsic tuffs, conglomerates, wackes, and slates. The reworked tuff unit is found at the base of the sequence. It is composed of medium- to fine-grained subrounded quartz and feldspar grains in a very fine grained groundmass and may be conglomeratic, massive, or layered. Layered exposures are commonly graded. The reworked tuff unit grades vertically and laterally southward into a sequence of layered wackes to slates. These sedimentary rocks are compositionally similar to the reworked tuff unit, but can easily be distinguished by a more advanced degree of reworking and sorting.

All of the supracrustal rocks contain varying amounts of carbonate in the form of Fe-rich calcite, ferroan dolomite, and ankerite. The carbonate may be pervasive throughout the rock or confined to veins. In general, the rocks with a greater amount of carbonate are also the most deformed.

A late, multiphase diorite to granodiorite intrusion (the McKenzie Island Stock) crops out exclusively on McKenzie Island. Gabbroic to quartz monzonite dikes are found scattered throughout the area.

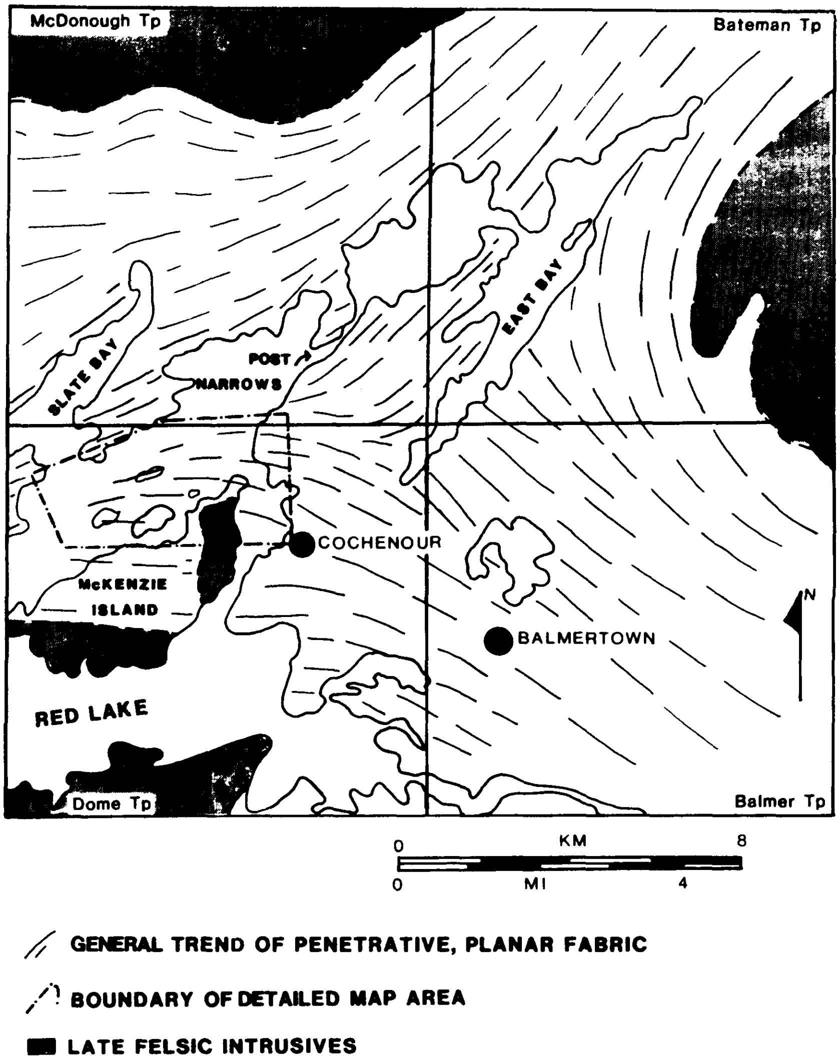


Figure 1. Generalized geology of McDonough, Bateman, Dome, and Balmer Townships illustrating the location of the study area and the general orientation of fabrics. (Project 34.)

STRUCTURAL GEOLOGY

Most exposures examined show a penetrative, planar fabric defined by preferentially oriented grains, clasts, or pillows. The nature of this structure varies according to rock type. Numerous shear zones are observed throughout the metavolcanic units and the massive carbonate-rich sedimentary units. Layered sedimentary rocks are, however, characterized by folding rather than shearing.

The strike of the penetrative fabric changes gradually and continuously from southeast (120° to 140°) near Cochenour, to northeast (50° to 70°) at the mouth of Slate Bay (Figure 1), and throughout the rest of the map area is orientated east-west. Dips are generally steep and range from 65° to 90° both to the north and south. This change in trend is part of a similar regional swing through Balmer, Dome, and McDonough Townships (Figure 1). The southwest-trending fabric in Balmer and northeastern Dome Townships and the east- to northeast-trending fabric in McDonough and the rest of Dome Townships were previously interpreted as 2 separate fabrics (Andrews and Wallace 1983; Berger and Summers 1983). However, examination of the surrounding regions has shown it to be a single continuous feature.

No consistent sense of rotation or offset associated with this fabric has been observed in either outcrop or thin section. Stretching and mineral lineations pitch steeply (>60°) to vertical within the cleavage plane.

The penetrative, planar fabric is axial planar to symmetrical and asymmetrical folds on the outcrop scale. Bedding throughout the map area strikes east to northeast and dips steeply north and south. Folds on McKenzie Island and to the south, where bedding and cleavage are at a >30° angle, are gentle to tight, and plunge 30° to 70° northwest. Folds to the north of McKenzie Island are isoclinal to tight and plunge 60° to 90° east and west. The folds observed in outcrop are minor, decimetre-scale folds on the limbs of more regional folds, the hinges of which are inferred from bedding reversals, cleavage refraction reversals, and symmetry of minor fold reversals. The regional-scale fold configuration cannot be determined due to lack of outcrop.

Reversals in younging direction near McKenzie Island, where bedding strikes northeast and cleavage southeast, along with inconsistencies in minor fold configuration about known fold hinges and overturned beds in the northern part of the area, suggest the possibility of early, precleavage folding of the sedimentary rocks.

Throughout the map and surrounding areas, the penetrative fabric is cross-cut and rotated by shear zones. These are developed in conjugate sets; the acute (60°) angle bisected by the earlier cleavage. In any one outcrop, one shear set dominates and may be cross-cut by the other. The penetrative fabric bounded by the shears is slightly more parallel to the dominant shear. Intersection of shears is near vertical. The dominant sense of shear is transcurrent left-handed northeast-southwest of the earlier fabric, and right-handed southeast-northwest of it.

These shear zones are millimetres to a centimetre wide over most of the area, except southwest of Post Narrows, where they can reach widths of greater than 3 m. The larger, northeast-trending shears near Post Narrows are invariably left-handed and have a well developed, penetrative planar fabric within the shear zone boundaries. This fabric strikes <10° south of the boundaries and dips subparallel (near vertical) with them. Thin section examination of this fabric has revealed that shears cross-cutting amphibole-rich rock are devoid of amphibole. The minerals composing the shear planes consist of chlorite and minor amounts of biotite, indicating that most shear zones formed following the peak of regional metamorphism.

A late conjugate fracture set overprints the penetrative planar fabric and ductile shear zones. This late set can be observed throughout the entire Red Lake Belt (Wilson *et al.*, this volume). The fractures vary in orientation from 130° to 70° and 10° to 50°. They are generally expressed as a widely spaced joint set, each joint less than 1 cm in width. Locally, however, they may be more penetrative and may make up a crenulation cleavage in fine-grained material. Offset was observed along some of the widely spaced fracture planes, and though the 130° to 170° plane was dominantly right-handed, exceptions exist.

INTERPRETATION AND SUMMARY

Folding prior to the development of the penetrative fabric is suggested by inconsistencies observed in minor fold configuration and younging reversals. Further evidence to confirm the presence of 'early folds' should be obtained elsewhere in an area where younging directions are more abundant.

The metavolcanic-metasedimentary pile was subjected to a regional, bulk shortening event. The penetrative fabric observed in most outcrops was formed roughly perpendicular to the maximum shortening direction. Maximum extension was generally subvertical. The direction of maximum shortening changed regionally from northeast-southwest in Balmer and western Dome Townships to northwest-southeast in McDonough Township. Throughout most of the map area (northern Dome Township) the maximum shortening was north-south.

The sedimentary units responded to this compression by folding. The penetrative fabric developed axial planar to the folds. Folds are tighter and more steeply plunging northward from McKenzie Island.

As the compression continued, shears developed within the more competent metavolcanic units. The shears developed at a small angle to the 'flattening' direction (30°). This angle is predicted by Ramsay (1980) for shears developing in a ductile environment. Dominant left- or right-handed sense is locally, though not regionally, developed. Near Post Narrows, however, the width of the left-handed set has increased, and a penetrative shear fabric is developed within the boundaries of northeast-trending, steeply dipping shear zones.

The region was then subjected to a similar, north-south to northeast-southwest oriented compression. This affected the rocks after they had become 'more brittle' and consequently the rock fractured rather than sheared and no regionally penetrative fabric developed.

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35. Shear Fracturing, Dike and Vein Intrusion, and Gold Mineralization in the Red Lake Belt

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INTRODUCTION

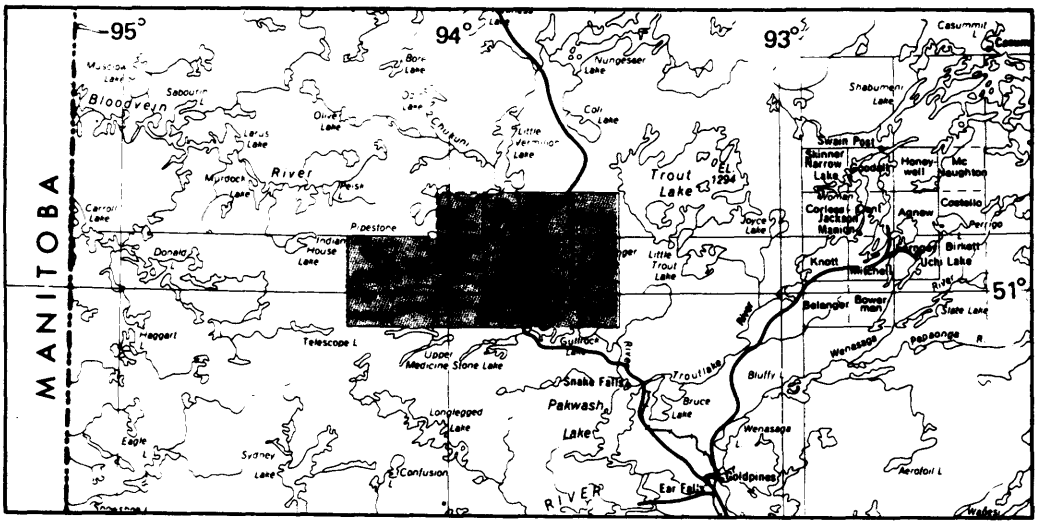
Recent exploration for gold deposits has been based upon models of syngenetic accumulations of gold. These models often incorporate later remobilization of the gold, regulated by structural processes which control the distribution of fractures and the flow of mineralizing fluids. To test these hypotheses, a regional study of deformation and fracture-controlled intrusion and mineralization was initiated in the Archean, Red Lake supracrustal belt. During the 1983 and 1984 field seasons, selected bedrock outcrops from across the 48 by 15 km belt were examined. The project was funded through grants received from the Natural Sciences and Engineering Research Council of Canada. Logistic support was provided by the Ontario Ministry of Natural Resources.

GENERAL GEOLOGY

The Red Lake belt comprises metamorphosed, ultramafic to felsic, volcanic and subvolcanic rocks and related chemical and clastic sedimentary rocks surrounded by, and in part intruded by, intermediate to felsic granitic rocks. For a summary of the history and geology of the area, the reader is referred to Pirie (1981).

STRUCTURAL GEOLOGY

Supracrustal rocks in the belt show evidence of 3 main periods of deformation. Ductile deformation dominated the earliest period and led to the development of preferred orientations of inequant minerals such as phyllosilicates and amphiboles and to the distortion of features such as pillows, varioles, amygdules, and clasts. Flattening foliations defined by the subparallel alignment of minerals are the most prevalent, penetrative structural element in all rock types. Less common, but no less widespread, are elongation lineations which lie within associated flattening planes.



LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

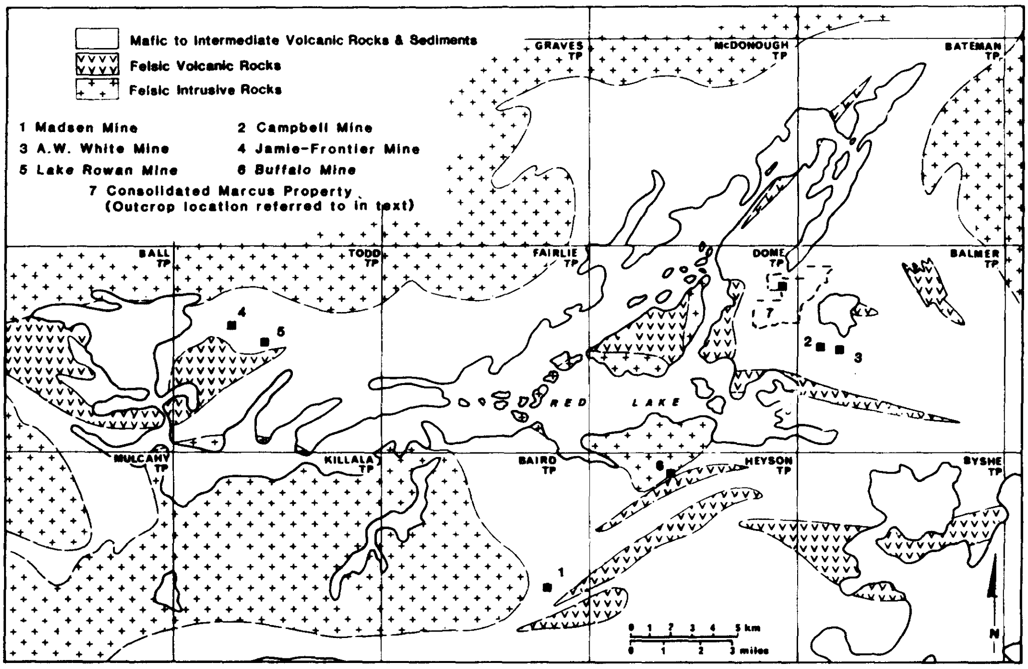


Figure 1. General geology of the Red Lake supracrustal belt. (Project 35.)

On a regional scale, flattening planes roughly parallel the contacts between the supracrustal rocks and the granitic rocks. Locally, variations in orientations of flattening and elongation reflect ductility contrasts between rock types or, at the smallest scales, between rock features or competent minerals. Flattening planes and elongation lineations commonly dip or plunge very steeply indicating that, during the first deformation period, axes of greatest shortening were near-horizontal and axes of greatest elongation were near-vertical.

Continuous with the first deformation period, the second period is a dominance of brittle-ductile to brittle deformation. Planar structural elements developed range from networks of relatively closely spaced, mineral foliations and shear fractures defining shear zones to more widely spaced shear fractures, or faults. Continued ductile deformation, though reduced in intensity, led to further flattening and to the rotation of shear planes towards the flattening planes. Throughout the belt, shear planes are rarely penetrative over widths of more than a few tens of centimetres.

Intersections of conjugate pairs of shear planes lie within, or close to flattening planes and most plunge at >45°. Corresponding mineral lineations within shear zones, and slickenside lineations on shear fracture surfaces plunge at <45°, indicating a predominance of strike-slip motion. Some intersections, however, plunge at much <45° and steeply plunging shear lineations demonstrate a predominance of reverse, dip-slip motion. During the second deformation period, therefore, all axes of greatest shortening and most axes of greatest elongation were near-horizontal.

Although some shear planes are now found to lie at <45° to axes of greatest shortening, most are oriented at >45° and thus at <45° to flattening planes. At the Marcus property (Figure 1), conjugate shear fractures lie at only 15° to a weakly developed flattening foliation in virtually undistorted, mafic pillows, showing that the fractures were not rotated by ductile deformation and therefore must have formed in approximately that orientation. To account for angles of <45°between shear and flattening planes, angles not predicted by current failure criteria, it is proposed that "failure envelopes" converge, but do not close, at high confining pressures. A mathematical analysis of stress, in which rocks are treated as fluids over geological intervals of time, leads to the prediction of a continuum of such envelopes for which the critical parameters are confining pressure, temperature, strain rate and rock composition.

Where planar rock anistropies lie at an angle to flattening planes (the angle was dependent upon the above mentioned parameters), shear planes were developed preferentially along those planes of weakness. For example, over large areas to the east and northeast of the Madsen Mine (Figure 1), shear planes commonly parallel bedding. Homogeneous portions of rocks in that area, however, typically display evidence of conjugate shear planes and ductile flattening. Observations made throughout the belt show clearly that the second deformation period involved a combination of ductile and brittle deformation. The existence of large, transcurrent 'deformation zones', characterized by a single sense of shear, as proposed for example by Durocher and Hugon (1983), is considered to be unlikely.

An analysis which takes into consideration the amount of work done during combined ductile and brittle deformation suggests that when shear planes form at an angle of >45° to the axis of greatest shortening, they may be expected to form in *en echelon* arrays (B.C. Wilson, work in progress). Although direct evidence of such arrays is not obvious in the Red Lake area, patterns of intrusion described below lend support to this hypothesis.

The third period of deformation, separated in time from the first 2, resulted in brittle, and a minor amount of brittle-ductile, deformation. Spaced shear fractures with no associated flattening foliations may be observed in all rock types, including the granitic rocks which surround and are internal to the "greenstone" belt. Intersections of conjugate shear fractures generally plunge steeply and slickenside lineations plunge at shallow angles, indicative of strike-slip motion and near-horizontal axes of greatest shortening, and elongation. Fractures commonly lie at <45° to axes of greatest shortening, which are consistently oriented approximately north throughout the area. As a consequence, southeast-trending shear fractures are predominantly right-handed and southwest-trending shear fractures are predominantly left-handed.

INTRUSIONS

Ultramafic to felsic dikes and a variety of veins intruded into fractures during the second deformation period. Few dikes or veins were emplaced in fractures lying perpendicular to flattening planes, the orientation expected for extension of "tension" fractures. Instead, intrusion took place and vein patterns: those emplaced along left-handed shear planes tend to step to the left along strike whereas those emplaced along right-handed shear planes tend to step to the right. Contacts of tabular bodies which are continuous across steps show intermittent offsets which, where steps are small relative to intrusion widths, give the appearance of isoclinal folding or interfingering with the country rock. Dikes and veins which are discontinuous across steps form *en echelon* arrays.

Shear movement along stepping planes produced, at each offset, dilatant zones which were particularly favourable loci of dike intrusion, vein formation and mineralization. Axes of steps, and thus of dilatant zones, parallel intersections of associated conjugate shear planes. Those intersections rarely plunge at exactly 90°, consequently, systematic offsets and *en echelon* patterns of dikes, veins and mineralization may be seen in both horizontal and vertical geological sections.

Throughout the area, the interrelationship between dike and vein cross-cutting, rotation, boudinaging, and folding is consistent with repeated cycles of deformation and intrusion within the second period of deformation with no significant reorientation of principal stress axes. Shear deformation is inferred to have occurred under conditions of increased stress, and intrusion under conditions of decreased stress. Flow into shear planes began as the component of compressive stress across fractures dropped below the pressure of the source fluid.

ECONOMIC GEOLOGY

In the Red Lake belt, 2 related styles of ore bodies occur in structures belonging to the second period of deformation. The most common type, which occurs in rocks that deformed in a brittle manner, resulted from the intrusion of mineralized veins along linear arrays of spaced fractures. A careful examination of the Campbell Red Lake, A.W. White, Jamie-Frontier, Lake Rowan and Buffalo properties (Figure 1) reveals that in these gold deposits both types of shear planes are about equally well developed. Gold-bearing veins, however, were commonly emplaced preferentially, though not exclusively, within 1 member of conjugate shear sets. This was most likely a product of slight reorientations of principal stress axes so that, at the time of dike and vein formation, the component of compressive stress across 1 member was greater than the component across the other. Veins were emplaced along the planes held closed by the lowest stresses.

Typical of this style are ore zones within greenschist facies, mafic rocks in the Campbell Red Lake and A.W. White Mines. For example, on the 19th level of the Campbell Red Lake Mine, most gold-bearing veins occur along left-handed shear planes in the F_2 Zone and along right-handed shear planes in the G and A zones. In the north L zone on that level, mineralized veins are about equally distributed between left- and right-handed shear planes. At the Jamie Frontier Mine, gold is present along quartz veins which intruded into southeast-trending, right-handed shear fractures. The best mining widths were restricted to a thickened, right-stepping offset in a vein. On the neighbouring Lake Rowan property, auriferous quartz veins were intruded in *en echelon* arrays along southwest-trending, left-handed shear fractures. On the Buffalo property, gold was found in southeast-trending, right-handed, *en echelon* quartz-tourmaline veins.

The second style of ore body was produced in brittle-ductile rocks by fluid flow localized within zones of dilatancy. Examples include ore zones within ultramafic rocks in the Campbell Red Lake Mine and within an amphibolite facies, mafic rocks in the A.W. White Mine. These zones are characterized by penetrative silicification, disseminated mineralization and very narrow, closely spaced veins. Unlike the vein-type ore bodies, mineralized zones may occur with long axes lying at high angles to flattening planes. Like the vein-type bodies, however, veinlets and ore comprising the mineralizing zone are arranged in patterns typical of emplacement along conjugate shear planes at <45° to flattening planes. The single most important factor in the development of dilatancy which resulted in these ore zones was commonly proximity to steps or "rolls" in the contacts.

SYNTHESIS

The first and second deformation periods are distinguished by changes from ductile to brittle-ductile deformation and from vertical to predominantly horizontal axes of greatest elongation. It is not possible, however, to define a single time which separates the 2 periods. The transition from ductile to brittle-ductile deformation was undoubtedly a slow, continuous process dominantly controlled by rock compositions and decreasing temperatures. The initiation of brittle-ductile deformation, and thus of dike and vein intrusion, must have occurred at different times in different rock types and must have followed migrating isotherms, in part, in directions perpendicular to the regional "granite-greenstone" contacts. Ductile deformaton probably coincided with the highest temperatures attained, consequently fracturing, intrusion of dikes and veins, and mineralization would have been contemporaneous with, and/or later than, the peak of regional metamorphism.

Orientations of fabrics formed during the first and the second deformation periods are consistent with horizontal compressive stresses directed perpendicular to the granite-greenstone contacts, suggesting that deformation was synchronous with the subsidence of the supracrustal rocks and rise of the granitic rocks. Shear fractures formed during the third deformation period are also consistent with horizontal compressive stresses but the uniform north orientation of axes of greatest shortening indicates that deformation must have been related to tectonic processes acting on a scale much larger than the Red Lake supracrustal belt.

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36. Structural Geology and Mineralization of the West Carbonate Zone, Cochenour Willans Gold Mine, Red Lake

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INTRODUCTION

The Cochenour Willans Gold Mine, situated in Dome Township, Red Lake Mining District, was in production from 1939 to 1975 and produced 1 131 000 ounces of gold from 2 million tons of ore. In 1979 the mine was dewatered and a major reassessment and exploration program was initiated by Wilanour Resources Limited.

The Carbonate Zone lies 550 m southwest of the main Cochenour shaft (Figure 1b). During the mid-1960s, this zone yielded 86 000 tons of ore averaging 0.351 ounce gold per ton, produced entirely from large, banded, ferroan-carbonate veins. The mineralization occurred in zones of breccia and cross-cutting quartz veins within the massive carbonate. These large carbonate bodies occur entirely within one specific, altered, deformed unit (dark lava) which, along with other components, comprises the West Carbonate Shear Zone (Sanborn 1983). This year, examination of extensive drillhole data, in conjunction with underground mapping, has led to further observations as to the geometry and orientation of the carbonate veins and their relationship to the principal structural features which characterise the West Carbonate Shear Zone.

WEST CARBONATE SHEAR ZONE

During the 1983 field season, a number of small scale structural features within the highly deformed region of the West Carbonate Zone were examined (Sanborn 1983) which indicate the presence of a shear zone characterized by low angle, thrust displacement. Detailed examination of small scale structures, together with examination of lithological types and relationships, enabled the definition of the West Carbonate Shear Zone as a continuous planar feature, striking 130° to 140° and dipping approximately 40° to the southwest. The highly deformed rock within the shear zone is dominated by a unit historically termed the 'granular altered formation', whose unique characteristics and origin are discussed in greater detail below. A less deformed sequence of highly carbonatized and silicified mafic flows, historically termed 'rhyolite X', forms the footwall to the 'granular altered formation' along its northeastern contact. A highly chloritized mafic unit, termed 'dark lavas', occur along the hanging wall contact.

The shear zone, averaging 30 m in width, dominantly comprises the 'granular altered formation', together with chlorite schist, the latter most likely derived from the 'dark lava' on the hanging wall (Figure 1b).

Additional important components of this zone include a system of felsic dikes and massive ferroan-carbonate veins.

FAULTING

Observations to date define the presence of 2 separate fault systems. The earliest, possibly coeval with the development of shearing, is manifested by the movement of large domains of rock. As such, the complete central region of the West Carbonate Zone has been laterally displaced to the northeast (050°). This faulting is evidenced by a consistent offset of lithological units observed in drillhole data recorded on 20-scale mine plans. A later system is defined by an extensive pattern of faults, which are characteristically subvertical and strike consistently at about 150°. These late faults cause vertical displacement of the shear zone and are therefore post-shear (Figure 1a). Chemical sedimentary rocks occurring in proximity to faulted areas of the shear zone are preferentially mineralized in cross-cutting quartz veins. This gold mineralization is, therefore, also post-shear.

GRANULAR ALTERED FORMATION

The characteristic texture and fabric of this highly strained carbonate-chlorite-sericite±talc schist enable it to be defined as a distinctive mappable unit. This unit is characterized by a strongly developed shear fabric (alignment of chlorite and sericite) which strikes 140° to 150° and dips steeply to the southwest. A commonly developed stretch lineation is developed along shear planes and is compatible with subvertical motion parallel to shear boundaries. A well developed banding, comprising quartz and carbonate segregations (millimetres in width), is apparent in sections perpendicular to the plane of flattening. Rotation of these bands pro-

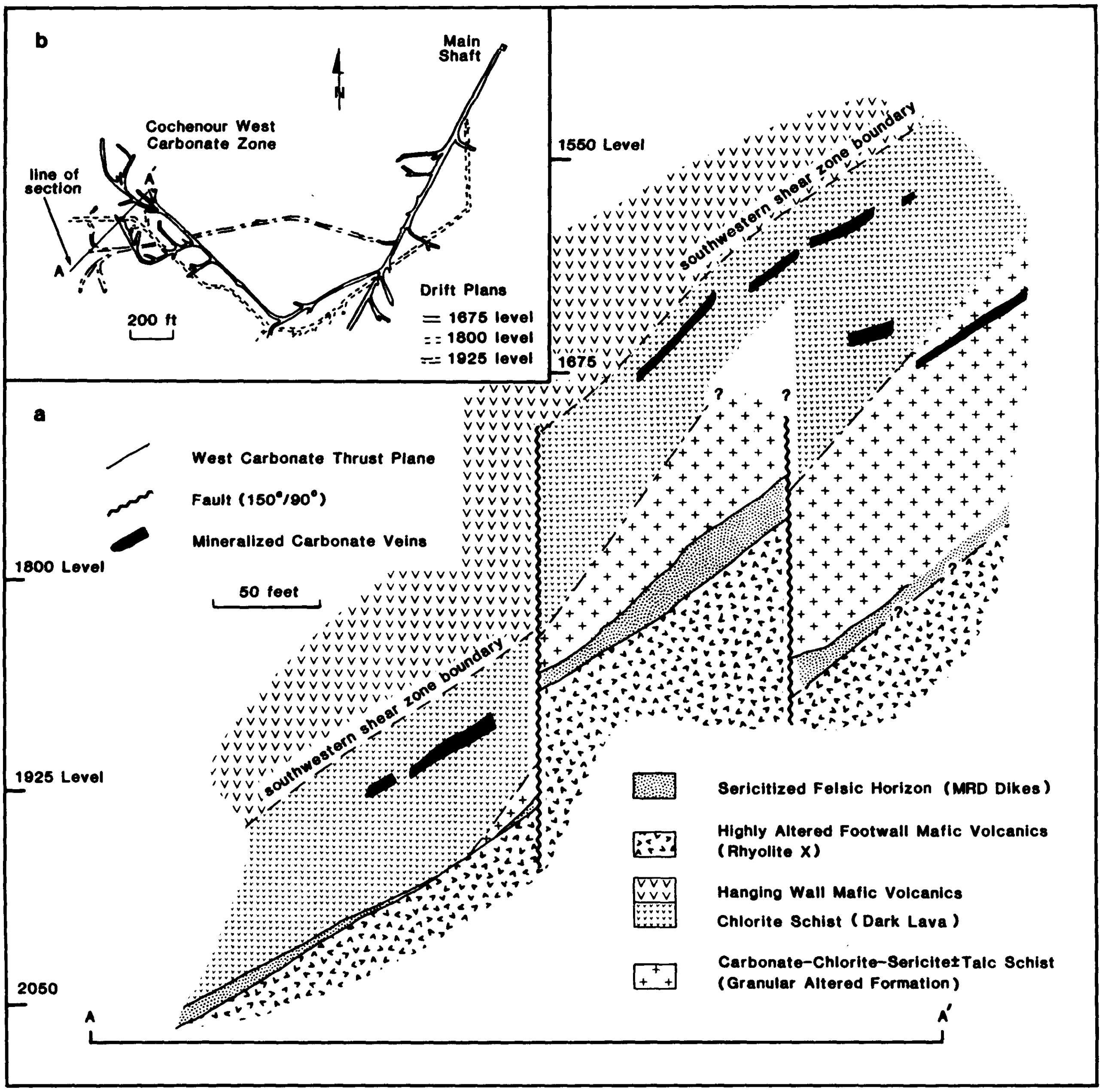

Figure 1. Cross-section of the West Carbonate Zone, Cochenour Willans Gold Mine. (Project 36.)

vides kinematic indications of a low angle, reverse sense of shear.

A limited number of chemical analyses suggest that the 'granular altered formation' and 'rhyolite X' are distinct lithologies, and originally ultramafic and mafic in composition, respectively (J. Pirie, District Geologist, Esso Minerals Limited, personal communication, 1984). The 'granular altered formation' is spatially correlatable with a northeast-trending ultramafic dike (the East Bay Serpentinite) prevalent in the eastern portion of the mine workings. Drillhole data confirm the presence of the East Bay Serpentinite in the southwestern section of the mine workings. The drillhole data, combined with the structural observations of this study, suggest that in the general area of the West Carbonate Zone, the East Bay Serpentinite has been transposed during shear deformation into a northwest-southwest disposition. Thus the 'granular altered formation' is interpreted to represent the highly altered and deformed product of the East Bay Serpentinite.

MOTTLED RHYOLITIC DIKES

A system of highly altered, felsic dikes, historically termed 'mottled rhyolite dikes' (MRDs), occurs along the West Carbonate Shear Zone. These laterally continuous, 1 to 10 m thick dikes are aphanitic (with occasional quartz-eyes) silica-rich (SiO_2 ~ 90% by weight) and exhibit intense, pervasive sericitization, rendering a waxy, whitish-buff appearance. With few exceptions, the MRDs occur in close spatial association with the shear zone and serve, in conjunction with late mafic dikes, to separate the 'granular altered formation' within the shear zone from the footwall mafic lithologies (Figure 1a). Where the 'granular altered formation' thins at depth in the extreme northwest of the mine workings, the disposition of the MRDs serves to outline the continuation of the shear zone.

In contrast to the surrounding rocks within the shear zone, the MRDs do not exhibit intense deformation (at maximum, a moderately developed space cleavage). This observation, combined with the close spatial association and alignment of these dikes with the West Carbonate Shear Zone, suggests that they post-date shearing, and were preferentially emplaced along this pre-existing structure.

FERROAN-CARBONATE VEINS

Large, banded, ferroan-carbonate veins occur within the West Carbonate Shear Zone, situated for the most part near the southwestern hanging wall contact and hosted predominantly by chlorite schist (originally 'dark lava'). Figure 1a illustrates the stoping areas along section AA' and the consistent nature of the carbonate vein structures, trending 160° and dipping approximately 30°SW.

The veins are generally 2 to 3 m in width but occur as elongate, often misaligned, segments down-dip (this pattern is reflected by the offset of stoping areas, which measure on the order of 2 to 30 m in length). This may be due to shear deformation and/or to the effect of late cross-cutting faults (trending 150°, dipping subvertical), which were described above, to offset and post-date shearing.

GOLD MINERALIZATION

In the West Carbonate Zone, gold mineralization occurs exclusively in the ferroan-carbonate veins. The carbonate veins are themselves barren and host gold only where they have been brecciated or cut by quartz veins. As such, they represent a preferred structural host. The mineralization is tentatively related to brittle deformation, post-dating shearing of which the late, cross-cutting faults are an expression. As described earlier, chemical sedimentary rocks occurring in proximity to the West Carbonate Zone are preferentially mineralized (in quartz veins) where they occur in close spatial association with the late, post-shear faults. The 'granular altered formation' is mineralized in other areas of the mine but not in the West Carbonate Zone.

SUMMARY

The observations to date may be used to propose the following sequence of events which affected the West Carbonate Zone of the Cochenour Mine:

1. Extrusion of the volcanic flow units
2. Intrusion of the East Bay Peridotite
3. Generation of the West Carbonate Shear Zone, possibly coeval with large scale block faulting
4. Formation of massive ferroan-carbonate veins, pre- or syn-shearing
5. Intrusion of 'mottled rhyolite dikes'
6. Brittle deformation and generation of the late cross-cutting faults
7. Gold mineralization.

The relationships between these events and alteration processes are complex and not yet defined.

Continued study will include petrographic and geochemical studies to help elucidate the complex relationships between lithology, alteration, structure, and mineralization, and the relative timing of events in the West Carbonate Zone.

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S37. The Structural and Stratigraphic Control of Gold in the Lake of the Woods Area

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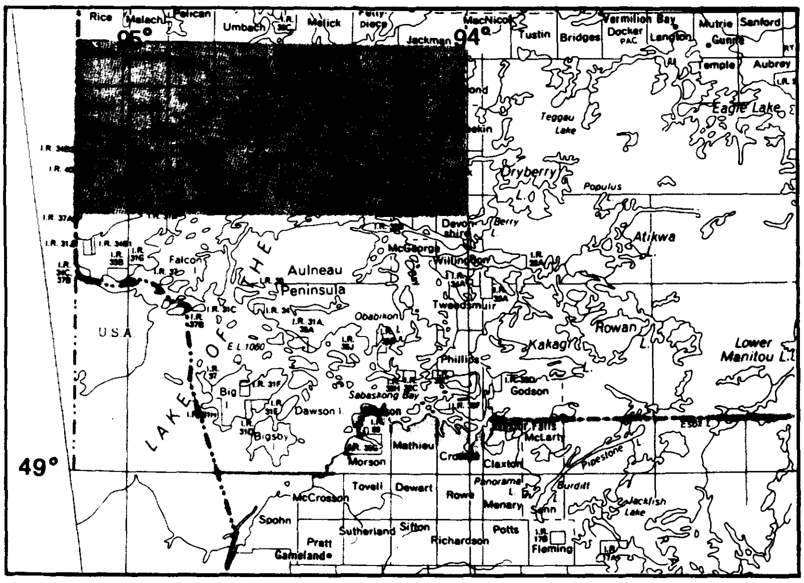
This project was funded equally by the governments of Canada and Ontario under the Northern Ontario Rural Development Agreement (NORDA).

INTRODUCTION

The gold potential of the Lake of the Woods area was the focus of much attention during the 1890s. From the numerous properties where gold was reported, several mines were developed and significant gold production was realized. By 1907 virtually all production had ceased, but the old workings were periodically reexamined and a number of gold-mining operations were recorded during the 1930s and 1940s.

In 1982 the results of drilling at the Shoal Lake Property of Consolidated Professor Mines Limited, and at the Cameron Lake Property of Nuinsco Mines Limited, once more focused attention on the old gold occurrences at the Lake of the Woods. Widespread staking took place in the latter part of 1982 and the first half of 1983. Partially in response to this activity, a 2-year program of field and laboratory study was initiated in order to document the structural, chemical, and stratigraphic controls on gold mineralization in the area.

The work to date has shown that the majority of the gold occurrences are in a lower sequence of tholeiitic basalts and that the more important past producers of gold are located near the top of that sequence and are associated with fault or shear zones. The following summarizes, by subarea (Figure 1), the results of the program.



LOCATION MAP Scale : 1 : 548 000 or 1 inch to 25 miles

HIGH LAKE

Tholeiitic basalts at High Lake (Figure 2) were intruded by massive to porphyritic granodiorite and by quartz-feldspar porphyry dikes (Davies 1965). Coincident with the onset of felsic volcanism, a significant but possibly local unconformity was developed and conglomerate, sandstone, wacke, and chert were deposited. The overlying intermediate to felsic flows, pyroclastic rocks, and basaltic flows, in general, young to the northeast. Folding is well developed in the sedimentary and overlying rocks, and strong foliation occurs on fold limbs and adjacent to the numerous east-trending shears or faults. Some folding developed as a result of differential movement along close-spaced slip planes which obliquely crossed primary bedding.

Gold mineralization is largely restricted to fractures in the porphyritic granodiorite and porphyry dikes and to the adjacent basalt, e.g. Electrum Lake Occurrences. This is interpreted to be due to brittle deformation in the granodiorite, in contrast to ductile deformation in the younger rocks; the brittly deformed rocks provided better conduits for hydrothermal fluid flow. The basaltic roof pendants in the granodiorite are locally more magnetic at their contacts. The fractures are

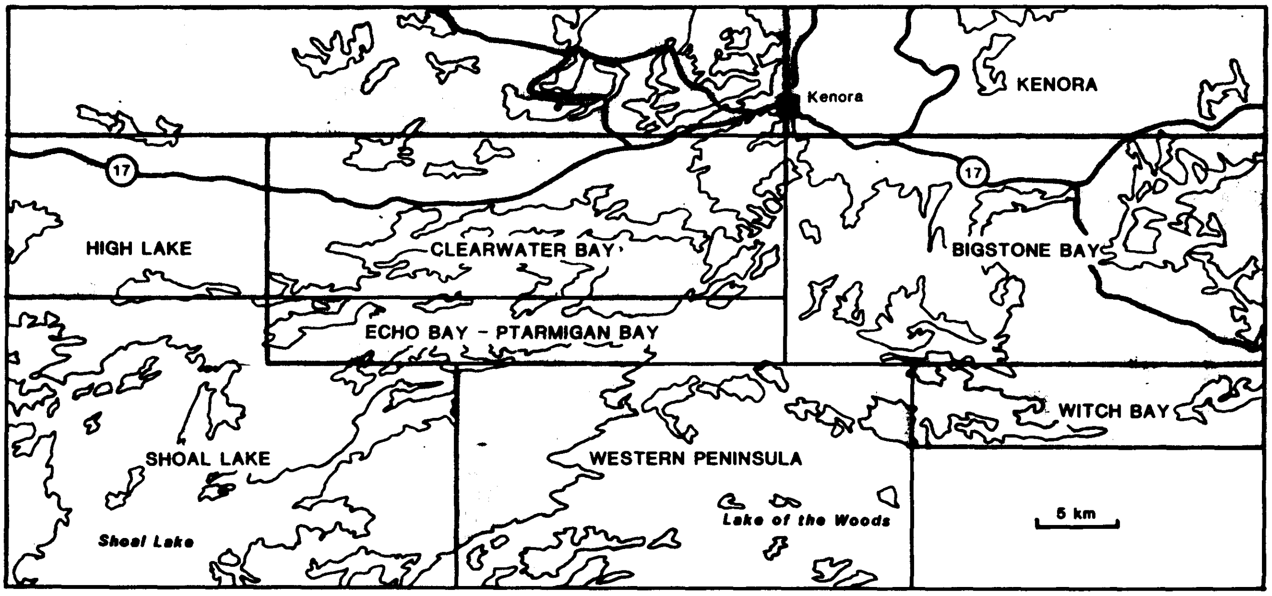


Figure 1. Location map, showing subareas discussed in text. (Project S37.)

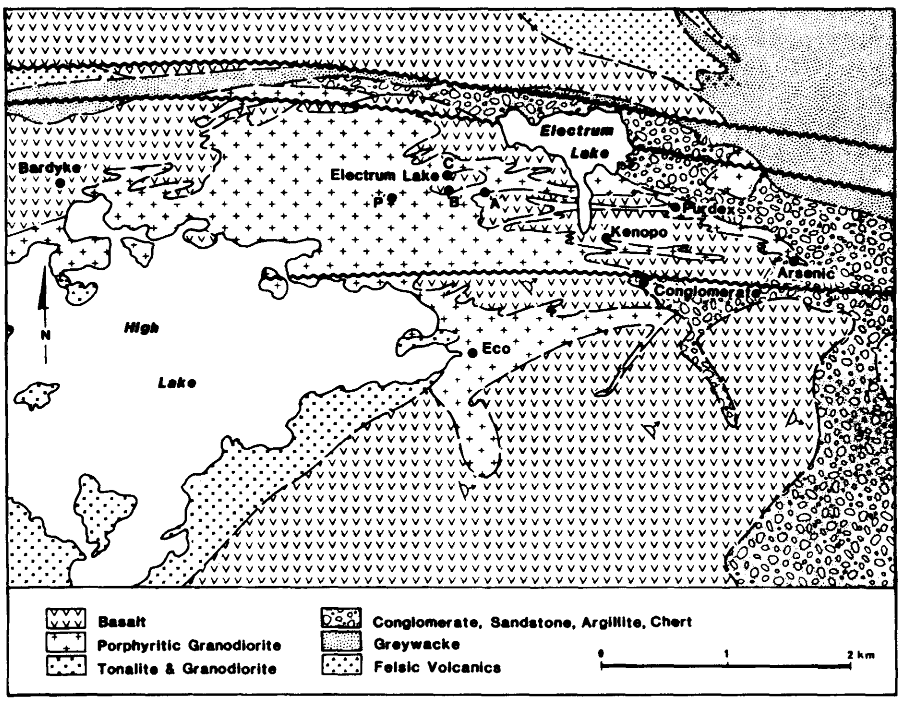


Figure 2. Geology of the High Lake area. (Project S37.)

siliceous and contain pyrite and chalcopyrite and, at the Eco Occurrence, molybdenite with the gold. Gold is also present in quartz which filled open fractures in places where there was competency contrast adjacent to shear zones (e.g. Kenopo and Purdex Occurrences), including the Conglomerate Occurrence in the basal sedimentary rock, where it is surrounded on 3 sides by basalt.

SHOAL LAKE

At Shoal Lake (Figure 3), a lower sequence of tholeiitic basalts, interlayered with coarser mafic and ultramafic sills and minor komatiitic flows, is overlain by calc-alkaline, intermediate to felsic pyroclastic rocks with some volcanic sedimentary rocks and minor mafic flows. These are overlain by an upper sequence of mafic flows with minor felsic volcanic rocks. A thick sill-like body, the Stevens Island Diorite, lies near the top of, and intrudes the tholeiitic basalt sequence.

The Canoe Lake quartz diorite stock, which lies at the northeastern end of Shoal Lake, terminates to the southwest against the tholeiitic basalts. It is mostly saussuritized and chloritized and is strongly sheared in places. The Snowshoe granodiorite, the eastern nose of which intruded the intermediate to felsic volcanic rocks, is fresher and is exposed in the west central part of the lake. Smaller granodiorite stocks are also present, and dikes of felsite or fine-grained granodiorite are numerous.

The Gull Bay-Bag Bay anticline extends southwest from the Canoe Lake stock. The thickness of northwest-facing volcanic rocks is estimated to be about 7000 m.

The regionally dominant east-northeast foliation direction bends east as the Crowduck Lake-Rush Bay dextral fault zone is approached. Within a "shadow zone" southwest of the Canoe Lake stock, the mafic volcanic rocks are not foliated, but a series of east- to east-southeast-trending faults with a large vertical component of movement has offset the volcanic stratigraphy (Davies 1978). These faults probably formed during emplacement of the Canoe Lake stock. Faults with vertical displacement have also been interpreted to coincide with the northern and southern contacts of the Snowshoe pluton. Some faults parallel to volcanic stratigraphy are attributed to emplacement of the Snowshoe pluton.

Most of the gold occurrences are in the tholeiitic basalt sequence. Those associated with the east-southeast trending faults typically consist of a chloritic shear zone 1 to 6 m wide in which a felsite dike was emplaced. Quartz veins or lenses are discontinuous and most are accompanied by pyrite and traces of base-metal sulphides and rare visible gold. Many of the quartz-rich zones may be traced for over 100 m, but the gold content is low; some gold was produced at the Cedar Island and Olympia Mines from fractures of this type.

South-southeasterly trending fractures developed at the margin of the Canoe Lake stock following its intrusion. At the Mikado Mine, 2 parallel fractures, which trend 150° and dip steeply northeast, cut across a thick dike of quartz diorite which dips 30° south (Davies 1978). The No. 1 vein is in the western fracture and consists of a well-defined vein up to 150 cm thick where it passes through the quartz diorite, and a zone of quartz stringers where it passes through basalt. The quartz contained abundant sulphides (pyrite, chalcopyrite, bismuthinite, tetradymite, and molybdenite); the gold is present as grains and fine fracture fillings associated with the sulphides, and the gold content is reported to be higher where the host rock is basalt. Felsite is present in places. Conditions were similar at the No. 2 vein along the eastern fracture, but little production was recorded here.

Fault and shear zones parallel to the volcanic lithology are mostly narrow, and quartz veining within them is similarly narrow and discontinuous. The northeast trending fault that is the host to ore zones at the Duport Mine is much wider and is here interpreted to have formed during intrusion of the Snowshoe pluton. The gold mineralization at the Duport Mine is presently being evaluated (Smith, this volume).

ECHO BAY AND PTARMIGAN BAY

No recent systematic mapping of the Echo Bay-Ptarmigan Bay area has been carried out, but it is probable, on the basis of strike continuity, that the basalts and felsic volcanic rocks are mostly equivalent to the upper volcanic sequence at Shoal Lake.

The dominant structural feature of the area is the Crowduck Lake-Rush Bay fault zone (Figure 3) in which the volcanic rocks are locally strongly to intensely foliated.

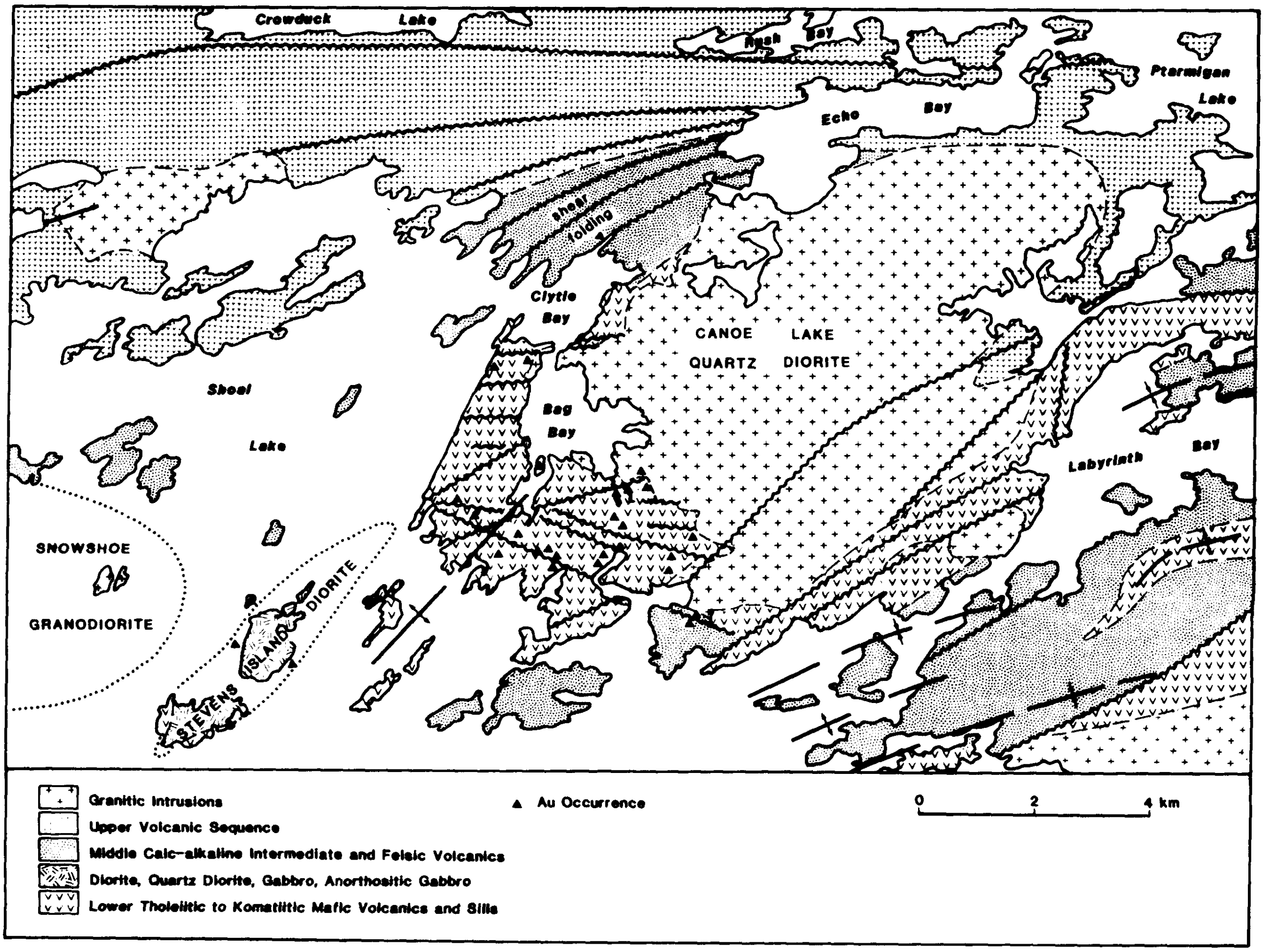


Figure 3. Geology of the Shoal Lake, and Echo Bay-Ptarmigan Bay areas. (Project S37.)

Carbonate is abundant, but only in a few places is there evidence for much mobilization of silica. Within the fault zone at Echo Bay, gabbroic dikes or sills have resisted shearing resulting in topographic highs.

A number of gold occurrences are known along the fault zone. At Rush Bay, the Golden Horn Occurrence consists of thin quartz veinlets in irregular fractures in strongly foliated felsic pyroclastic rocks. Adjacent to the fractures, sulphides in the felsic rock are accompanied by gold. Near the eastern end of Echo Bay, felsic volcanic rocks have, in part, been deformed to blue-grey schists which contain weakly disseminated pyrite and rare pyrite-bearing veins and veinlets. The gold content of the schists is mostly low, but erratic higher values have been obtained. Similar gold-bearing schists are present at the Nor-Penn Occurrence near the southern shore of Northern Peninsula at the eastern extremity of Ptarmigan Bay, which is on the probable extension of the Crowduck Lake-Rush Bay fault zone.

East trending auriferous quartz veins in basalt also occur north of the blue-grey schists at Echo Bay, and in basalt marginal to the Canoe Lake stock near the southern shore of Echo Bay.

CLEARWATER BAY

In the Clearwater Bay area, intermediate to felsic pyroclastic rocks predominate and are interlayered with basalt and overlain by fine clastic sedimentary rocks (Thomson 1937). An east-striking synclinal axis lies along the Bay, and well developed foliation trends within 30° of east. In places, bedding is at a high angle to foliation and small-scale features indicate that the area has undergone some shear folding.

A number of quartz porphyry dikes trend generally east, possibly marking zones of shearing in both the mafic and intermediate volcanic rocks. Quartz veins are mainly in areas of intermediate lapilli tuff and tuff-breccia, especially in the vicinity of the former Kenricia Mine. Typically, the veins are nearly parallel to foliation and consist of sugary quartz with carbonate, minor sulphides, and tourmaline. Sulphides are also present in the wall rocks. Thomson (1937) reported that, at the Kenricia Mine, the sulphides include pyrite, chalcopyrite, and galena, and that gold is present as fine grains and veinlets. He recognized 3 phases of quartz, the gold being associated with the tourmaline-bearing second phase.

WESTERN PENINSULA AND CENTRAL LAKE OF THE WOODS

Most of the volcanic rocks of the Western Peninsula, and of the islands of the Lake of the Woods to the east, are characterized by well developed foliation and, in places, by widespread carbonatization. Lenses of more massive rocks are present in what appears to be a very broad zone of deformation. As this zone narrows to the east, it may be represented in part by the Pipestone-Cameron Fault.

Within this area the known gold occurrences are associated with east trending dikes of porphyry or felsite or with small (synvolcanic?) intrusions of syenitic or granitic composition. Local fracturing of these rocks has been accompanied by sulphide formation at fracture edges and by silica flooding. At Gull Island and at the Florence Occurrence, distinct quartz veins are present in and adjacent to fractured porphyry and contain sulphides and visible gold. At Bath Island the veins are narrow and discontinuous. At the Gold Mountain Occurrence both the fractured syenite and the enclosing schists are carbonatized and gold is associated with galena in quartz-filled fractures. At the Norah Occurrence the fractured felsite lies in a zone of carbonatized basalt, and at the Sentinel Occurrence mineralization is restricted to a few fracture zones in relatively unaltered granite.

The above observations suggest that the foliated volcanic rocks of this area were relatively impermeable to silica-bearing mineralizing fluids and that potentially favourable hosts are those which deformed brittly.

KENORA

A wedge-shaped area of volcanic and sedimentary rocks extends northeast from the main body of supracrustal rocks in the vicinity of Kenora (Figure 4). Gneisses of the English River Subprovince lie to the northwest, and the Long Tent Bay and Island Lake granitoid stocks, which may be related to the Dryberry batholith, lie to the east (King 1983). The stratigraphy may be divided into lower tholeiitic basalts and overlying intermediate to felsic pyroclastic rocks, which are capped by fine clastic sedimentary rocks.

A gabbroic sill up to 400 m thick, with melanogabbro to peridotite on the northwestern

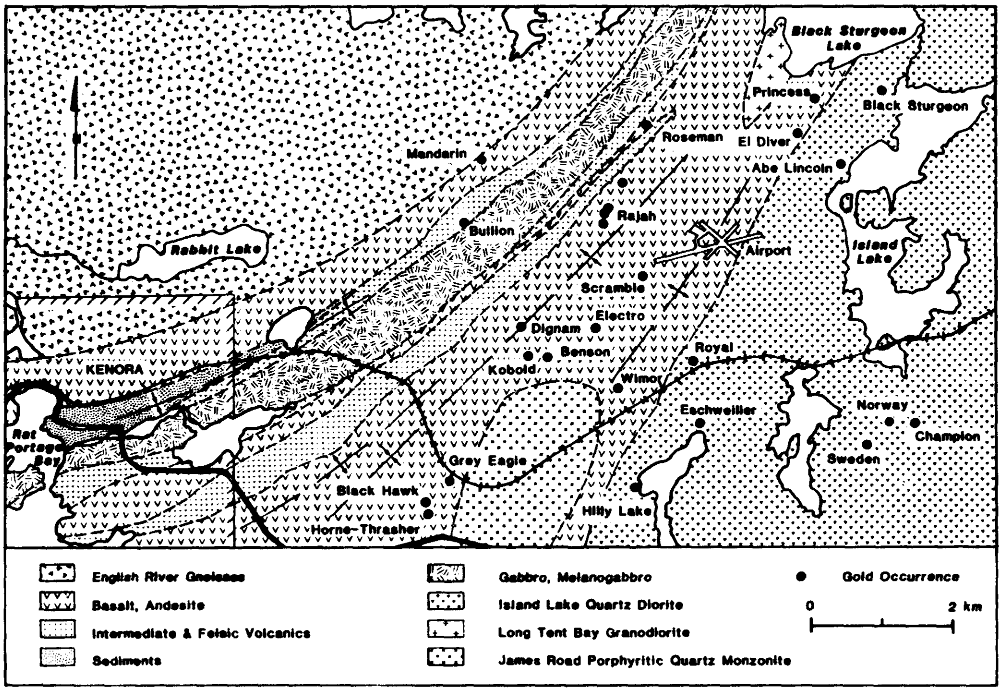


Figure 4. Geology of the Kenora area. (Project S37.)

side, lies near the basalt-pyroclastic rock transition. Pillowed basalt near the southeastern side faces northwest, so that the sill appears to be reversed, with the more mafic portion toward the top. Alternatively, the sill may represent a multiple intrusion or its southeastern contact may be faulted.

An oval stock of porphyritic quartz monzonite occurs along the axial trace of the Airport anticline. Felsite dikes are locally abundant and some show evidence of rotation by shearing into the plane of foliation.

The principal direction of faulting, the weak to strong foliation, and the trace of fold axes are all approximately parallel to wedge boundaries and converge to the northeast. At the northwestern side of the wedge mafic rocks display metamorphic layering but elsewhere primary features are preserved.

Only one of the gold occurrences, the Bullion, lies within the intermediate pyroclastic rocks. Here, gold was apparently associated with a quartz vein which is parallel to foliation. The remaining volcanic-hosted gold occurrences are in basalt and are associated with quartz veins or silicified shears. The mineralized zones trend northeast and are interpreted to be related to movement along near-vertical axial planar shears. Tourmaline and minor sulphides are associated with most veins; chlorite, biotite, carbonate, and sulphides are common in the sheared basalt. Felsite dikes occur in some shear zones and have been fractured and weakly mineralized.

Gold occurrences in the Island Lake diorite-quartz diorite stock are associated with shearing. Most of the mineralization is in or near quartz veins which occupy zones of dilatancy. Gold is associated with pyrite, especially along minor fractures in the vein and diorite. Dike-like bodies of ultramylonite lie close to mineralized and silicified shears at 2 of the occurrences.

During the summer, surface work was carried out at the Scramble Occurrence by Boise Cascade Canada, Limited, the property owners. A magnetometer survey indicated a weak magnetic high over a northeast-trending zone of strong shearing. At the old shaft site, surface stripping has revealed that an irregular felsite dike is enclosed by sheared basalt and that the basalt is locally silica-rich. Pyrite, chlorite, biotite, and carbonate are common in the sheared rocks, and in the immediate shaft area all of the sheared rocks contain minor gold. Non-auriferous quartz-tourmaline veins occur in the felsite but are oriented parallel to axial planar foliation and at a small angle to felsite contacts. Brittle deformation of more competent rocks adjacent to a strong northeasterly shear provided a conduit for gold-bearing hydrothermal solutions.

BIGSTONE BAY

Tholeiitic basalts with an estimated thickness of 8000 m underlie Bigstone Bay and are broadly folded about the Hay Island antiform (Ayer, this volume). Mafic and ultramafic sills or flows, which lie near the top of the sequence, are exposed on the southern limb of the fold and on the northwestern limb near the fold nose. The mafic rocks are overlain by intermediate to felsic pyroclastic rocks and flows which lie in a syncline that appears to have been folded about the Hay Island antiform.

Granodiorite of the Dryberry batholith occupies the core of the antiform; the intruded basalts typically show little change in texture or grain size adjacent to the contact. The Quarry Island stock, which intruded the top of the basalt sequence, similarly shows no contact effects; it consists of medium-grained quartz diorite with a central core of porphyritic granite in the northeastern part of Quarry Island and western part of Sultana Island.

The Hay Island antiform and Sultana syncline are the major structural features of the area. Abrupt termination of the mafic and ultramafic sills northwest of Hay Island may be due to faulting parallel to the east-southeasterly fault zone mapped by Ayer (J.A. Ayer, Geologist, Ontario Geological Survey, personal communication, 1984) near the southern side of Hay Island. Most minor faults or shears are parallel to the limbs of the antiform and locally extend into the granodiorite.

On the northwestern limb of the antiform, virtually all of the gold occurrences are associated with shear zones parallel to volcanic stratigraphy. Quartz veins with pyrite, many of which contain tourmaline, typically pinch and swell or occur as *en echelon* lenses in the chlorite schists. Visible gold is erratically distributed in the quartz. On the southern limb the volcanic rocks vary in strike, especially near the granodiorite contact. In the southeastern part of Bigstone Bay and extending east to the Islet Lake area, several east-southeast-trending shears dip steeply south and show evidence of reverse slip; the shears are carbonatized and contain pyrite and narrow auriferous quartz veins.

Several old workings are in silicified and carbonatized shears which are parallel to foliation in the intermediate pyroclastic rocks. At Middle Island a shaft was sunk on a strongly carbonatized zone in which gold is associated with galena.

The only important gold production in the Bigstone Bay area was at the Sultana Mine on the western side of Sultana Island, which operated from 1891 to 1906. Gold-bearing veins hosted by sheared quartz diorite and porphyritic granite of the Quarry Island stock were reported to have been most productive at the contact between the 2 intrusive rocks (Resident Geologist Files, Ontario Ministry of Natural Resources, Kenora). A geological summary based on surface observations and underground plans was prepared by Bruce (1926).

At the northern edge of Sultana Island the basalts are sulphide-rich and overlain by cherty sedimentary rocks and by intermediate to felsic pyroclastic rocks and flows. The sulphidic zone is parallel to bedding in the overlying rocks and may mark an unconformity or a fault, or both. The contact of the zone with the Quarry Island stock is not exposed.

Within the stock the main mineralized shear zones, and secondary foliation in less-deformed rocks, strike about 010°. In a few places this foliation is dextrally offset by minor northeast-striking shears. Most of the veins in the main zones were generally parallel to the 010° shears, but the Crown Reef, about 230 m south of the main shaft, was broadly S-shaped in plan, dipped steeply north and cut across foliation. At the Ophir Mine, a further 500 m south, a gold-bearing quartz vein strikes 045°, dips steeply north, and decreases in width northeastward. Both the Crown Reef and Ophir vein are interpreted to be quartz-filled tension features produced by sinistral movement.

WITCH BAY

Pillowed and massive tholeiitic basalts in the Witch Bay area were intruded by layered sills of peridotite to leucogabbro, and the sequence has been folded about east trending axes (Figure 5). Intermediate and felsic volcanic rocks overlie the mafic rocks and are exposed at Witch Bay. Granodiorite of the Dryberry batholith is 2 km

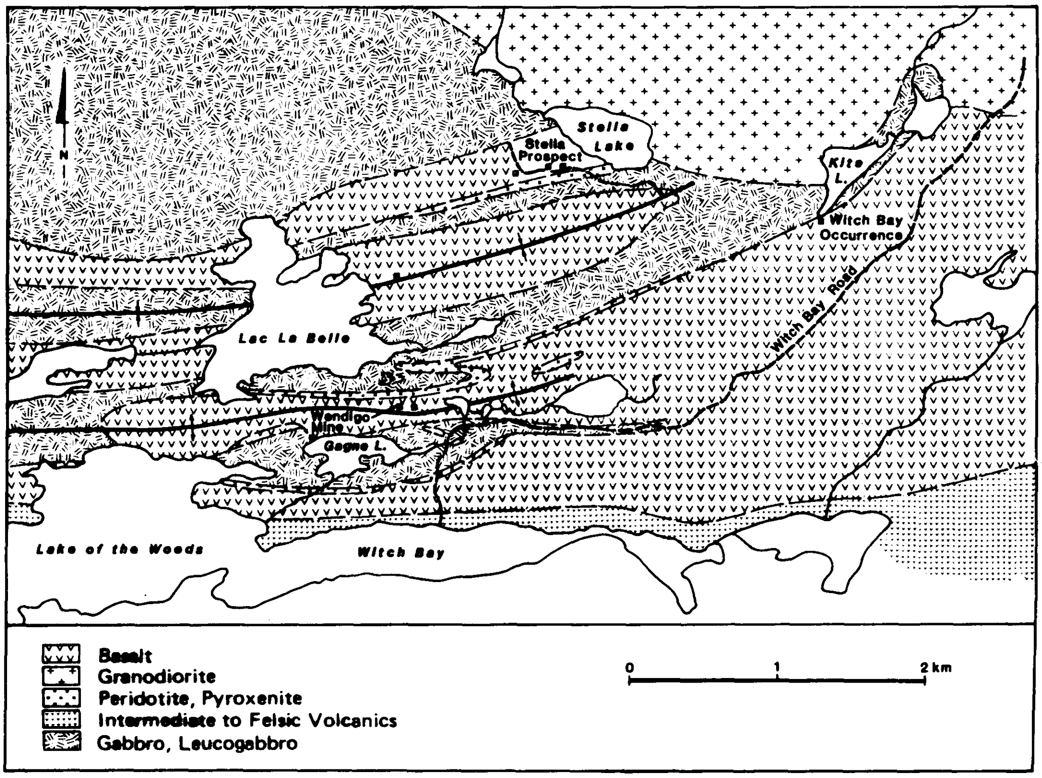


Figure 5. Geology of the Witch Bay area. (Project S37.)

north of Witch Bay, and the Viola Lake granitic stock lies about the same distance south of Witch Bay.

Gold occurrences are in carbonatized shear zones in basalt. The gold is hosted by silicified and pyritiferous schist or by quartz veins containing up to 20% sulphides. At the Wendigo Mine and Stella Occurrence, the mineralized shears lie stratigraphically below the peridotitic base of a sill. The Witch Bay Occurrence is at the same stratigraphic horizon. The shearing is believed to be related to competency contrast between the basalt and the sill.

The main quartz vein at the Wendigo Mine is in a carbonatized chloritic shear zone which strikes 080° and dips steeply north. The vein was up to 75 cm wide but averaged 30 cm, and contained up to 50% sulphides (pyrite, pyrrhotite, and chalcopyrite) as stringers and small masses which were more concentrated at vein edges. Sulphide mineralization, in lenses and streaks, was common in the chloritic schist wall rocks. Below the 335 m level, there was a marked increase in the pyrrhotite to pyrite ratio and a corresponding decrease in the gold content (Brownell 1943).

CONCLUSIONS

Work carried out during 1983 and 1984 permits the following conclusions to be made with respect to the gold occurrences in the Lake of the Woods area:

1. The majority of gold occurrences are in tholeiitic basalts which were extruded prior to any significant felsic volcanism.
2. The most important past producers are near the top of this tholeiitic sequence where preliminary data indicate a higher iron to magnesium ratio. Gold at the Sultana Mine is in sheared granite, but the enclosing basalts are at the top of the mafic sequence.
3. All of the occurrences are associated with fault or shear zones, and most of the gold production has come from shears which are nearly parallel to stratigraphy of the host volcanic rocks.
4. The hydrothermal solutions responsible for gold mineralization were rich in silica and carbon dioxide and either enriched or depleted in sulphur, potassium, and boron. Shear zones which acted as conduits for the solutions are typically silicified and contain veins and lenses of quartz. The quartz contains sulphides and tour-

maline and the host schists have been partly replaced by sulphides and biotite.

5. Gold may have been carried as a sulphur complex in the hydrothermal solutions, and its precipitation may have been enhanced by combining sulphur with iron. Thus, the more iron-rich basalts may have been the preferred site for gold deposition.

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S38. The Geological Setting of the Duport Mine, Cameron Island, Shoal Lake

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This project was funded equally by the governments of Canada and Ontario under the Northern Ontario Rural Development Agreement (NORDA).

INTRODUCTION

Originally discovered in 1896, the Duport Mine has been explored and developed several times during the past 88 years. Total production to 1936 was approximately 4500 ounces of gold and 1150 ounces of silver. Extensive surface diamond drilling since then has indicated additional reserves, which are now estimated at 1 927 000 tons grading 0.30 ounce gold per ton over 9.75 feet (Northern Miner, October 13, 1983). At present the property is being evaluated by Consolidated Professor Mines Limited and Union Carbide Canada Limited. An 1185 m decline has been driven to intersect the 2 main mineralized zones and is continuing to greater depth. The zones are being explored by drifting, raising, and underground diamond drilling.

Previous workers have suggested both stratiform and structural models to explain gold mineralization at the Duport Mine. Thomson (1936) interpreted the mineralization to be hosted within sheared diorite, which was replaced by silica and sulphides. Blackburn and Janes (1983, p.196) indicated that gold mineralization is in felsic tuffs. They state "it appears likely that the felsic tuff units acted as a favourable, sheared host for gold-bearing solutions. It is also possible that the gold in these felsic units is syngenetic". In order to resolve these divergent views, the Ontario Geological Survey initiated, in July 1984, a study on the style and controls of gold mineralization within the Duport Mine. To date, this study has concentrated on detailed underground mapping and relogging of critical diamond-drill core.

REGIONAL GEOLOGY

The volcanic stratigraphy within the area may be divided into a "Lower Komatiitic-Tholeiitic Series" (LKTS) and an "Upper Calc-alkaline Series" (UCS). The LKTS is characterized by Mg and Fe-rich tholeiitic basaltic flows, komatiitic basaltic flows, and peridotitic flows/sills. A feldspar-phyric basaltic flow has been identified in the mine area, and may prove to be a marker horizon. The UCS consists of fine-grained felsic tuffs and tuff breccias, and andesitic flows and tuffs.

The orebodies are hosted by the LKTS along the western limb of the northeast-trending Gull Bay-Bag Bay anticline, and lie several hundred metres east of the UCS contact. Northwest-facing, weakly deformed pillows have been recognized within the new workings, consistent with the regional anticline. A lens of bedded chert-sulphide iron formation strikes 060° and dips about 75° northwest.

The volcanic rocks of Shoal Lake have been intruded by a granite batholith, several granitic stocks, and by numerous felsic and mafic dikes. The Stevens Island intrusion lies directly east of the ore zones, and ranges in composition from diorite to anorthositic gabbro. The intrusion may be a thick, differentiated, stratabound, subvolcanic sill. The Snowshoe granodiorite batholith lies about 1.5 km west of the ore zones and extends west across the Ontario-Manitoba border. Mafic and felsic dikes intrude both the volcanic rocks and the Stevens Island intrusion. Locally, mafic dikes cross-cut felsic dikes, and are interpreted to be the last intrusive event. Both types of dikes are more common within zones of greater deformation and they trend both parallel and oblique to schistosity.

Regional metamorphism appears to be lower-greenschist facies. In the immediate mine area the metamorphic assemblage is indicative of upper greenschist to lower amphibolite facies; however, close to the ore zones a lower greenschist assemblage is present.

GEOLOGY OF THE ORE ZONES

Both the previous diamond-drill holes and the current underground development intersected rocks, consisting primarily of metabasalt, pyroxenite, and varieties of chlorite schist; these units are strongly deformed and altered over substantial widths. Lithologies close to the ore zone are anomalously rich in chlorite, sericite, biotite, epidote, carbonate, and magnetite; the ore zones themselves are quartz and sulphide rich.

The 2 main ore zones, the East and Main Zones, lie within a zone which records relatively intense deformation, defined here as the Duport De-

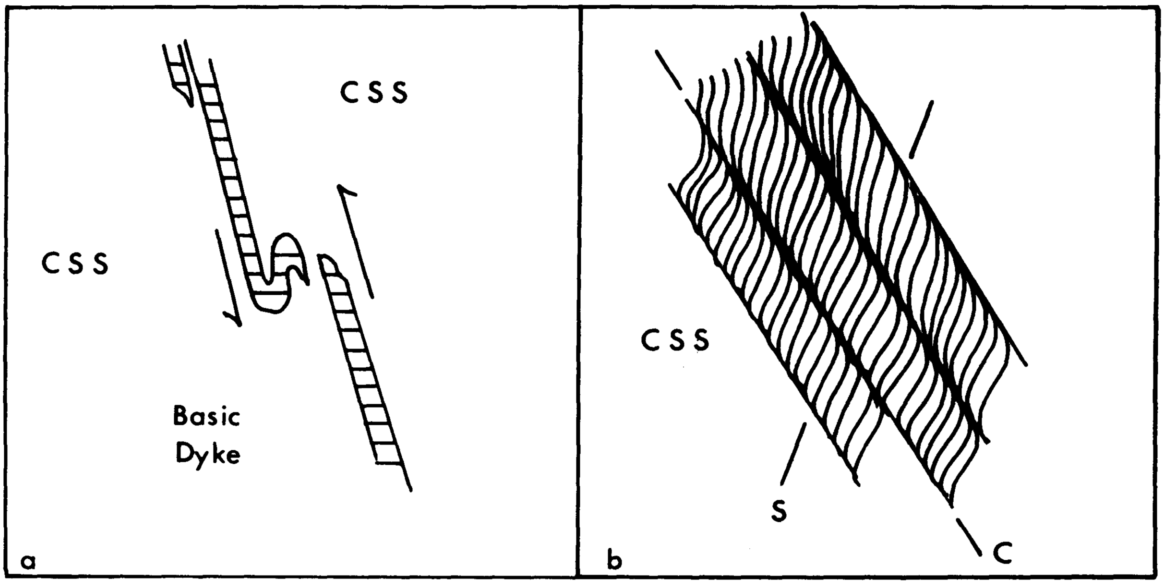

Figure 1. (a) Schematic drag folding of a basic dike hosted by chlorite-sericite schist (CSS), indicates reverse movement; (b) well-developed C and S fabrics, indicate reverse movement, dip is not accurate. (Project S38.)

formation Zone (DDZ). The DDZ is a reverse fault system, several hundred metres wide, trending approximately 035° and dipping about 75° northwest with unknown strike continuity. Reverse movement is indicated by numerous small-scale structural features (Figure 1). Drag folding is evident in a number of places, and is consistent with reverse movement. Well developed "C" and "S" fabrics have been recognized within the chlorite-sericite schist, the geometry of which also supports reverse movement.

From east to west, the deformation zone is characterized by chlorite-sericite schist and/or chlorite-talc schist and amphibolite, grading to zones of chlorite-actinolite-sericite schist, and finally to basaltic breccia.

The Main Zone is hosted principally by basaltic breccia, and to a lesser extent by actinolite-chlorite-sericite schist, amphibolite and porphyritic basalt. Located close to the western boundary of the DDZ, the Main Zone is characterized by both ductile and brittle deformation. The basaltic breccia contains angular to subangular basaltic fragments which range from several millimetres to tens of centimetres. Pervasive development of chlorite locally masks the fragment contacts and also the primary textures within the fragments. Chlorite development in the matrix is typically more intense than in the fragments. Feldspar phenocrysts, similar to those within the feldspar-phyric basalt, have been recognized within weakly altered breccia fragments, suggesting that the heterolithic breccia may be tectonic rather than pyroclastic. Proximal to the Main Zone, magnetite occurs at fragment margins, and the entire breccia zone, extending at least 50 m into the hanging wall, is weakly to strongly magnetic. Biotite development is spotty throughout the breccia, but it is strong to pervasive approaching the Main Zone. Abundant carbonate, commonly associated with gold occurrences within the western Wabigoon Subprovince, is noticably absent in the Duport Mine, although fractures in massive to brecciated basalts common on the hanging-wall side of the Main Zone, and to a lesser extent on the foot-wall side, are carbonate filled.

Gold is hosted by well developed quartz- and sulphide-rich zones. It appears to have a strong association with arsenopyrite, both in solid solution as noted by Thomson (1936), and also as free gold encrusted along grain boundaries. Free gold is also found

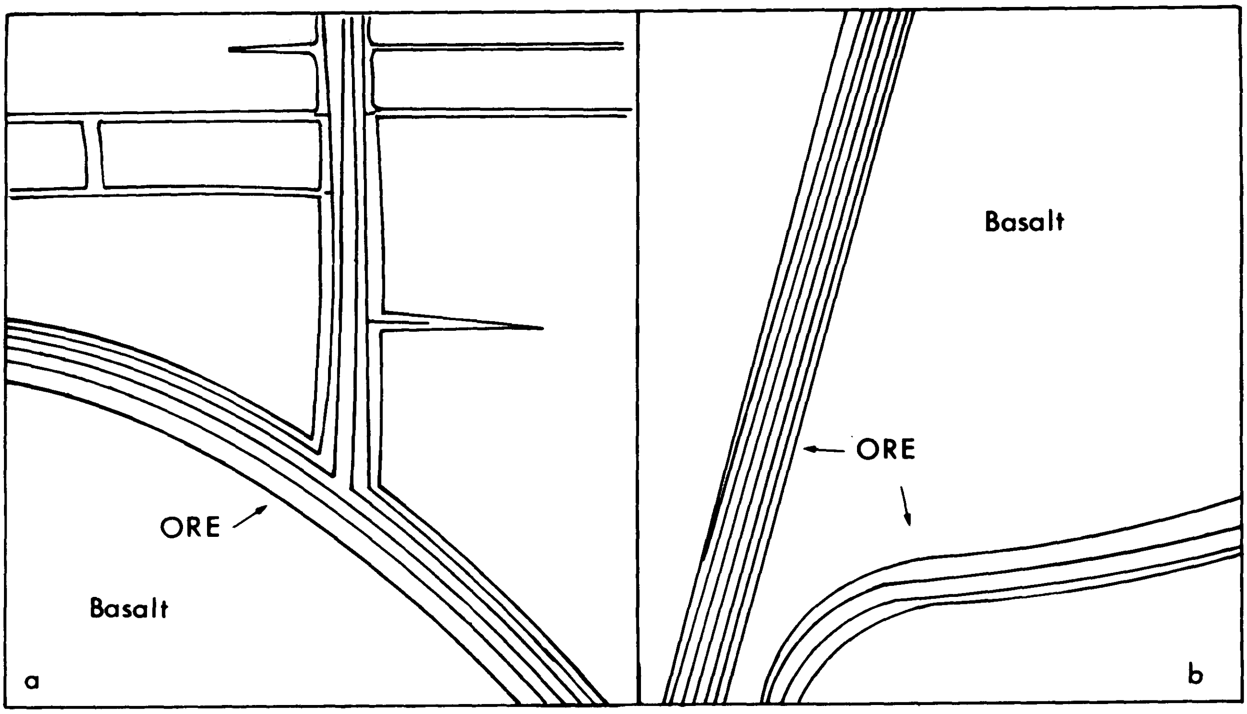

Figure 2. (a) Schematic longitudinal section through the flat-lying ore zone showing how ore fills any interconnected fractures; (b) cross-section through the ore zone showing the Main Zone to the left, and the flat-lying interconnecting vein. Note that the internal lines reflect arsenopyrite-silica layering parallel to contacts. (Project S38.)

in lesser amounts associated with pyrrhotite, pyrite, and chalcopyrite. As the DDZ is approached, the basaltic breccia shows evidence of greater plastic deformation. Flattening of fragments increases and, ultimately, chlorite-sericite schist is developed. In general, the Main Zone parallels the foliation or schistosity, trending approximately 035° and dipping 75° northwest. In places the ore fills branching, interconnecting fractures, or narrow, flat, shear fractures which appear to connect with the main ore zone. There is no indication that these oblique and perpendicular fractures crosscut the main ore zone; rather they seem to be contemporaneous (Figure 2).

Within the ore zones a pronounced but discontinuous sulphide-silica layering is evident parallel to subparallel to the contacts, and shearing is developed along most contacts. A narrow biotite-sulphide halo generally surrounds the ore and commonly dissipates into the surrounding magnetic basalt. Small-scale folding within the ore-bearing zones is evident locally, and the folds plunge about 80° to the north. Several weakly siliceous shear zones within both the footwall and hanging wall of the DDZ, containing 15 to 20% pyrite and minor magnetite, have been intersected in the ramp; however, only low gold values have been observed. Other auriferous, arsenopyrite-bearing, siliceous zones have been intersected during the diamond-drilling program but more work is needed to ascertain their significance.

Felsic and basic dikes intrude the schist and basalt oblique to subparallel to the main zone. In at least one place the margins of a felsic dike have been replaced by quartz, arsenopyrite, pyrite, and gold. The dike (Figure 3), which is red-brown, has been strongly fractured throughout. Fractures are filled with quartz and carbonate, and the margins of the fractures are surrounded by a pronounced halo of biotite. Towards the dike margins, and in particular the hanging-wall side, the dike material is very strongly fractured to brecciated. Dike fragments are suspended in a matrix of silica and arsenopyrite, which typically is layered; layering becomes more pronounced close to the dike margins, arsenopyrite and quartz content increases, and the number and size of dike fragments decreases (Figure 3).

Late brittle deformation features are superimposed on those of the ductile regime. Narrow albitic and siliceous shears offset zones of schist, ore, and both types of dikes, and a conjugate shear system was recognized from which principal stress directions were calculated.

Deformation increases towards the east. The East Zone, located about 60 m east of the Main Zone, is entirely hosted by chlorite-sericite/talc schist and amphibolite. Two different lithologies have been traced through increasing deformation and alteration up to chlorite-sericite/talc schist. These include coarse amphibolite or hornblendite and coarse metapyroxenite. As in the Main Zone, the schist is intruded by narrow mafic and felsic dikes. The dikes created a pronounced anisotropy in rock conditions. The schist is deformed in a ductile or plastic fashion, while the felsic dikes, and to a lesser extent the mafic dikes, are deformed in a brittle manner. The felsic dikes have been fractured, brecciated, and mylonitized, creating zones of permeabiltiy which were flooded and replaced by quartz, arsenopyrite, and gold. This replaced dike material can be traced along strike through lower degrees of deformation and replacement to less altered felsic dikes. Similar to the Main Zone, the intensity of deformation is stronger along the hangingwall margins. The ore-bearing altered dikes display a pronounced layering parallel to the host schistosity. In the absence of altered felsic dikes, gold values are present within biotite- and pyrite-rich portions of the schist.

Competency contrast between the dikes and the chlorite-sericite/talc schist results in extensional features. Boudinage and boudinage-like structures are common, as are extensional shears (Figure 4). In some locations, primarily within the immediate East Zone area, a repetition of both types of dikes is evident. This resulted from the overthrusting of lower portions of the dikes over upper portions, and is consistent with a reverse fault system (Figure 5).

About 10 m east of the East Zone, a wide zone of arsenopyrite and silica with high gold values was intersected along the ramp. This zone, termed the Intermediate Zone, is suspected to be part of a large-scale fold, similar to that shown in Figure 1(a). In this zone arsenopyrite is layered similar to that observed within the Main and East Zones. However, remnants of an earlier fabric (S_1) may be recognized locally. The later fabric (S_2) is parallel to the axial plane of the fold, and does not necessarily parallel the zone contacts. Where the contacts

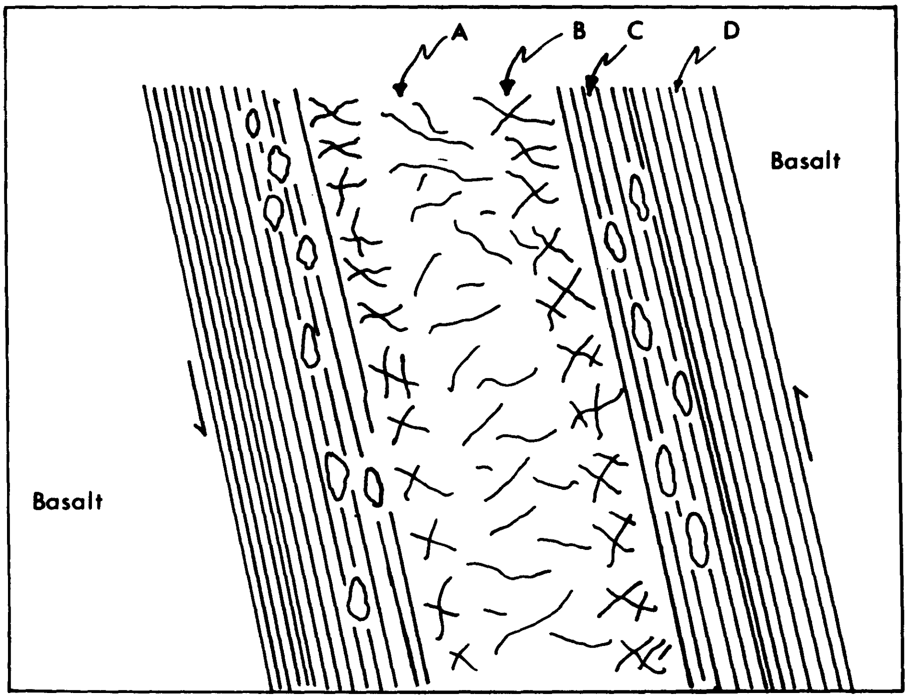

Figure 3. Schematic cross-section through an altered felsic dike: A-fractured core, B-brecciated zone, C-partially assimilated felsic fragments in a matrix of layered arsenopyrite and quartz ore, D-layered arsenopyrite and quartz ore. (Project S38.)

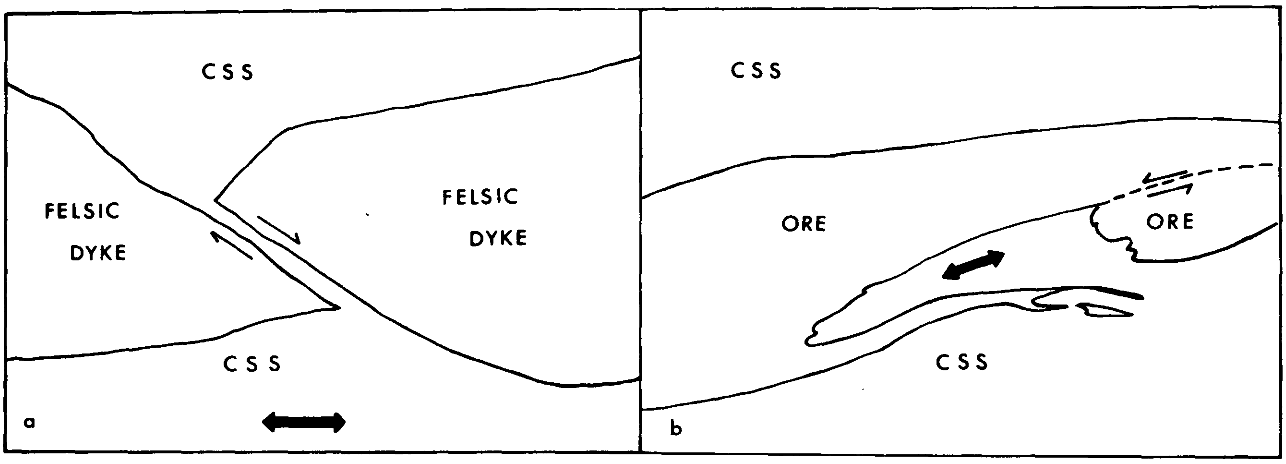

Figure 4. (a) An extensional shear plane (broad arrow indicates the vector of σ_1 or tensile stress); (b) boudinage-like structure, wherein ore is pulled from the gap which is now filled with chlorite-sericite schist (CSS). (Project S38.)

of the zone are oblique or perpendicular to the foliation, arsenopyrite mineralization extends along the schistosity over 1 cm into the host schist. The folding accompanying S_2 postdates at least early ore emplacement, and there appears to have been minimal remobilization during this folding event.

Alteration within the East Zone is considerably more intense than that within the Main Zone (Figure 6). Strong biotite-sulphide halos surround the dike margins, and biotite is common in patches and layers throughout the adjoining chlorite-sericite/talc schist. The schist is a highly deformed and altered amphibolite or metapyroxenite and retains none of the primary mineralogy. Pervasive sericitization/steatization characterizes the schist, and appears to increase in intensity

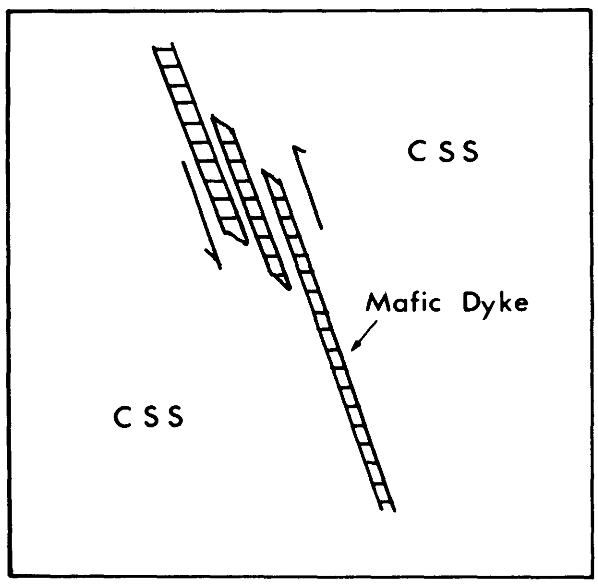

Figure 5. Schematic of the stacking of a mafic dike in a reverse sense, within chlorite-sericite schist (CSS). (Project S38.)

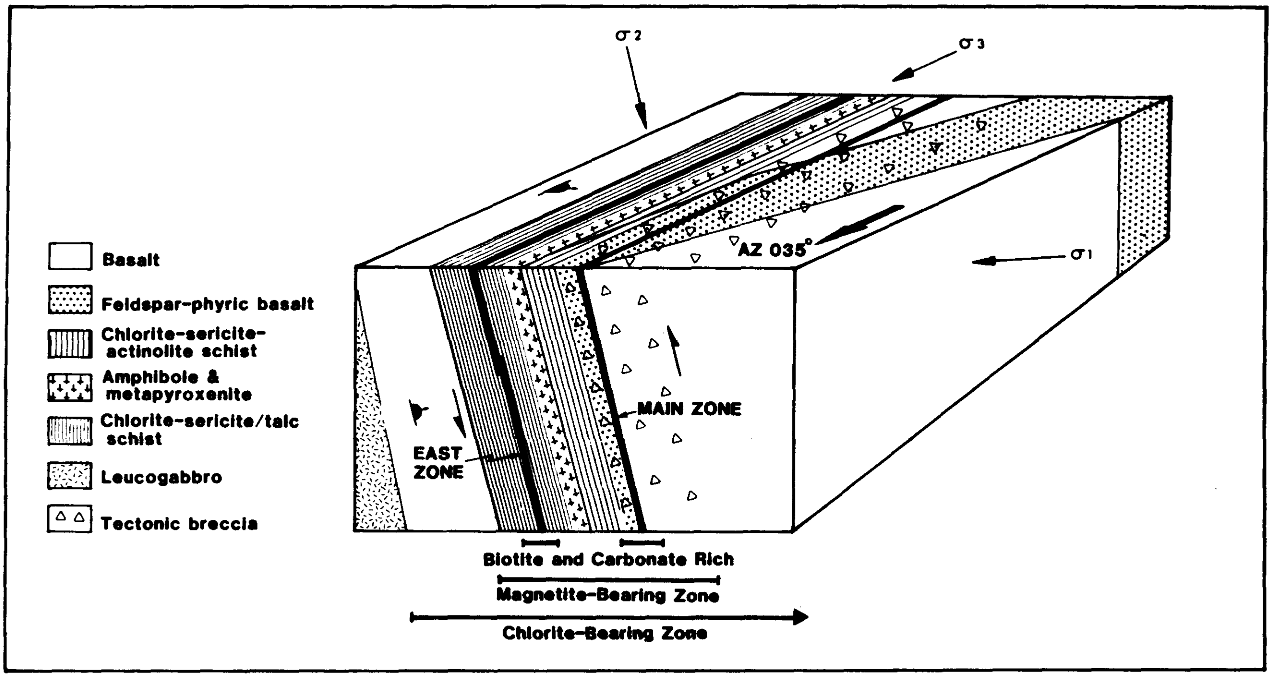

Figure 6. Schematic block diagram of the Duport Deformation Zone. Gross alteration pattern is shown below the block. σ_1, σ_2, and σ_3 indicate maximum, intermediate, and minimum principal stress directions, respectively. (Project S38.)

with increased deformation. Magnetite porphyroblasts are developed throughout the schists, but are not evident within the quartz- and sulphide-rich gold-bearing zones which, in the absence of pyrrhotite, are essentially non-magnetic.

Less than 10 m east of the East Zone, the contact between chlorite-sericite/talc schist and virtually undeformed pillow lavas marks the eastern boundary of the DDZ. The transition between basalt and chlorite schist occurs over 2 m, and is relatively sharp when compared to the hanging-wall contact.

Strong deformation zones, similar and parallel to the DDZ, are evident within the Stevens Island intrusive complex, which is in contact with the basalt over 100 m east of the East Zone.

DISCUSSION

The extensive deformation, pervasive alteration, and vein orientations suggest that the gold-bearing zones, in their present positions, are structurally controlled. Conceivably, gold may have been remobilized into the present structural traps from an earlier stratiform exhalative system.

Ore is hosted within zones of high permeability. In the East Zone, felsic dikes behaved in a brittle manner, creating fluid traps within otherwise tight chlorite-sericite/talc schist which was deformed in a ductile fashion. Similarly, where felsic dikes intersect the gold-bearing system in the Main Zone, they too act as preferred hosts for gold mineralization. Elsewhere within the Main Zone, ore fills permeable channels created by brittle failure of the basalts, and is concentrated into openings created by movement over irregular fault planes.

The DDZ was active over a prolonged time period, passing from ductile to brittle regimes with no apparent change in principal stress direction. Gold was emplaced prior to or early in the brittle period.

Phillips *et al.* (1984) suggest that gold is transported as sulphur complexes within hydrothermal fluids, and that magnetite may act as an activator, removing sulphur from the fluid to form pyrite and precipitating gold. At the Duport Mine, the high magnetite content of the DDZ proximal to the ore zones, and the high sulphide content of the ore bodies may reflect a mechanism of this type.

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S39. Gold Mineralization in the Shebandowan Area

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This project was funded equally by the governments of Canada and Ontario under the Northern Ontario Rural Development Agreement (NORDA).

INTRODUCTION

A regional investigation of gold mineralization in the Shebandowan area, between Thunder Bay and Atikokan in northwestern Ontario, was initiated in July 1984. The project involves lithological and structural mapping, followed by petrographic and geochemical studies, and will be carried out over 2 years.

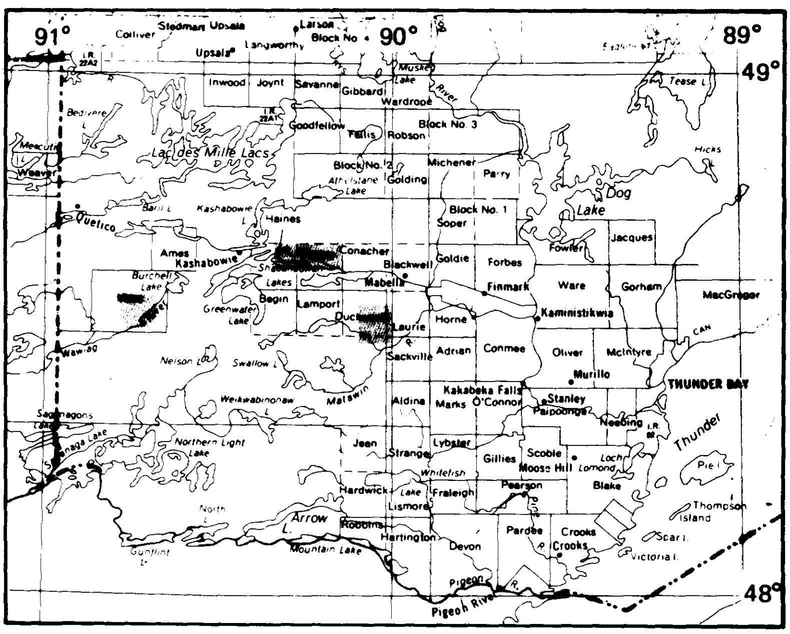
GENERAL GEOLOGY

The area was first regionally mapped by Tanton (1938) and later included in a 1:253 440 compilation map by Pye and Fenwick (1965). Parts of the area were mapped on a 1:31 680 scale (Giblin 1964; Hodgkinson 1968; Harris 1968, 1970; Morin 1973). Srivastava and Fenwick (1973) produced a 1:15 840 preliminary map of parts of Duckworth Township.

According to these geologists, most of the area (Figure 1) is underlain by a Keewatin succession of greenschist to amphibolite facies, mafic to felsic metavolcanic rocks with minor sedimentary intercalations, intruded by several generations of magma. The earliest intrusions are subvolcanic metadiabase to metagabbro sills, less common ultramafic to anorthositic differentiated intrusions, and small trondhjemite granophyre domes. Later intrusions include numerous small quartz-feldspar porphyritic, dacitic bodies and larger intrusions of variable composition (e.g. monzonite to quartz diorite), followed by granitic to syenitic potassic stocks. Lamprophyre and olivine diabase dikes are among the youngest intrusions. Northwest of the metavolcanic terrain and commonly, but not everywhere (Harris 1970), separated from it by a complex of ductile shear zone and/or faults (e.g. Postans Fault Zone) is an amphibolite facies metasedimentary terrain (Kashabowie Group), which grades into migmatites. The migmatites pass with local gradation into extensive granite. The metasedimentary rocks may also be cut by metadiabase, and by later granitic to syenitic stocks (Harris 1970).

An association of predominantly alkaline volcanic rocks and alluvial-fluvial sedimentary rocks (referred to here as Timiskaming-type) is preserved along some of the major fault/shear/fracture systems (Figure 1) and is probably fault-controlled and significantly younger than the Keewatin metasedimentary-metavolcanic rocks (Shegelski 1980).

The tectonic history of the area is complex. Suggestions have been made of very early nappe-like structures in the study area (Morton 1982) and to the west (Poulsen *et al.* 1980). Two major structural events, D_1 and D_2, and one mi-



LOCATION MAP

Scale : 1 : 1 548 000 or 1 inch to 25 miles

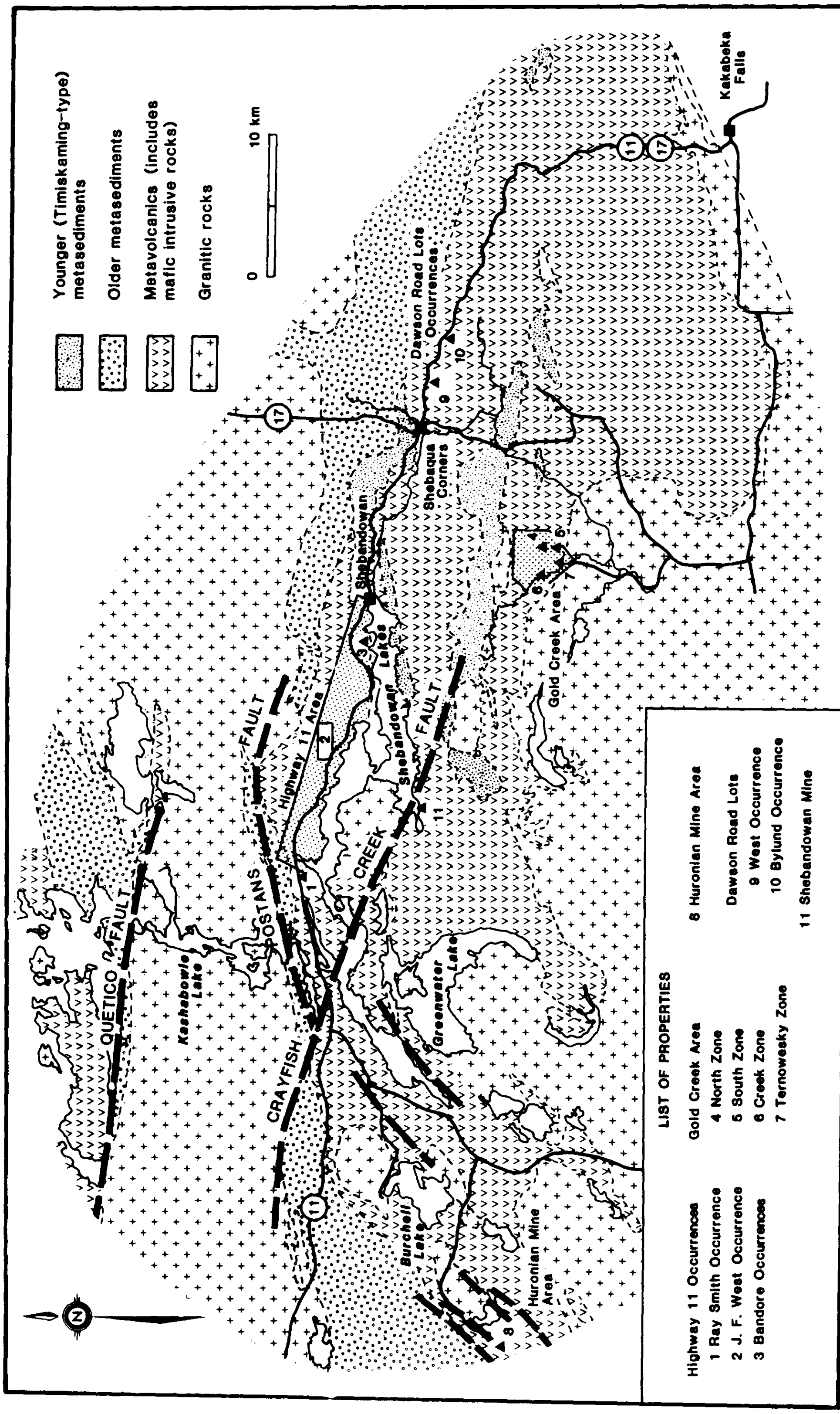


Figure 1. General geology of the Shebandowan area (after Pye and Fenwick 1965), with mineral occurrences examined in 1984. (Project S39.)

nor event, D_3, have been recognized by Stott and Schwerdtner (1981) in the study area and by Bau (1975, 1979) to the west of the study area. There is agreement that D_3 is represented by kink bands and minor faults across the regional grain imposed by F_1, D_2, and stratigraphy. However, Bau (1975, 1979) attributed formation of a strong foliation to D_1, and folding of foliation to D_2 and suggested that D_2 activity is related to the development of the west-trending, dextral Quetico Fault, a broad mylonite and ductile shear zone immediately west and north of the study area. He further suggested that the main fault/shear systems occur as a conjugate set: a generally earlier northeasterly to northerly trending sinistral set; and a later, superimposed northwesterly to westerly trending dextral set, including the Quetico and Crayfish Creek Faults (Figure 1). This conclusion was supported by Poulsen (1981, 1983). Stott and Schwertdner (1981) placed emphasis on regionally penetrative mineral lineations, supported by magnetic susceptibility measurements, and have defined D_1 and D_2 structural domains. The first is characterized by predominantly southwesterly plunging lineations (L_1); and the second, by predominantly northeasterly plunging lineations (L_2). D_2 strain is thought to be later than, and to overprint, D_1 strain in the D_2 domains.

East-trending zones of intense shearing and carbonatization in the eastern half of the Shebandowan Lakes area were noted by Morin (1973), who attributed them to the emplacement of the Shebandowan Lake stock.

GOLD MINERALIZATION IN THE SHEBANDOWAN AREA

The Shebandowan area hosts many gold occurrences (Springer 1978), among them the Huronian Mine (alternate names Ardeen Mine, Moss Mine), one of Ontario's earliest producing gold mines (Watson 1929a). A more recently explored auriferous zone is present around Gold Creek (Jalna Property; Northern Miner 1984) in Duckworth Township (Figure 1).

Many of the general features of Archean gold-bearing terrains outlined by Colvine (1983) are present in the study area including:

1. Greenschist facies mafic metavolcanic rocks
2. Iron formation
3. Felsic intrusions, notably small bodies of feldspar porphyry and late stocks of alkali-rich granite to syenite
4. At least 2 major, locally intersecting, fault and/or ductile shear systems
5. Intense alteration, such as wide zones of chloritization, silicification, and potassic alteration (sericite or K-feldspar)
6. Locally profuse quartz±carbonate veins in subplanar sets or locally as vein stockworks.

Profuse pyrite and, locally, other base-metal sulphides accompany gold mineralization, as in other gold camps (Springer 1983).

Many of these features are absent from individual occurrences in the Shebandowan area, and many occur in "greenstone" belts that produce base metals, but not gold. The presence of nonauriferous sulphide concentrations in the Shebandowan area, such as the early Keewatin, copper-nickel deposit of the Inco Shebandowan Mine (Cross 1920, Watson 1929b, Morton 1979, 1982), and copper mineralization in Keewatin felsic volcanic rocks of the North Coldstream Mine at Burchell Lake (Giblin 1964), have been interpreted as synmagmatic with the Keewatin succession. In the latter case, coeval alteration, including silicification, potassic alteration, and quartz stockworks, might be recorded in nearby associated rocks, and similarly derived concentrations of sulphides present in equivalent strata. An attempt will be made in this study to screen features of nonauriferous, probably synvolcanic or stratabound, mineralization from those of auriferous sulphide mineralization. This might best be done by documenting the timing of the development of each of the characteristic features in the region relative to a regional tectonic framework, accompanied by extensive petrographic and geochemical sampling.

An apparent correspondence between D_2 structural domains, as defined by Stott and Schwerdtner (1981), and the location of known gold occurrences was noted by Stott and Schneiders (1983). This strongly suggests structural control of the siting of gold in the Shebandowan Lakes area. Demonstrated siting of gold mineralization along shears related to the Quetico Fault system west of the study area (Poulsen 1981, 1983) further suggests the possibility of structural control of gold mineralization in the Shebandowan area. Therefore, it is one of the aims of this study to further investigate the tectonic significance of the structural domains defined by Stott and Schwerdtner (1981), and to see whether the exploration guideline proposed by Stott and Schneiders (1983) can be extrapolated, in its present or modified form, further from the Shebandowan Lakes area.

ACTIVITIES DURING THE 1984 FIELD SEASON

Several target areas were selected for preliminary study on the basis of accessibility, bedrock of exposure, and presence of gold mineralization. These are:

1. A section along Highway 11 from Postans Lake, eastward to Shebandowan, encompassing the Ray Smith, J.F. West, and Bandore Occurrences
2. A broad, gold-bearing pyritiferous zone near Gold Creek in Duckworth Township (the Jalna Property; Northern Miner 1984)
3. The Huronian Mine area in Moss Township
4. The Dawson Road Lots (Bylund and West Occurrences) southeast of Shebaqua on Highway 11/17.

These areas are outlined, and properties within each identified, on Figure 1.

In addition to work in these areas, a broad regional reconnaissance of metavolcanic and metasedimentary rocks, granitoid rocks, and general structural and metamorphic patterns was begun.

Significant field observations from this work are summarized below.

HIGHWAY 11 SECTION

1. General observations: The section is dominated by Keewatin mafic to intermediate metavolcanic rocks cut by numerous metadiabase sills. Lenses of rhyolite are more common in the west. Siliceous to graphitic siltstone, feldspathic crystal tuffs, felsic lapilli tuffs and felsic to intermediate tuff-breccias and pillow breccias are interbedded with flows. A highly sheared, coarse polymictic breccia or conglomerate, containing fragments of pyrite, massive sulphide, and highly silicified, epidotized metabasalt (?), as well as silicic siltstone and other volcanic fragments, is exposed north of Lower Shebandowan Lake. Small bodies of plagioclase feldspar±quartz porphyry cut the metavolcanic sequence, and appear distinct from a locally quartz-phyric to equigranular and much more highly altered granite plug on the J.F. West Property. Fine-grained, pink granite appears to cut one of these feldspar porphyries in a shear zone south of Postans Lake. The Shebandowan pluton (monzonite to quartz diorite) cuts these rocks along the southeastern part of the section.

Highway and lake shore outcrops reveal high strain, ductile shear zones spaced 0.5 to 1 km apart. Metasomatic alteration has invariably accompanied the development of these zones. Some of the western metadiabase exposures have become serpentinose and talcose, and elsewhere, protoliths of mafic metavolcanic rocks, metadiabase, and granite have been transformed into sericite-carbonate-chlorite or sericite-carbonate schists in high strain zones. In the latter zones, iron-rich carbonate was introduced as veinlets which are mainly oriented counterclockwise to the prominent foliation on horizontal surfaces, suggesting a sinistral shear zone accompanying emplacement. These veins have apparently been further extended, and locally traversed by later shear planes with orientation suggesting subsequent dextral displacement. Some of these zones are highly pyritiferous; the pyrite occurs especially along fractures traversing competent fragments, lenses, or boudinaged layers. In contrast, a broad zone of epidotization and patchy silicification in comparatively unstrained pillow basalts, metadiabase, and pyroclastic rocks is exposed from Young Bay through the J.F. West Occurrence as far west as the Swamp River. It is characterized by magnetite-rich interpillow zones and magnetite in the fine-grained matrix of felsic lapilli tuff and breccias, by magnetite patches overprinting coarse-grained metabasalts, and by magnetite grading locally to specular hematite along late, discontinuous, north- to northwest-trending fractures.

2. Ray Smith Occurrence: The Ray Smith Occurrence is within a northwest-trending fault zone with minor dextral offset along which a thick, branching, sulphide-rich quartz vein has been emplaced contemporaneously with late faulting (the vein is locally deformed). The fault zone is characterized by zones of fault gouge and anastomosing shear fractures which cross-cut earlier, southeast-branching foliation and high strain zones. Early quartz veins, and carbonate-rich infillings of early fractures and foliations opened during the southeasterly dextral shifting on the fault zone, are also truncated by the thick veins.

3. J.F. West Occurrence: Central to the J.F. West Property is a highly sericitized and carbonatized, but not highly foliated, granitoid stock crisscrossed by auriferous quartz veins of various orientations. The stock and the surrounding metavolcanic rocks are transected by the west-trending sericite/carbonate schist zones noted above. Northwest-trending minor faults and fractures (some magnetite-and/or hematite-filled) were also noted, as well as one west-northwest-trending zone of shear fracturing and pervasive K-feldspathic alteration which may have coincided with the emplacement of syenitic dikes, intense carbonatization, and pyritization along the powerline in the centre of the property. The shear fractures are also followed by quartz veins containing actinolite-pyrite, varying to chlorite-magnetite in the powerline area. Many distinct units and alteration types were sampled for trace element and metal assays.

4. Bandore Occurrence: Trenches across an east-trending sericite/carbonate schist zone in the Shebandowan pluton expose steeply dipping, discontinuous (either *en echelon* or boudinaged), pyritiferous quartz veins cutting the schists. Veins and the host schist were sampled for trace element and metal assay.

GOLD CREEK AREA

An area recently denuded by timbering has lately focussed intensive exploration activity (*see* Northern Miner 1984). The area is underlain by mafic to felsic volcanic and subvolcanic rocks. Both flows and pyroclastic rocks are common, and minor sedimentary rocks are exposed in the northwest part of the cleared area. Auriferous rocks are highly charged with pyrite, a feature which drew earlier prospectors to more limited exposures along Gold Creek itself (Coleman 1896).

Several important geological events are evident in these exposures. Their chronology, which may be significant in developing a model for the mineralizing process, includes:

1. Deposition and emplacement of most of the volcanic and subvolcanic rocks.

2. Widespread and intense fracturing, which is especially prominent in the area spanning both the Creek and North zones, coeval brecciation, with at least some mixing of fractured wall rocks of contrasting lithology (metadiabase with dacite), occurred locally between the Creek and North zones; it is conceivable that laharic-looking pyroclastic rocks on the eastern side of the cleared area (e.g. exposed in the North zone) may have been derived from the breccia-tion.

3. In no demonstrated relative order:

(a) A penetrative, steeply northwest to rarely west-plunging lineation is superimposed on all rocks. The lineation is most prominently displayed in the fracture zones which are especially rich in sericite (flakes are elongated to define an L-fabric).

(b) Both carbonatization of mafic flow rocks and potassic alteration of pyroclastic rocks (possibly also mafic rocks) are displayed in the northern part of the cleared area. Carbonatization at least locally affects lamprophyre dikes, but one olivine diabase dike (not near carbonatized lamprophyre) appears unaffected.

(c) Actinolite-quartz veins with leached alteration halos (in places zoned) were emplaced along planes of weakness, such as lithological contacts, fractures, and minor faults. These are especially profuse in the North zone.

4. Cross-cutting these veins, or intruding along them, are more massive quartz veins. Massive quartz was also locally emplaced between breccia blocks.

Gold enrichment is associated with pyritization which affects subvolcanic, pyroclastic, and flow rocks. Pyrite appears to have been affected by the strong linear fabric, and therefore was introduced during either stage 1 or stage 2. The veins (stage 3c and stage 4) are also sulphide-bearing and auriferous. A knowledge of the relative timing and duration/hiatus between events, along with their placement in the context of regional geological development, is essential before deciding whether the mineralization can be categorized as synvolcano-magmatic, or linked to later tectonic activity. It will be investigated during this project.

HURONIAN MINE AREA

The Huronian Mine is sited within Keewatin mafic and possibly intermediate metavolcanic rocks with associated felsic(?) volcanoclastic rocks and magnetite iron formation cut by small bodies of feldspar porphyry. These rocks have been affected by north to northeasterly-trending, steeply dipping shear zones which have converted the metavolcanic rocks to sericite/chlorite schist. Near the mine area, carbonate has also been introduced, and is most evident in the sheared porphyry. Several long quartz veins intruded along the shear zones near the mine are exposed in trenches and pits to the southwest. These veins invariably dip more steeply than the west-dipping foliation (where the foliation steepens, the veins similarly rotate to a vertical or southeast-dipping attitude), and strike counterclockwise relative to the foliation in horizontal projection. The zones of highest strain show a southwest-plunging mineral lineation.

Fluorite-bearing alkali granite grading to syenite (Moss Lake stock, Harris 1970) truncates the schistosity of the high strain zones.

Quartz veins and their margins, mineralized samples from the mine dump, iron formation, porphyry, metavolcanic rocks, and alkali granite-syenite were sampled for geochemistry.

DAWSON ROAD LOTS

Both the West and Bylund trenches of the Dawson Road Lots gold zone expose intensely carbonatized, massive, mafic volcanic(?) rocks associated with cherty rocks (originally interbedded jaspilitic iron formation ?), apparently coarsely brecciated prior to shearing. An apparently continuous, steeply dipping, east-trending shear zone along the central part of the trenches is heavily quartz veined and silicified. Pyrite is exceptionally abundant in these zones. Exposures in the trenches are also cut by gently west-dipping fractures, along which the emplacement of white quartz veins and silicification has also occurred locally.

Several outcrops indicate that carbonatization of the Keewatin volcanic rocks persists along strike of the fracture zone, and for several kilometres to the south of the trenched zone.

It should be noted from the observations above that both the gold-bearing Huronian Mine and Gold Creek area display regional mineral lineations which are not parallel to the southeast-plunging trend which characterizes the D_2 domains of Stott and Schwerdtner (1981). Therefore, the correspondence of gold showings and D_2 domains cannot in itself be extrapolated as an exploration guideline beyond the Shebandowan Lakes area for which it was proposed (Stott and Schneiders 1983). The validity of the observation made by these authors is not challenged, but its tectonic significance must be understood more thoroughly before it can be applied in modified form to mineral exploration beyond the Shebandowan Lakes area.

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S40. Structural Studies in the Geraldton Area

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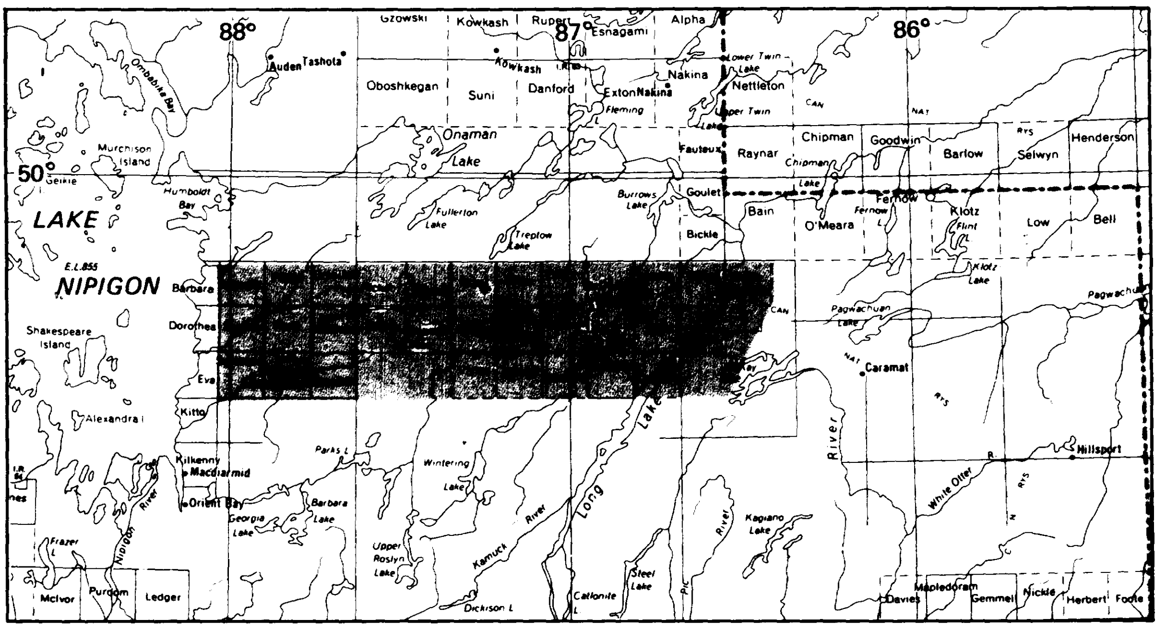
This project was funded equally by the Governments of Canada and Ontario under the Northern Ontario Rural Development Agreement (NORDA).

INTRODUCTION

In 1982 the Mineral Deposits Section of the Ontario Geological Survey commenced a study of gold mineralization in the Geraldton Camp, with the initial objective of determining whether banded iron formation, host to some 30% of the ore, provided a protore source for the gold. Results of this study (Macdonald 1982, 1983a, 1983b) suggested that gold was introduced late in the geological history of the supracrustal host rocks, following intrusion of mafic/ultramafic and felsic rocks and following at least some deformation. As a consequence of these observations, Lavigne (1983) and Kehlenbeck (1983) commenced investigations of the structure; Lavigne concentrated upon the Bankfield-Tombill Fault and Kehlenbeck studied the large-scale structures of the Beardmore-Geraldton "Greenstone" Belt. This study complements the work commenced by Lavigne (1983), and investigates the distribution of deformed rocks in the Geraldton Camp, and addresses the relationships, if any, between mineralization and deformation. The study was restricted to an area bounded by Latitudes 49°39'N and 49°43'N, Longitudes 86°51'W and 81°05'W. This area is located in Errington and Ashmore Townships which were mapped by Horwood and Pye in the late 1940s and early 1950 (*see* Location Map).

Guided by the excellent geological framework provided by Horwood and Pye (1955) and Pye (1952), north-south traverses were conducted across the fault and the zone of spatially associated deformation. Structures at each outcrop were studied in detail in order to determine: (1) the sense of motion displayed by structures in the rocks; (2) the style of deformation within the zone; (3) the degree of deformation and its areal extent throughout the zone; and (4)



LOCATION MAP

Scale : 1 : 1 548 000 or 1 inch to 25 miles

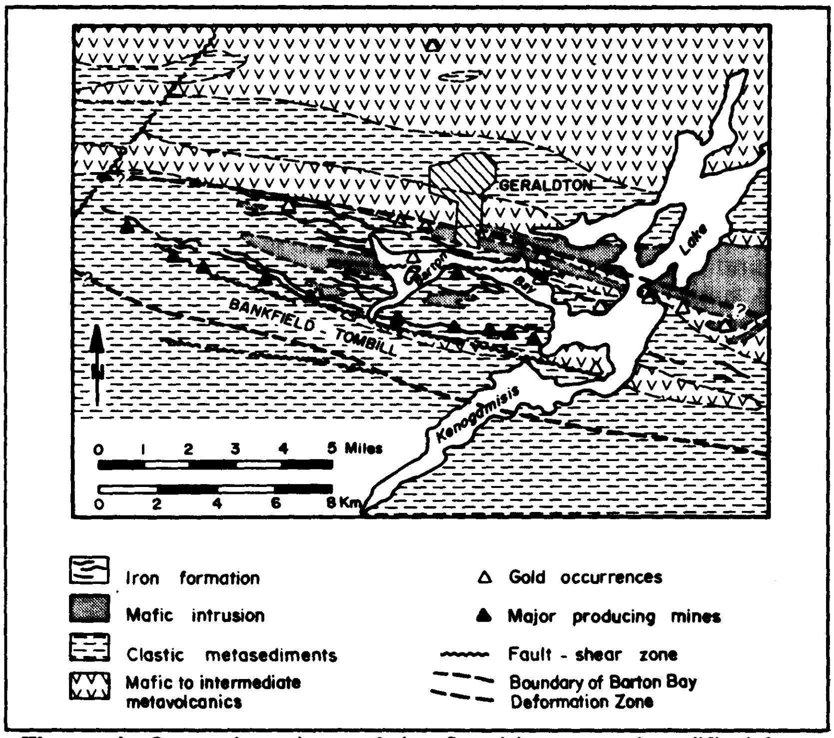


Figure 1. General geology of the Geraldton area (*modified from* Macdonald 1984). (Project S40.)

the differing effects of deformation upon different rock types.

MINERAL EXPLORATION

The Geraldton area has been extensively explored for gold since the 1920s. The most important period was the 1930s to 1940s when several gold mines commenced operations, including the Bankfield Consolidated Mines, the Magnet Mine, Consolidated Mosher Mines, the MacLeod-Cockshutt Mine, the Hard Rock Mine, and the Little Long Lac Mine. None of these are now operating, the latest closure being the MacLeod-Cockshutt in 1970. Recent gold discoveries in the Hemlo area sparked renewed interest in the Geraldton area resulting in extensive restaking and some exploration programs. Exploration for gold has been concentrated mainly around units of iron formation both within the study area and to the east and west along regional strike. An underground drilling program is being undertaken in the Magnet Mine. Considerable stripping has been done on claims which cover a large peninsula on Kenogamisis Lake (Figure 1); during the present study visible gold, within quartz veins, was observed on this property.

GENERAL GEOLOGY

All of the rocks in this area are Precambrian in age and can be separated into mafic to intermediate metavolcanic rocks, metasedimentary rocks including wacke, conglomerates and banded iron formation, and mafic and felsic porphyritic intrusions. The youngest rocks are diabase dikes of probable Proterozoic age.

The volcanic rocks include massive and pillowed mafic to intermediate flows as well as mafic tuffs and tuff breccias. In many locations epidote alteration and veining are present. During the 1983 field season Lavigne (1983) observed that units mapped as tuff and tuff breccia by Horwood and Pye (1955) and Pye (1952) may actually be a sheared gabbro. Further refinement of this map may be possible due to access to recently exposed outcrop on the large peninsula in Kenogamisis Lake. Stripping at this location has exposed outcrops of pillowed volcanic rocks and also a felsic intrusive which appears similar to the plagioclase diorite porphyry mapped by Horwood and Pye (1955).

The metasedimentary rocks in the southern part of the area are relatively unaltered wackes which often exhibit easily recognizable graded bedding. In the central part of the map area the sedimentary unit consists of a more massive, coarser grained rock referred to as 'arkose' by Pye (1952). Also present in this area are units of a polymictic pebble conglomerate, with pebbles ranging in size from 1 cm to 20 cm. The matrix varies from coarse- to medium-grained wacke.

The iron formation in the Geraldton area occurs mainly as alternating beds of magnetite and silicified mudstone or dark chert, with some minor magnetite/jasper iron formation (Macdonald 1982). Intrusive rocks include mafic gabbros and felsic porphyries which, due to subsequent shearing, usually have contacts concordant with sedimentary layering. However, in a few locations such as at the Bankfield Mine site, intrusive, discordant contacts of gabbro into wacke, and porphyry into gabbro provide a clear sequence of events. Underground evidence of these relationships was established at many of the mine sites by Horwood and Pye (1955) and Pye (1952).

STRUCTURAL GEOLOGY

The main purpose of this project was to study the regional structures, specifically the Bankfield-Tombill Fault, and to determine any significance in relation to known gold deposits in the Geraldton area. The most outstanding aspect of the area was pointed out by Horwood and Pye (1955) and Pye (1952): all of the past producing mines are spatially related to the Bankfield-Tombill Fault within a zone of strong deformation characterized by shearing and folding adjacent to the fault. As pointed out by Lavigne (1983), this "deformation zone" is a minimum of 1 to 3 km wide and has been termed the Barton Bay Zone by Macdonald (1984). Observations made during the present study suggest that the Barton Bay Zone may be as much as 5 km wide (Figure 1). The length of the fault was mapped by Horwood and Pye (1955) from the western end of Errington Township to the southeastern corner of Ashmore Township. Recently exposed outcrop on the peninsula in Kenogamisis Lake confirms the extension of the fault on the tip of this point.

Observations made by Lavigne (1983) and verified during the present project have revealed that the most significant deformation process within the Barton Bay Zone was ductile shearing, rather than the brittle faulting. While brittle failure is clearly present, it was possibly a late stage deformation superimposed on earlier shearing. This brittle stage may have been the result of strain hardening, or an increased strain rate producing lower apparent rock ductility. Evidence for ductile shearing with a dextral sense is abundant, with kinematic indicators including stretched pillows and conglomerate clasts and ductility-displaced markers such as quartz veins. The asymmetry of folding, such as the ubiquitous Z-style folds, may not be conclusive by itself, but when combined with other indicators is also suggestive of dextral motion.

The degree of shearing within this zone is evident in the presence of 2 to 3 m wide discrete zones of extensive simple shear. These shear zones are most easily recognized in the coarse-grained mafic intrusive where progressive degrees of strain can be observed through reduction of grain size, mineral alignment, and the development of a penetrative foliation. Within the shear zone the extent of deformation is revealed by the presence of shear bands of C' fabrics (Berthe *et al.* 1979, Lister and Williams 1979), which develop oblique to the boundary of the shear zone. This fabric causes dextral displacement and counterclockwise rotation of the strong foliation (C) parallel to the shear zone, producing the "tuff breccia" noted by Pye (1952). Although an S fabric (Berthe *et al.* 1979) is commonly observed outside the intensely sheared zones, it is not present within these zones due to its rotation parallel to the C foliation. Evidence of ductile deformation is also present in the felsic intrusions which become strongly foliated, and also in the wacke units where deformation is concentrated along shale layers. These layers often have developed a strong shear foliation and a C' or shear band fabric.

The progressive deformation within this zone is demonstrated by the presence of the mafic and felsic intrusive rocks, which are localized within the general area of the deformation zone. It is reasonable to suggest that this structure acted as a conduit for magmas which on crystallizing were subsequently deformed by continued shear. Other evidence of continuous deformation is the presence of unrefolded folds in banded iron formations and wackes (H. Hugon, Post Doctoral Fellow, Department of Geology, University of Toronto, personal communication, 1984).

The mechanism causing ductile shearing may also result in strain hardening, while increased strain rate could also cause brittle deformation in less ductile rocks. Macdonald (1984) observed in the Hard Rock Mine gloryhole that Z-folded iron formations and wackes with different ductility exhibited fracturing of the iron formation, subparallel to the fold hinge lines. These fractures were later infilled by quartz-carbonate-sulphide-gold veins.

SUMMARY

Detailed structural mapping during the present field season verified the observations of Lavigne (1983) that a wide "deformation zone" associated with the Bankfield-Tombill Fault is present in the Geraldton area. A strong dextral sense of displacement throughout the Barton Bay Zone was observed from the presence of kinematic indicators as well as the presence of discrete, strongly sheared zones with

one or more shear fabrics. This deformation zone may have been partly responsible for gold deposition in several ways. For example, it acted as a conduit for mafic and felsic magmas as well as volatiles and hydrothermal fluids throughout the entire deformation. Secondly, it produced dilation associated with fold hinge zones and brittle fractures in rocks of low ductility. Further exploration for gold in this area should be concentrated not only on the fault but also in neighbouring zones of intense shearing and folding.

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41. The Hemlo Deposit: Gold Mineralization Within a Dextral Shear Zone

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INTRODUCTION

This study offers a contribution to the understanding of the complex structural geology of the host rocks in the Hemlo deposit area. Without an understanding of the degree and nature of the deformation, stratigraphic reconstruction is not feasible and the context of the ore deposit within the stratigraphic framework cannot be established.

The structural geology of a narrow strip along Highway 17 was studied in June 1984. This structural analysis was initiated in order to obtain a better understanding of matrix-hosted gold deposits and to be able to attempt a comparison between the Madsen (Red Lake) and Hemlo deposits. Both deposits are located in a belt whose central part is occupied by a granitoid pluton (e.g. the Dome Stock in the Red Lake belt and the Cedar Lake Pluton in the Hemlo belt). Both deposits are hosted by strongly deformed rocks that are metamorphosed to amphibolite facies grade.

The Hemlo deposit is located north of the Hemlo fault (*see* Figure 1) at the contact between felsic metavolcanic and metasedimentary rocks (Muir 1982). The ore-bearing rocks are sericite schists, siliceous metasedimentary and fragmental rocks (Patterson 1984, p.8). The ore-bearing zone, which has been previously named the Lake Superior Shear Zone, has an overall strike of 110° and can be traced on surface for over 11 km (Muir 1982, p.55). A detailed description of the geology of the area is presented by Muir (1982). Previous observations (Patterson 1983) along Highway 17 indicate that the attitude of the stretching lineation gradually changes from plunging steeply to the east near the Cedar Lake Pluton, to being subvertical in the Cache Lake vicinity, to plunging steeply to the west near Rous Lake. Field data presented below will contribute new information about the deformation history of the Hemlo area.

In the following paragraphs the term "mylonitic fabric" will be used to describe fine-grained tectonite containing a well developed L-S fabric and the term "tectonometamorphic layering" will be used to describe strongly deformed and highly metamorphosed rock material of sedimentary origin.

FIELD OBSERVATION

At the contact with the Cedar Lake Pluton, the metasedimentary rocks show a schistosity dipping less steeply than the tectonometamorphic layering. Passive folds with a Z asymmetry plunge shallowly to the southeast and seem to indicate a normal displacement of the Cedar Lake Pluton relative to the metasedimentary rocks. The data concerning this area are summarized in Table 1.

The data indicate that the fold axis and the intersection layering (S_0)/schistosity (S_1), are nonparallel. Structures that seem to be cogenetic are the stretch lineation (L) which is outlined by metamorphic minerals and the intersections S_0/S_1, as they are suborthogonal. In the case of layer-parallel shearing, an angle of 90° would be expected between the stretch lineation and the intersection shear plane/principal plane of deformation. Therefore, the schistosity-layering relationship indicates an oblique shearing with a dextral component of displacement between the Cedar Lake Pluton and the metasedimentary rocks.

West of the bridge over Cedar Creek, a fold closure can be observed on both sides of Highway 17 (Stop K on Figure 5, Patterson 1984). The constructed fold axis has a plunge of 50° and a trend of 60°. The eastern limb strikes 155° and dips 50° to the northeast. The constructed axial plane strikes 140° and dips 52° to the northeast while the western limb strikes 125° and dips 35° to the northeast. Geometrically this defines a reclined fold, as the strike of the axial plane is subperpendicular to the fold axis plunge, which is opened towards the northwest. Minor Z structures on the eastern limb, and minor S structures on the western limb, seem to indicate shearing parallel to the bedding during the folding. Data on this megastructure are summarized in Table 2.

These data demonstrate that there is no apparent relationship between the fold axis and stretch lineation, and the fold axis and intersection S_0/S_1 except on the western limb. Possible other cogenetic structures are the stretch lineation and the intersection S_0/S_1 on the eastern limb of the megastructure. One peculiar feature to be pointed out is the inversion in plunge of the minor folds from one limb to the other. This interesting feature might indicate a complex history, but can also be explained in a single progressive defor-

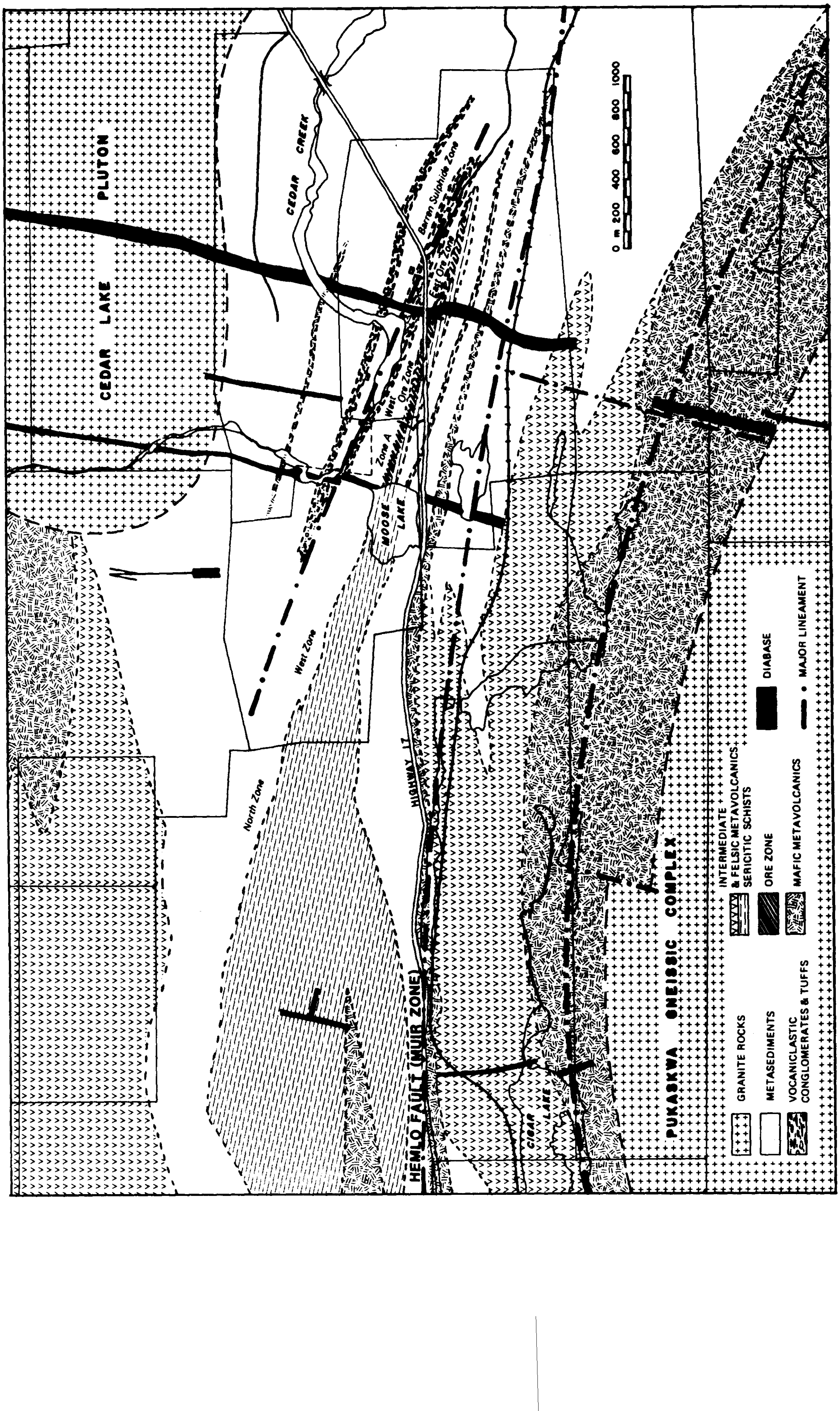

Figure 1. General geology of the Hemlo area after Muir (1982), Patterson (1984), and Milne *et al.* (1972). (Project 41.)

mation history which will be discussed later in this report. Other major folded structures in the metasedimentary rocks have the same spatial orientation, i.e. reclined folds with axis 55° to 60° trending north 50° to 65°, such as the folded structure near the Teck Corporation/International Corona Resources Limited Property entrance, or as the similar folds at the power line outcrop on the Lac Minerals Limited Property. However, in these 2 locations the fold axes of mesostructures and the intersections S_0/S_1 are more or less coaxial. One important feature to note about these folds is the axial planar schistosity defined by oriented metamorphic minerals. This indicates that metamorphism and deformation were coeval.

It is perhaps significant to note that on the Lac Minerals Limited Property, while oriented metamorphic minerals define the axial planar schistosity, the host rock contains randomly oriented tourmaline crystals (Muir, this volume). This would suggest that whichever event was responsible for the formation of tourmaline at Hemlo is later than deformation and metamorphism.

Moving westward along Highway 17 from the hinge of the above described megastructure, one observes that minor S folds progressively disappear, to be replaced by minor Z folds within a few hundred metres, and without involving an apparent closure of a major fold. This would indicate that bedding-parallel shearing changed its sense on the same limb of a major structure. This is very difficult to explain from a mechanical point of view. Further westward, up to a point where Highway 17 cuts the Heron Bay pluton, only

TABLE 1: STRUCTURAL DATA FROM THE METASEDIMENTARY ROCKS AT THE CONTACT WITH THE CEDAR LAKE PLUTON (DIP/STRIKE). (PROJECT 41.)

Fold	Fold Axis	Intersection S_0/S_1	Stretch Lineation (L)	Angle between L and Intersection S_0/S_1
Z	06°/156°	26°/005°	28°/110° to 26°/116°	90° 96°

TABLE 2: STRUCTURAL DATA OF THE RECLINED FOLD WEST OF THE BRIDGE OVER CEDAR CREEK (DIP/STRIKE). (PROJECT 41.)

Fold Asymmetry	Eastern Limb Z	⇔	Fold Hinge M	⇔	Western Limb S
Fold Axis	6°/150°	25°/120°	50°/060°	24°/320°	
Intersection S_0/S_1	26°/005°	30°/012°	25°/085°	40°/340°	12°/318°
Stretch Lineation	30°/125°	18°/140°	5-10°/115°	10°/114°	20 °/110°
Bedding	46°E/155°	45°E/154°	60°N/100°	54E/125°	55 °E/128°
Schistosity	38°E/144°	45°E/131°	51°N/101°	43E/101°	44°E/107°
Angle between L and S_0/S_1	100°	110°	12°	116°	142°

minor Z folds and structures associated with dextral shear can be observed. Along the same traverse, a gradual variation in the plunge of the stretch lineation can be observed. The plunge changes from 20°E near the reclined fold, to subhorizontal where Highway 17 cuts the ore horizon, to 41°W near Cigar Lake.

When remnants of S structures can be seen, they show disrupted competent layers embedded in a ductile matrix in which the schistosity pattern defines a right-lateral movement of shearing. These features can be observed immediately above the Barren Sulphide Zone on the northern side of Highway 17 (*see* Figure 1). On that outcrop, a conspicuous large increase in strain intensity in a direction toward the Barren Sulphide Zone is exposed. Within 10 m, continuous competent layers are increasingly boudinaged and disrupted to such a degree that boudins and rootless folds are isolated in a biotitic matrix.

The Barren Sulphide Zone has been described as a crystal tuff (Patterson 1984, p.3), which is now a quartz-sericite schist with a mylonitic fabric. Futher study of thin sections will show whether or not the observed fabric is due to mylonitization *sensu stricto*. Such a mylonitic fabric can also be seen in a crystal tuff lying between the Barren Sulphide Zone and the West Ore Zone on the Teck-Corona Property. There, ribbon quartz embedded in a quartz-sericite matrix can be observed. Other features of intense strain and very high strain rate are present in the outcrop facing Moose Lake. Other evidence of intense strain and very high strain rate is present on the outcrop of "finely laminated metasedimentary rocks" facing Moose Lake. This evidence is 1 cm to 1 m wide brecciation of the tectonometamorphic layering, and 1 cm wide bands of ultramylonite subparallel to the layering. These bands of ultramylonite are associated with pseudotachylite injections in some cases. Preliminary study of thin sections confirms these field observations. The ore horizon itself exhibits a mylonitic fabric and the numerous mesoscopic kinematic indicators of dextral movement, together with the subhorizontal stretch lineation, indicate that the Hemlo deposit lies within a major dextral zone of ductile shear. Part of this major ductile shear zone is the Hemlo Fault which hosts the Muir Zone.

A preliminary estimate of the width of the sheared domain would be of the order of 2 km between the hinge of the megastructure and the mafic metavolcanic rocks at the edge of the Pukaskwa Gneissic Complex. Although more data are needed, the author suggests that the whole domain between the Cedar Lake Pluton and the Pukaskwa Gneissic Complex has undergone dextral ductile shearing; the most intense ductile deformation occurring at the contact between metavolcanic and metasedimentary rocks. Accordingly, the author suggests to name this wide domain of dextral ductile shear the "Hemlo Shear Zone".

CONCLUDING DISCUSSION

The subhorizontal stretch lineation, together with the mesoscopic kinematic indicators demonstrates that the Hemlo deposit is contained within a major dextral ductile shear zone. The ore horizon itself has been described as the Lake Superior Shear Zone and is situated at the boundary between felsic metavolcanic and metasedimentary rocks. The metamorphic fabric of the rock material indicates that the shear zone has been active during the peak of metamorphism. The curvature of the most intensely deformed rocks around the Pukaskwa Gneissic Complex seems to suggest accomodation of the shear to the boundary of this complex. This is further supported by the plunge of the stretch lineation, i.e. eastward at the eastern edge, subhorizontal in the middle, and westward at the western edge. The interrelationship between metamorphism and deformation indicates that the shear zone was active either during a late stage of emplacement of the Pukaskwa Gneissic Complex, or during the emplacement of the Cedar Lake Pluton. Further field work is needed, but the problem could be resolved with radiometric age-dating of these intrusions, and of the plagioclase porphyry dikes, which are spatially associated with the ore zone (Patterson 1983) and are far less deformed than the ore horizon.

The inversion of fold axis plunge from one limb to the other of the megastructure can be explained by a dextral deformation process. Experimental deformations by simple shear demonstrate that competent layers embedded in a ductile matrix form buckle folds whose orientation depends on the initial obliquity of the layers relative to the shear planes (Hugon 1982). Thus, apparent S and Z folds with opposite plunge can develop from a horizontal open fold by transcurrent shearing. It is therefore suggested that the large scale structure in the Hemlo area was entirely formed during an event of heterogeneous dextral shearing. Accordingly, the western limb of the structure is equivalent to the eastern limb but transposed by dextral ductile shear, with a shear gradient increasing towards the southwest. Bedding reached an oblique position during the shear-induced rotation that permitted northwest plunging folds to form. Further deformation and accomodation to the Pukaskwa Gneissic Complex overturned and rotated the hinge of the megastructure while minor folds on the eastern limb started to develop. Subcoaxiality of the fold axis and intersection S_0/S_1 on the western limb, and oblique dextral shearing on the eastern limb give support to that interpretation, as well as the progressive change of asymmetry from S to Z on the western limb. This suggests that the actual geometry of the structure was not caused by regional compression or buckling.

The comparison of the Hemlo deposit with the Madsen deposit leads to interesting parallels. Both deposits show some similar characteristics: (1) they are tabular bodies within the plane of foliation; (2) the ore in both cases is hosted by relatively high grade metamorphic rocks; (3) both deposits are located within ductile shear zones that were active during a peak of metamorphism; (4) both deposits occur at a contact between 2 different lithological units. They both also display an alteration of the feldspar into sericite although in different degrees—considerable microcline is preserved at Hemlo. This sericitization permitted feldspar or quartz grains or aggregates to remain quasi-rigid within a soft micaceous matrix, despite high strain intensity in the rock. In the case of the Madsen deposit, thin sections reveal that the quartz grains or quartz aggregates of the most deformed sericitic schists are in fact strongly deformed into ribbon quartz parallel to foliation. Work with thin sections from the Hemlo area will indicate if further parallels between the 2 deposits can be drawn. At the present stage of the study the only noticeable difference between the 2 areas is the sense of shearing.

Our present understanding of the geology of the Hemlo area does not permit establishment of a genetic model for mineralization. Patterson (1984) summarized a number of possible models. The Hemlo deposit contains minerals such as orpiment, realgar, and thallium-rich minerals, leading one school of thought to propose similarities with epithermal gold mineralization, and further suggesting a New Zealand hot spring model for mineralization. The 2 islands of New Zealand are dissected by a fault system several hundred kilometres in length (the Alpine Fault in South Island), related to plate tectonic processes. The hot springs of New Zealand show a marked spatial relationship with the regional fault systems (*see* for example, Ellis and Mahon 1964, Figure 1). Therefore, *if* the Hemlo deposit has any genetic affinity with hot-spring type deposits, perhaps their mutual association with regional fault systems is the critical relationship.

ACKNOWLEDGMENTS

The author wishes to thank Steve Manz (Fourth year student, University of Toronto) for assistance in the field, P.C. Walford (Chief Geologist, Lac Minerals Limited) for his helpful cooperation and W.M. Schwerdtner (Professor, University of Toronto) for improvements to the author's manuscript.

The author also wishes to thank A.C. Colvine, A.J. Macdonald (Mineral Deposits Section), and T.L. Muir (Precambrian Geology Section) for constructive discussion.

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42. Studies of Mineral Deposits in the Abitibi Belt

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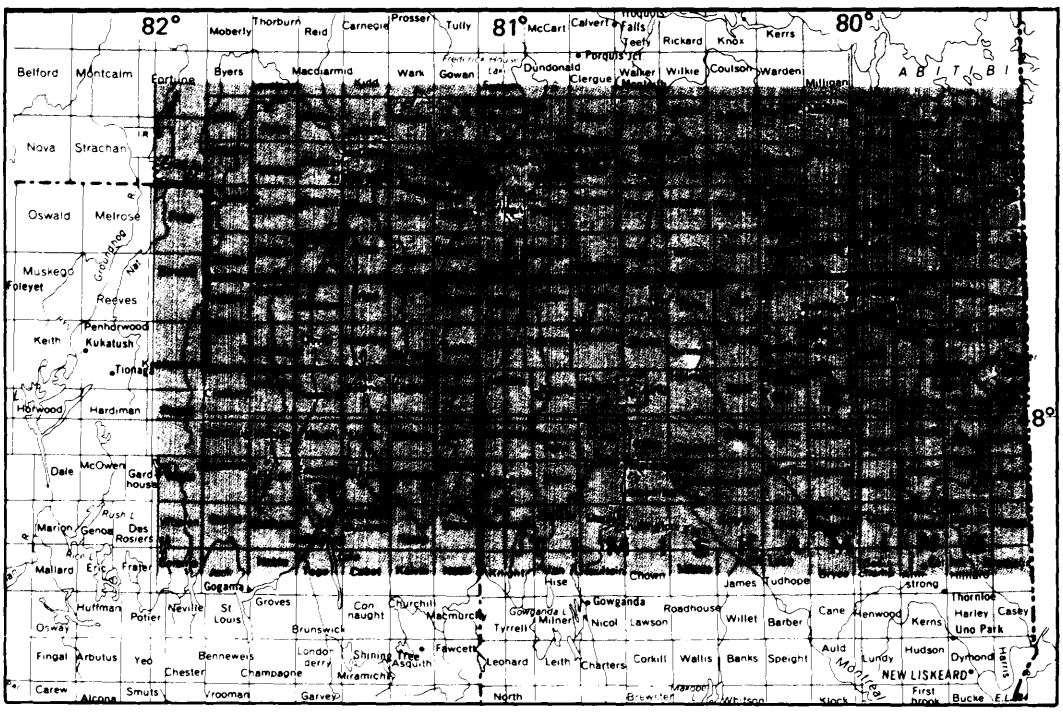
INTRODUCTION

Studies by personnel of the Mineral Deposits Section in the Abitibi Subprovince in 1984 again concentrated on the geology of gold mineralization. The author continued an investigation of the association of gold mineralization with felsic magmatism, by reconnaissance surveying of granitoid rocks in the Timmins-Kirkland Lake area, and by sampling at the Macassa Mine (Lac Minerals Limited) at Kirkland Lake, and at the Murphy-Garrison Mine (Kerr Addison Mines Limited) in Garrison Township. J.V. Hamilton (Hamilton and Hodgson, this volume) completed field work for a study of lithologies and structures in Hearst, Gauthier, McGarry, and McVittie Townships in the highly gold-productive area of Larder Lake. Soussan Marmont continued her program of U-Pb zircon geochronology, primarily in the Timmins area (Marmont, this volume). Studies of base and precious mineral deposits and occurrences and an evaluation of industrial mineral potential were initiated by John Malczak and P.J. Whittaker (Whittaker and Malczak, this volume) within a 40 township block centred on the Destor-Porcupine Fault Zone in the Black River-Matheson area. These latter studies are the initial participation by the Mineral Deposits Section in an interdisciplinary geoscience program (BRIM) in the Black River-Matheson area. The intent of this comprehensive study is discussed elsewhere (Fortescue, this volume). Contributions to bedrock and surficial mapping programs as well as geophysical and geochemical studies, are integral components of the BRIM program, and are also presented elsewhere in this volume.

FELSIC MAGMATISM AND GOLD MINERALIZATION

Previous work in this program (Cherry 1982; Cherry *et al.* 1983) concentrated on field observations and sampling. The current emphasis in the program is upon petrological and petrochemical studies utilizing samples collected largely during this earlier field work. During the 1984 field season, additional sampling was done at the Macassa and Murphy-Garrison Mines.

Sampling was done at the Macassa Mine in requirement of 2 aspects of the continuing study of gold mineralization in the syenite complex that hosts



LOCATION MAP

Scale : 1 : 1 584 000 or 1 inch to 25 miles

much of the gold in the Kirkland Lake camp. One group of samples was taken as sequences collected at starting points away from major faults (Main and '04 Breaks); then through altered basic syenite, porphyritic syenite, and tuff; and into their unaltered equivalents, to provide a suite of sample material for studies of the alteration. One characteristic of many of the intensely altered, ore-associated rocks in the Macassa Mine is a thorough reddening (Watson and Nemcsok, in preparation). Specularite veins that cut altered rocks are common in the mine; the reddening and specularite are evidence of hematitization as an ore-related alteration process which will be investigated by petrographic and petrochemical studies. The second sampling program gathered quartz from veins in the Main and '04 Breaks, from lode and breccia stopes, and from the post-ore Tegren Crossfault over a vertical distance from the 1500 level to the 6300 level. These samples, which provide the greatest vertical range currently available through a gold deposit in North America, will be used in a fluid inclusion and stable isotope study to document any vertical variations in the ore-related fluids.

Kerr Addison Mines Limited has recently completed a diamond-drill program to evaluate additional gold-bearing zones on the Murphy-Garrison Deposit, and allowed examination and sampling of core from this drilling. These samples will be incorporated into a study of this deposit.

Several research programs, conducted with the assistance of the Mineral Deposits Section, and pertinent to understanding the association of gold mineralization with felsic intrusive rocks, have recently been completed. These include B.Sc. theses on the Canadian Arrow Mine in Hislop Township (McNeil 1983) and on the Murphy-Garrison Mine (Carrigan 1984), and a Ph.D. thesis on the geology of the Macassa Mine (Watson, in preparation). The latter is the basis of a research paper supported by the Mineral Deposits Section (Watson and Nemcsok, in preparation) which will provide a new description of the geology of the Macassa Mine.

ACKNOWLEDGMENTS

Kerr Addison Mines Limited and Lac Minerals Limited (Macassa Division) permitted sampling and provided access to properties. Discussions with Shawn Trueland, Exploration Geologist, Kerr Addison Mines Limited, and with George Nemcsok, Area Chief Geologist, Macassa Division, Lac Minerals Limited, and the geological staff of the Macassa Mine, are gratefully acknowledged.

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43. Structural Geology and Gold Mineralization in the Kirkland Lake-Larder Lake Deformation Zone

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INTRODUCTION

Most geological studies of vein-type gold deposits done previous to the 1960s interpreted their location to be controlled mainly by structures in the host rocks. More recent studies, specifically on Archean gold deposits, have tended to stress the importance of stratigraphic setting. In terms of exploration strategies for gold it is important to carefully determine, from all available data, the most relevant controls of gold deposition.

Within the context of this metallogenic problem, a study of the geology, in particular deformational styles and lithologies, was initiated in 1983 in McGarry, McVittie, Gauthier, and Hearst Townships—an area within the highly gold-productive south central part of the Abitibi "greenstone" belt—to document the relative structural chronology of the area, and to determine the controls on the lode gold deposits (Hamilton 1983). The results of the 1984 continuation of this program are described in this summary report.

The volcanic stratigraphy in the Kirkland Lake area has been described by Jensen and Langford (1983), and certain lithological relationships pertinent to gold deposition in the area have been defined. Thomson (1943, 1949) and Downes (1979, 1981) have previously described the area around Larder Lake and have made important observations on the structural and stratigraphic complexities in the rocks.

STRATIGRAPHY

Thomson (1943, 1949) recognized 2 major time-stratigraphic units of volcanic and sedimentary rocks: an older Keewatin Series of mafic to felsic volcanic rocks with minor interflow sedimentary rocks, and an unconformably overlying, younger Timiskaming Series comprising dominantly clastic sedimentary rocks and trachytic flow units. As part of an Ontario Geological Survey program of synoptic mapping in the Abitibi belt, Jensen (1978) and Jensen and Langford (1983) subdivided and redefined Thomson's units, recognizing 2 major volcanosedimentary cycles in the area. Each cycle was recognized as having a basal komatiitic, middle tholeiitic, and upper calc-alkalic sequence. A differentiation trend from mafic or ultramafic to more felsic rocks was defined within each sequence. The sedimentary rocks south of the Kirkland Lake-Larder Lake 'Break', which had been assigned by Thomson to the Timiskaming Series, were assigned by Jensen and Langford (1983) to part of the basal unit (Larder Lake Group) of the upper volcanosedimentary cycle. This was done because the interbedded conglomerates lack the trachyte and jasper clasts characteristic of sedimentary rocks north of the Kirkland Lake-Larder Lake 'Break', and because they contain ironstone and abundant komatiite clasts. In this study, a number of areas were examined where Thomson mapped unconformable relationships between sedimentary and volcanic rocks in Hearst Township. Most of these contacts were found to be loci of intense deformation. At several localities pillow elongation and facings were inclined at a high angle to bedding in the sedimentary rocks, suggestive of an unconformable relationship. Further south in Skead Township, Hewitt (1949, p.17) clearly demonstrated an unconformity between the Keewatin Series and the overlying Timiskaming sedimentary rocks. Considering also that there is a similarity in the textural features of sedimentary rocks north and south of the 'Break', the differences in clast types and in their proportions are considered not to be sufficient evidence to confidently redefine Thomson's Timiskaming Series. Thomson's interpretation, that Timiskaming Series sedimentary rocks unconformably overlie Keewatin Series volcanic and interbedded sedimentary rocks, best fits the field relationships mapped by the present survey.

STRUCTURE

Structurally, the Kirkland Lake-Larder Lake area consists of wedge and lozenge-shaped domains of relatively little internal strain, bounded by zones of intense shear and strain, and, similar in many ways to the structural pattern suggested by Poulsen (1983) in the Mine Centre-Fort Frances area of northwestern Ontario. The overall zone encompasses an area several kilometres wide and crosses the central part of the area shown in Figure 1. Numerous subparallel and anastomosing shear zones, lozenge-shaped areas of relatively undeformed rock, and a high ratio of deformed to undeformed rocks are character-

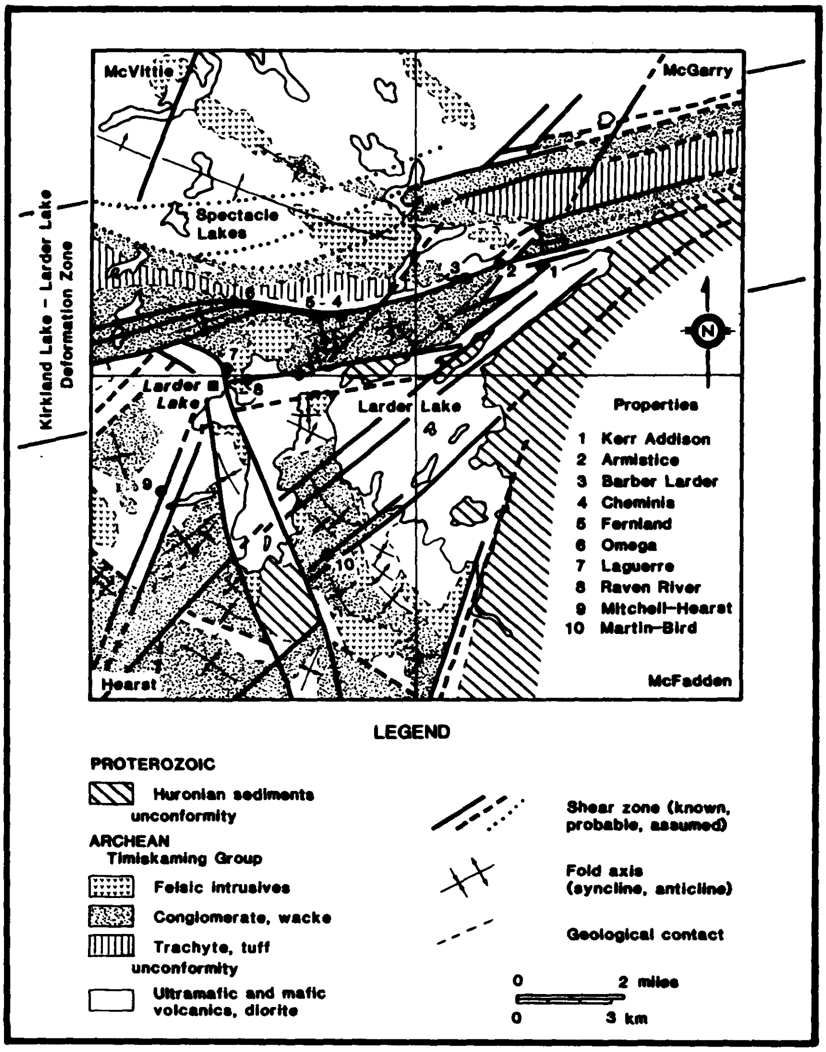

Figure 1. Geological sketch map of the Larder Lake area, showing major structures and stratigraphy within and adjacent to the Kirkland Lake-Larder Lake Deformation Zone (*modified from* Thomson 1949). (Project 43.)

istic of this zone, which has traditionally been called the Kirkland Lake-Larder Lake Break, but which is probably better termed the Kirkland Lake-Larder Lake Deformation Zone. A highly characteristic feature of this deformation zone is the variability in the structural and lithological characteristics of the relatively undeformed blocks within it. For example, north of the Kerr Addison Mine, a block of thin-bedded turbidites with traceable bedding subparallel to the block boundaries is contrasted to the south, across a planar zone of high strain, with a block of thick-bedded, tightly folded arkose. To the north, across a shear zone, the block of turbidites is contrasted with a block of trachyte in which the bedding is inclined to the block boundary. The apparent juxtaposition, at other locations, of thin-bedded turbidites with fluviatile or fan conglomerates suggests that considerable telescoping of stratigraphy has taken place across shear zones within the larger scale of the Kirkland Lake-Larder Lake Deformation Zone. This telescoping of stratigraphy many account for the lithological differences of clast types in conglomerates north and south of the main east-west shears in the area.

SHEAR ZONES

Several sets of major shear zones of specific orientations cut the study area into large domains of complexly folded strata. The intersections of these major structures commonly host gold occurrences.

The most prominent shear zones in the area trend generally east-west and dip steeply to the south. One zone of particularly high shear strain, the Kirkland Lake-Larder Lake shear zone, which varies in width from metres to 10s of metres within the Kirkland Lake-Larder Lake Deformation Zone, can be traced along strike from Matachewan in the west into Quebec in the east (Thomson 1943). These east-west shears become less prominent to the north in Arnold, Katrine, and Ossian Townships, where shearing becomes less intense. Field evidence suggests that these shears were probably active over a long period of time and may have recorded both sinistral and dextral relative movements during this long strain history. The Kerr Addison, Omega, McBean, Upper Canada, and Ossian gold deposits, and many other gold occurrences lie: (1) within shear zones of this orientation, (2) along related splay shears, or (3) at intersections of shears.

Another prominent set of subvertical shear zones is oriented in a northeast-southwest direction. This orientation is prominent in Hearst and McGarry Townships, where the northeastern arm of Larder Lake is underlain by shears of this set. These dominantly sinistral shears offset and are deflected by the east-west shears, but tend not to develop the same degree of intensity of deformation. The Martin-Bird Property in Hearst Township lies within a shear zone of northeast-southwest orientation, while the Kerr Addison Mine in McGarry Township lies within the intersection of shears of this orientation and the east-west shears.

A set of subvertical, sinistral shears, trending 020° to 030°, and prominent in Teck and Lebel Townships, is only occasionally developed in the Larder Lake area. The development of these shears and associated sympathetic faults probably postdates activity on the east-west and northeast-southwest oriented shear sets. Several gold properties, including the Mitchell-Hearst Property in Hearst Township, are situated within shears of this orientation.

A subvertical shear system, generally trending 160° to 170°, is strongly developed parallel to Highway 624 south of the town of Larder Lake in Hearst Township. Several of these shears bound the north-south oriented peninsula on the southern shore of Larder Lake. Gold mineralization is associated with shears of this orientation where they intersect east-trending shear zones in Arnold and Katrine Townships.

Within the shear zones, each rock type has developed different deformation and alteration products. Mafic volcanic rock usually is converted to a chlorite schist. Conglomerate is altered to a fissile rock with flattened or elongated clasts, and the finer-grained matrix foliated in the plane of flattening. Fine-grained sedimentary rocks initially acquire a banded cleavage through metamorphic differentiation, and then are transposed into the shear plane, resulting in a fine-grained, slatey rock. In some areas, conjugate or intersection cleavages are developed in quartz-feldspar porphyries. Where such rocks have been sheared, they can easily be mistaken for monomictic agglomerate or conglomerate. Some of the units mapped as 'cherty tuff' have been highly strained and show fine banding which is usually oriented in the local shear plane attitude. It is difficult to determine in many cases whether such rocks are highly strained and altered mafic volcanic rocks, or originally less competent, tuffaceous units that have accomodated strain more easily than the surrounding massive volcanic rocks. These possible physical and chemical alterations, produced by and associated with deformation, may be common in the lithologic assemblages of highly strained deformation zones.

STRUCTURAL EVOLUTION

Fold structures, planar fabrics, and shear zone development can be divided into 3 generations of deformation designated as D_1, D_2, and D_3.

D_1 STRUCTURES

F_1folds in the study area are large scale, tight folds with west-northwest-trending axial surfaces as determined by pillows and flow top determinations in volcanic rocks (i.e. Spectacle Lake Anticline in McVittie Township, *see* Figure 1), or by bedding top determinations in sedimentary rocks (i.e. Hearst Township, Figure 1).

The development of a subvertical, west-northwest- trending cleavage (S_1) axial planar to F_1 folds is variable, being absent on a mesoscopic scale in some areas, and well developed in others. This S_1 cleavage (Figure 2) is manifest most distinctly in fine- to coarse-grained sedimentary rocks bordering areas of high shear strain, and is defined by a lithological banding of variable thickness, averaging less than 1 cm. This striped cleavage is probably best attributed to pressure solution, with little or no apparent shearing, developed along cleavage surfaces. S_1 surfaces swing into the direction of shearing

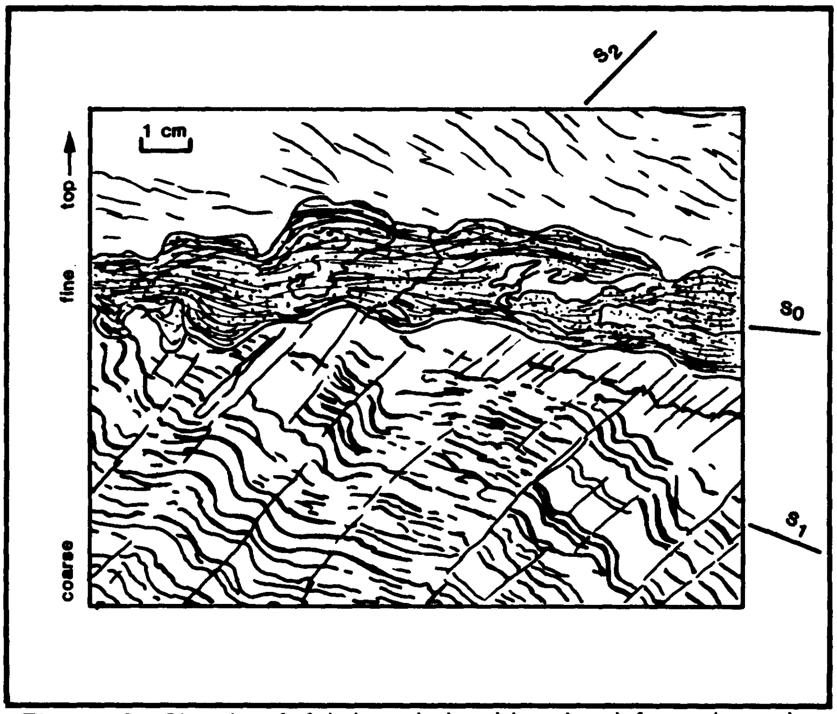

Figure 2. Sketch of fabric relationships in deformed wacke adjacent to a high shear strain zone. The fine-grained top of the bed is the locus of shearing that produces a fabric parallel to bedding. (Project 43.)

where shear fabric is developed.

D_1 structures flatten into an east-west direction near high strain shear zones. This may be a result of progressive deformation, or of continuous reorientation of principal stress axes on a regional scale.

D_2 STRUCTURES

F_2 folds, with subvertical axial surfaces trending 040° to 060°, are developed in sedimentary units near the Kerr Addison Mine and in Hearst Township (Figure 1). Axial planar cleavage (S_2) is well developed in sedimentary rocks, particularly near zones of high shear strain. The fabric is a slatey cleavage in fine-grained beds, a spaced cleavage in coarse-grained wackes, and a banded cleavage in more arenaceous beds. S_2 surfaces crenulate S_1 surfaces where both are developed; S_2 surfaces both crenulate, and bend into, the east-striking shear fabric (Figure 2). In beds where S_1 and S_2 surfaces are variably developed as banded surfaces, the S_2 surface partially or wholly rebands the early cleavage by metamorphic differentiation, developing thin seams of chlorite separated by more felsic material in the S_2 orientation. The S_2 cleavage is the strongest cleavage developed in the area.

D_3 STRUCTURES

There is a late development of a possible conjugate set of kink bands. One set is dominantly dextral with vertical boundaries oriented between 020° and 055°. The other set is sinistral with boundaries oriented between 080° and 120°. These kinks refold earlier surfaces and have no influence on the regional geometry of the stratigraphy.

STRUCTURAL INTERPRETATION

The principal structures described above are all features of deformation by regional compression. The early folds and shears can be related in a kinematic sense to regional wrench faulting as documented by Poulsen (1983) for the Wabigoon Subprovince in northwestern Ontario. The formation of different shear systems suggests an evolving stress environment which initially produced north-northeast-trending compression and relative sinistral movement on the early east-trending zone of shears. In the Larder Lake area, the major east-west deformation zone may represent part of a 'megashear' within a larger structural framework.

The distribution of lithologies with respect to internal structures and fabrics suggests that a large part of the deformation occurred during deformational event D_1. The original north-northeast orientation of the maximum compressive stress axis may have progressively evolved in to a more north-south orientation to produce the flattening and folding in an east-west plane. Thus, this latter stress field would have produced the major west-northwest-trending folds, east-trending folds, and sinistral movement on east-west and northeast-southwest oriented shears. A conjugate dextral shear system oriented approximately north-northwest may also have developed at this time (Figure 3a).

Deformational event D_2, with a northwest-southeast direction of maximum compressive stress, produced northeast-trending folds and possible relative dextral movement along some of the major east-

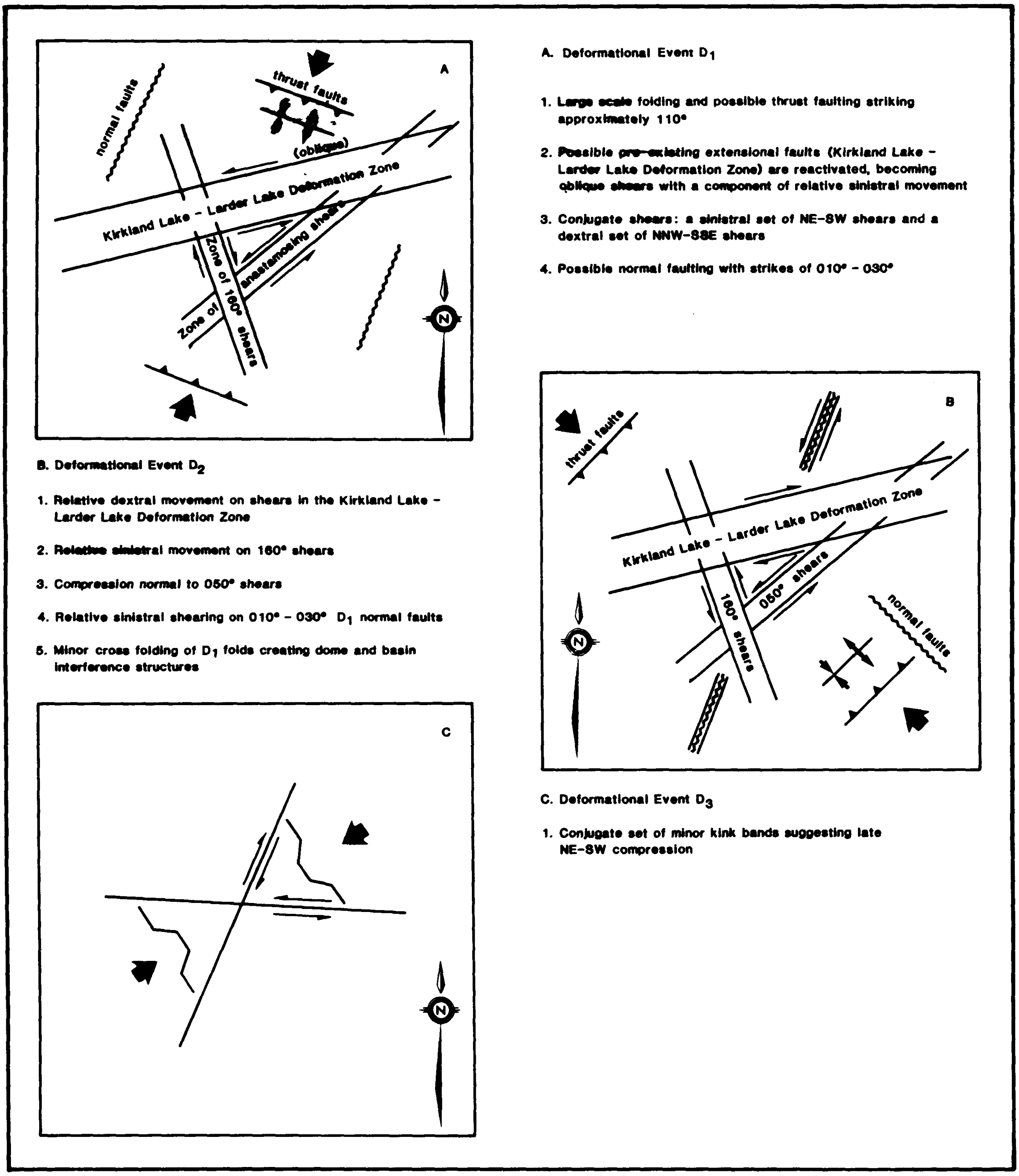

Figure 3. Schematic diagrams of a possible interpretation of the major structural elements and their relationship to maximum compressive stress directions during deformational events D_1, D_2, and D_3. (Project 43.)

trending shears (Figure 3b). A dome and basin interference pattern in central Hearst Township may have been produced by the cross folding of F_1 folds by F_2 folds.

Minor D_3 kink band structures developed late in the deformational history and would have required a northeast-southwest directed compression (Figure 3c).

The unconformity separating the Timiskaming sedimentary rocks from the underlying volcanic and minor sedimentary rocks represents a significant break in the history of the area. The present interpretation of the deformational history is largely dependent on information on the structural fabric gleaned from the overlying Timiskaming sedimentary rocks. Consequently, the entire history of deformation may be more complicated than that outlined above, as the pre-Timiskaming Series history has yet to be deciphered. The early structural history may only evolve through the careful mapping of flow contacts, individual flows and markers, pillow facing directions, and shearing. Given the general paucity of instructive outcrop in key areas, this may prove to be a formidable task.

GOLD MINERALIZATION

Virtually without exception, all gold deposits and occurrences in the Larder Lake area lie within or adjacent to major shear systems. The deposits occur primarily as lodes of quartz-carbonate veins, pods, and shoots cutting all of the major rock types in the area. Gold also occurs associated with pyrite in replacement zones within larger shear zones, i.e. 'flow' ore at the Kerr Addison Mine. Many of the deposits have common alteration and structural characteristics depending to some extent on host rock lithology. The siting of gold concentrations is most significantly controlled by tectonothermal events in structural zones of intense shearing and folding, often intimately associated with felsic intrusive bodies. Ground preparation (i.e. dilation of shear fabric, dilation of fractures in competent rocks, and brecciation) is of major importance in the larger deposits (e.g. Kerr Addison Mine) which occur at the intersection of 2 or more shear zones. The multiple generations and complex configurations of quartz veins that characterize many of the deposits suggest a prolonged history of hydrothermal activity and deformation. Two important quartz-carbonate vein sets are common in the deposits. One set is usually subparallel to the shear fabric, which is characteristically subvertical; the other set is usually subhorizontal. Field relationships suggest that the timing of gold mineralization was late in the history of deformation, felsic intrusion, and alteration.

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44. Preliminary Report on the Geology of the Detour Lake Gold Mine, District of Cochrane

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INTRODUCTION

A project to study the geological setting of the Detour Lake open pit gold mine was started in the summer of 1984. The objectives of this project are:

1. To document, in detail, geological characteristics of the orebody as a guideline for further exploration in the immediate vicinity of the deposit as well as for prospecting of similar deposits in the region.
2. To compare the geological setting of this deposit with other areas of mineralization studied in the Archean lode gold deposits program of the Mineral Deposits Section. The objective of this program is to determine if systematic geological similarities exist between deposits, which may provide aid to further exploration.

The first stage of this project consists of detailed mapping of all available exposures in the open pit area. This phase was carried out during July and August, 1984, and will be continued with the development of the open pit. The field mapping will be followed up by petrographic, structural, and geochemical (including isotopic) studies. Future field work will incorporate a regional study away from the present mine workings as well as underground mapping of the mine when accessible.

BACKGROUND INFORMATION

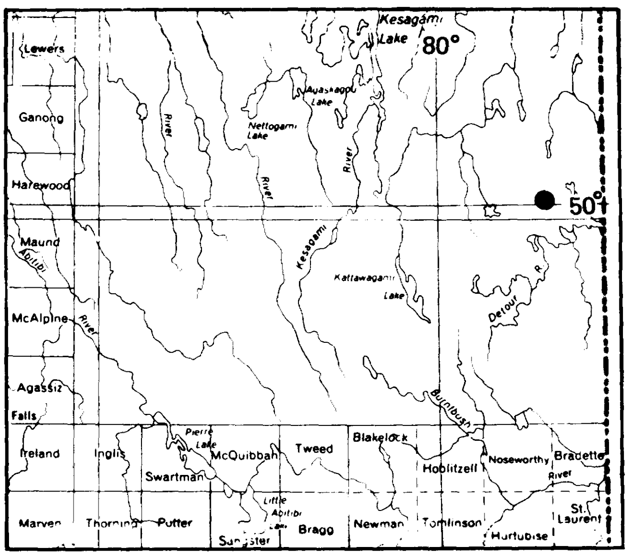
The Detour Lake Gold Mine is located approximately 140 km northeast of Cochrane in northeastern Ontario, at Latitude 50°00'50"N and Longitude 79°42'20" W, some 13 km west of the provincial border with Quebec (Johns 1982). Access to the mine site is via a gravel road (approximately 200 km) from either Cochrane or Iroquois Falls.

In 1974, Amoco Canada Petroleum Company Limited tested an airborne conductor by diamond drilling and discovered auriferous sulphide mineralization. In 1977, a 2500-foot (762 m) decline to the 396-foot (120 m) level, and 1000 feet (304 m) of drifting and cross-cutting were developed to further test the anomalous zone. A 100 ton bulk sample and extensive underground drilling established the presence of a sizeable orebody.

Presently the mine, which started production in August 1983, is being operated as an open pit (Figure 1) by Amoco's equal joint venture partner: Campbell Red Lake Mines Limited, Detour Lake Project. Open pit mining is planned to continue for another 4 years to a depth of 120 m. Overlapping with the open pit mining phase, production from underground workings will commence. The reported tonnage to date is 30.6 X 10^6 tons with an average grade of 0.113 ounce gold per ton (Toronto Star, November 5, 1983).

GENERAL GEOLOGY

The present survey has indicated that the orebody is an east-trending structure that dips to the north and plunges to the west. At the eastern end



LOCATION MAP

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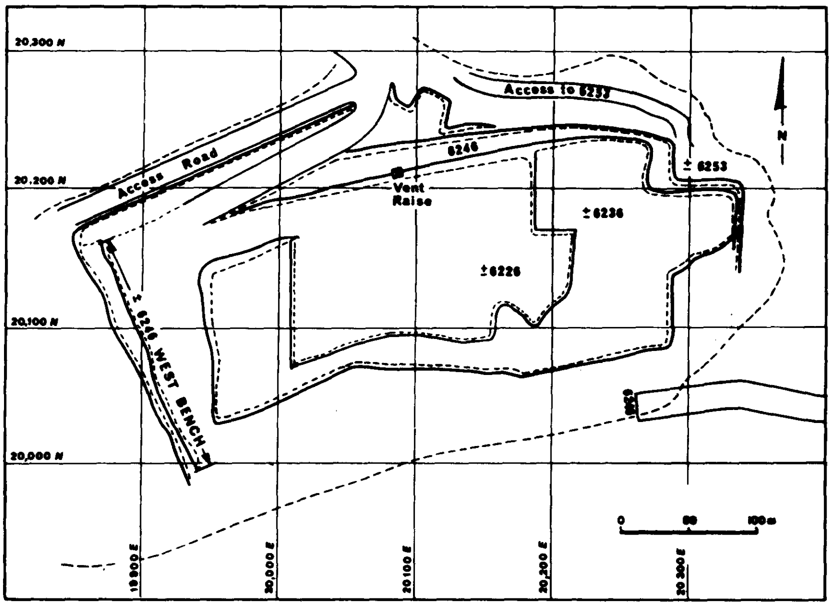

Figure 1. Simplified outline of the Detour Lake open pit, August 1984. (Project 44.)

it is faulted off and its extent to the west has not been defined.

The following is a brief description of the main geological features observed in the field. These observations may be further elaborated as laboratory studies take place. For the sake of consistency, references to the southern parts of the open pit can be equated with the mining term "footwall of the orebody" and the northern pit area refers to the mining term "hanging wall of the ore body". Alteration, deformation, and subgrade mineralization extend into the "footwall", however, and are pervasive throughout the "hanging wall".

MAIN LITHOLOGIES

The following is a brief description of the main characteristics of the lithological units recognized by the author in the mine area. Figure 2 is a vertical cross-section of the 6246W bench and, with the exception of clastic metasedimentary rocks and mafic dikes, shows all of the other units present in the open pit. It should be emphasized that the lithostratigraphic relationships of some of these units have not yet been determined and some may represent altered and deformed equivalents of one or more primary lithologies. Direct contacts between the main lithological units were observed in only a few places.

CLASTIC METASEDIMENTARY ROCKS

A series of dark grey-black units showing a prominent compositional layering is present in the southern (footwall) part of the mine. These rocks consist of light beige, medium- to coarse-grained, micaceous, quartzofeldspathic layers, 2 to 3 cm wide, in contact with dark grey-black, fine-grained to aphanitic layers, 5 to 6 cm wide.

The layers have an overall strike of 100°-120° and dip between 40° and 70°N. At the time of mapping, these layers were exposed over an intermittent strike length of approximately 200 m. Their lateral extent is not known due to a very thick cover of overburden. Their vertical (down dip) extent may become better defined with further development of the open pit. The stratigraphic location of these units has not yet been ascertained. With the exception of the northeastern corner, no direct contacts with the other lithological units are exposed.

Some of the significant features observed in the field are as follows:

1. Large, euhedral, black hornblende crystals overgrow the layers. In hand specimen it appears that these crystals have a random orientation, overgrowing the foliation plane. However, microscopic examination of oriented samples will clarify the timing of the growth of the metamorphic minerals relative to the development of the dominant fabric of the rocks. This will also aid in establishing the presence or absence of graded bedding.
2. The coarser grained layers show the development of small boudins. Boudins, 2 to 3 cm long, form either continuous sinuous layers or detached, spaced beads. In some instances subtle rotation of the boudins was observed.
3. In one of the most southerly exposures, highly con-

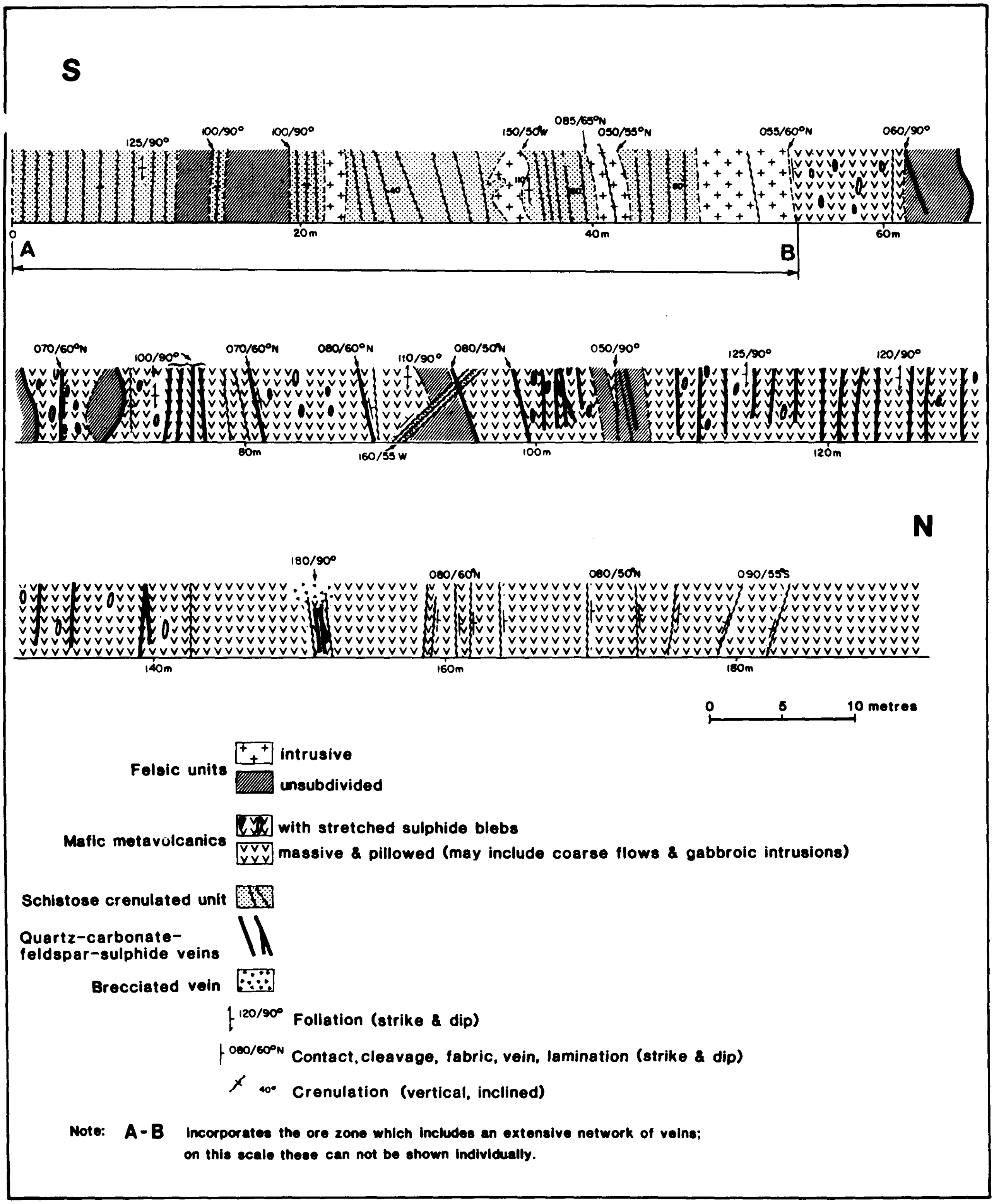

Figure 2. Vertical cross-section, from north to south, of the 6246 West Bench, Detour Lake open pit. (Project 44.)

torted beds are present. The fold closure and axis cannot be located at this site due to overburden cover. The contortions may represent parasitic folding on the limb of a major fold.

4. Throughout the exposed surface of the layered rocks rusty and calcareous patches are present. On a gross scale, the beige carbonate and the rusty sulphide appear to be concordant with the layering of these rocks. Close examination reveals that the carbonate material forms discontinuous, lensoidal seams that preferentially follow foliation planes, and the rusty sulphidic patches vary from concordant to cross-cutting stringers, or halos to quartz veinlets. These veinlets, although not of economic grade, constitute part of the mineralizing system.
5. A series of concordant and discordant, highly siliceous, whitish-grey units cut the well layered rocks. They vary in width from a metre to a few centimetres. The rock is aphanitic and strongly laminated. Normally, the lamination cleavage is parallel to the contacts of the siliceous unit with the layered rocks.

Sulphide mineralization, most commonly pyrite, is ubiquitous and accentuates the strong cleavage in this rock type. Although no igneous texture is visible in hand specimen, the geometry of these units and their cross-cutting relationship with the layered rocks suggest that they may represent dikes and offshoots of a felsic intrusive unit that is found in direct contact with these rocks, in the same exposure.

The concordant compositional layering may represent one of the following:

i. An originally graded bedded sequence which, in its present location and exposure, would indicate a north facing section.
ii. A sequence of sedimentary beds with strong tectonism accentuating layering of the bedding planes.
iii. A pile of mafic rocks of nonsedimentary origin which have suffered extensive shearing, and represent the focal region of strain in a shear zone.

The author considers these rocks as representive of a metasedimentary package (the facing direction of which is not yet known). They may, however, belong to the same environment as the metavolcanic package of rocks with which they occur, or they may have been juxtaposed against these rocks. In the latter case, their characteristics do not have any direct relationship to the environment in which the volcanic pile was formed. Trace element geochemistry of individual and collective samples from the layers may clarify the provenance of these rocks.

Felsic Rocks

The felsic rocks in the mine area are broadly categorized into 2 groups:

1. Felsic intrusive rocks which, through their field characteristics, their geometry, and sometimes a porphyritic texture in hand specimen, show well defined intrusive features.
2. Felsic units which do not show a granular texture in hand specimen, are aphanitic and massive, and, as a result of extensive alteration and strong deformation, lack any primary features. At this stage these rocks cannot be specified as intrusive, extrusive, or altered nonfelsic rocks. Their primary nature will become more evident after petrographic, structural, and geochemical studies. At this stage, all of the felsic units are known to be cut by auriferous veins.

Felsic Intrusions With the exception of some dikes, the areal distribution of the felsic units is restricted to the southern parts (footwall) and ore zone of the present open pit.

At the southeastern corner of the pit, a feldspar porphyritic unit, possibly a plug, can be seen in direct contact (115° strike, 90°dip) with the well layered sequence described above. This rock is light grey and highly siliceous with a fine-grained matrix which contains fine-grained (up to 1/2 mm) feldspar phenocrysts. Near the southern contact between the feldspar porphyry and the metasedimentary rocks, a very strong cleavage parallel to the contact is developed. In these areas, the feldspar porphyry shows a distinct resemblance to the siliceous units, which are both foliation parallel and foliation oblique to the well layered units. Angular, mafic xenoliths are observed in the vicinity of the contact. Sulphides, predominantly pyrite, are ubiquitous.

In the south central (ore zone) section of the open pit, the feldspar porphyry extends over a strike length of several tens of metres. It consists of a fine-grained maroon-mauve matrix with euhedral chalky feldspar phenocrysts and is cut by a stockwork of quartz-carbonate microveinlets and veins, each of which has its own alteration halo. The density of the veining is variable. In places, individual veinlets and their alteration halos are readily distinguishable. In most cases, however, the increased density of the stockwork of veins, and the merging of their alteration halos, gives rise to a totally bleached, aphanitic, and massive rock. This rock intrudes the layered sequence and mafic metavolcanic rocks (*see* below) and, in most instances, shows a sheared and veined "contact zone".

In the southwestern (footwall and ore zone) section of the open pit, another feldspar porphyry and a biotite-feldspar porphyry intrude the mafic metavolcanic rocks. The feldspar porphyry is a maroon, fine-grained granodiorite-diorite which contains fine-grained (0.5 to 1 mm) pink potassium feldspar phenocrysts. This unit is at a 110°/90° contact with a schistose unit (*see* below). The biotite-feldspar porphyry is a pink, fine- to medium-grained unit which carries euhedral feldspars and fine-grained books of black biotite. This rock is at an 085°/65°N southern and a 050°/55°N northern contact with the schistose unit.

Approximately 600 m to the west of the present limits of the open pit (at the decline), several feldspar porphyritic dioritic dikes cut variolitic pillow lavas. These dikes consist of a fine-grained matrix containing fine-grained (1 mm), euhedral, salmon pink feldspars. They have several orientations, the 2 more dominant being 055°/65°SE and 120°/80°N.

It should be pointed out that the pink feldspars which occur in all of the porphyritic units, may be original phenocrysts, or metacrysts produced during metasomatism. Further study may resolve their paragenesis.

Approximately 2000 m northeast of the present open pit, several outcrops were examined. A leucrocratic, coarse- to medium-grained, light pink trondhjemite intrudes mafic flows. This rock shows little alteration or deformation. Its contacts, in most cases, are highly brecciated, giving rise to a local hybrid zone.

Unsubdivided Felsic Units

Most of the felsic units exposed in the southwestern and west central parts of the open pit are massive, fine-grained to aphanitic, and equigranular. These rocks vary in colour from grey to pink to maroon. In all the cases observed, they occur either in direct contact with mafic flows (as seen on the southwestern extremity of the exposed area, immediately outside the present pit limits) or are bounded by a highly schistose unit. In the southwestern section of the open pit the contacts of the massive, pink-mauve felsic units are predominantly concordant with the regional foliation at 100° to 110°/90°. Further to the north they consist of aphanitic, highly altered rocks occurring as 3 to 4 m wide zones which cross-cut the mafic flows and, in most cases, are bounded by a schistose unit. These contacts, in most instances, are strongly curved and veined. The highly altered felsic units carry a network of quartz-carbonate veins and microveinlets with distinct alteration halos similar to the stockwork observed in the feldspar porphyry previously described. A mineral lineation predominantly plunging to the west is seen on most joint planes of these felsic rocks.

Based on observations in the underground workings (not seen by the author), J. Spiteri (Chief Geologist, Campbell Red Lake Mines Limited, Detour Lake Project, personal communication, 1984) suggests that these felsic units are rhyolitic flows interlayered with ultramafic (schistose units) flows and represent a volcanic succession. Field observations in the open pit area have not yet provided conclusive evidence, such as volcanic features, top indicators or stratigraphic markers to reinforce this interpretation. The cross-cutting nature of these felsic units, their occurrence away from the schistose unit (which may or may not represent an original ultramafic unit) within the mafic flows, the presence of stockwork veining similar to the network of veins observed in the feldspar porphyry, and in most exposures, their dike-like geometry render a volcanic origin uncertain.

Mafic Metavolcanic Rocks

A sequence of mafic flows comprises the largest volume of the rock units exposed in the open pit. They lie to the north (hanging wall) of the main ore zone, but are themselves mineralized to varying degrees over many tens of metres away from the main zone. They consist of amygdaloidal pillows, variolitic pillows, and massive flows. The amygdaloidal pillows and the massive flows seem to be interfingered and mapping of individual flows was not possible. These units are dark green-black, fine- to medium-grained rocks with a very thin weathered rind. In most cases they are magnetic, which is due to either their magnetite or pyrrhotite content. Where they occur as pillows, their selvages and amygdules are filled with sulphides and/or vein material. The selvages are usually quite thin but show thickening at the pillow corners. Pillow shapes can vary from rounded "light-bulb shapes" to highly stretched, thin lensoidal features. Measurement of numerous stretched pillows yielded ratios of 1:15 to 1:30 for the short and the long axes of the pillows (the 3rd dimension of the pillows is not exposed).

Top determination from pillow shape, location of the amygdules, or thinning/thickening of the selvages was not achieved as these features showed inconsistencies from one exposure to another.

Preliminary examination suggests that these units are tholeiitic basalts (possibly Mg-rich). Following petrographic examination of these flows, lithogeochemistry may yield useful results as throughout the mine extensive alteration of these units is prevalent, and their present geochemical composition is probably substantially different from their primary elemental signatures.

Where pillow structures are absent, the mafic units are massive, granular, medium-grained, black-green, and homogeneous. It is possible that some of these are either coarse-grained flows or gabbroic intrusions. However, considering that the metamorphic grade in the mine area is of upper greenschist to lower amphibolite facies, hornblende-rich, coarse mafic flows and gabbroic intrusions would be expected to appear similar. In the absence of direct, sharp contacts and characteristic geometry, the massive units are not separately mapped at this stage.

Variolitic pillows are exposed 600 m west of the present open pit, at the decline. These rocks consist of dark green mafic pillows containing pink-buff varioles. The varioles show rodded and tubular shapes which suggest extensive stretching. They plunge to the west at angles of 40° to 50°. Pillow selvages are filled with quartz, carbonates, and sulphides. A distinct feature of these flows is the presence of 3 to 4 mm porphyroblasts of greenish-black monoclinic amphibole, which weather in positive relief relative to the felsic varioles. Top determinations on pillows at this location are not possible. The relationship between the tholeiitic amygdaloidal flows and the variolitic pillows is unclear as no direct contact is exposed. In the 600 m distance between the exposures of the 2 lithologies, overburden is thick, and it may be that only in the underground workings will their relative stratigraphic positions become more apparent.

Schistose Unit

Throughout the open pit, a distinct schistose unit occurs in several settings:

1. As narrow, 2 to 10 cm wide, discrete zones within the mafic metavolcanic rocks (hanging wall). In these instances the contacts of the schistose unit and the mafic flows consist of rectilinear zones which vary in strike and dip. In most cases a transition from the dark green mafic flows into a medium grey-green, slightly schistose and friable rock, to a bright green, highly schistose and fissile unit can be traced. The occurrence of the narrow, schistose units in the mafic rocks resembles fault gouges and is attributed to shearing and extensive hydrothermal alteration of the tholeiitic basalts.
2. As 2 to 10 cm wide discrete zones with or within the felsic units, where these occur in the mafic flows (hanging wall). In these instances the schistose unit forms curved boundaries to the veined contacts of the felsic units or it can occur within the felsic rocks. Its presence in this setting is also attributed to alteration and deformation of the mafic wall rock.
3. As 2 to 30 m wide sections with the intrusive and unsubdivided felsic rocks in the area of the main ore zone. In this case, the schistose unit is in sharp contact with the felsic rocks. This contact is usually conformable with the general trend of the ore zone and the regional foliation of the mafic flows. The schistose unit in the ore zone is a highly altered and deformed, green, fibrous, strongly foliated, friable, earthy rock. The foliation is crenulated to degrees which vary from very tight folds to slightly folded, open flexures. Its main mineralogy in hand specimen consists of actinolite/tremolite fibres, carbonates consisting of calcite, and Fe-rich calcite,

and minor dolomite, epidote, talc, and chlorite, both in the matrix and as 4 to 5 mm long clots which commonly transect the crenulated foliation. The schistose unit is normally veined by quartz, chalky white calcite, and sulphide mineralization. In places it shows light green and dark green/black banding due to mineralogical segregation and preferential alteration. This is normally seen in conjunction with a vein halo. Along the foliation planes of the schistose rock, which are coated with black-green chlorite, extensive slickensiding has occurred. Sulphide mineralization, predominantly pyrite grown on the slickensided planes, plunges to the west. The rock has a smooth, soapy feel and it commonly breaks along its foliation planes.

J. Spiteri (personal communication, 1984) interprets the schistose units to the south (ore zone) to represent ultramafic flows. The original mineralogy, chemistry, and any primary lithological characteristics of this unit are considered to be totally obliterated. At this stage, in the absence of any apparent diagnostic features, interpretations as to the origin of this unit within the ore zone are pending.

Mafic Dikes

Within the present open pit, a number of mafic dikes cut the highly altered tholeiitic basalts. These dikes consist of 20 cm to 1 m wide, light green, fissile, biotitic, mafic rocks that resemble a highly altered lamprophyric unit. They cut some of the veining but are in turn cut by other sets of veins. The biotite may be secondary but the high degree of alteration precludes recognition of primary mineralogy.

In outcrops some 2000 m northeast of the present mine area, a black, very fine-grained, magnetic dike cuts both the mafic flows and the leucocratic trondhjemite. On weathered surfaces, laths of feldspar and ferromagnesian minerals suggest a diabasic texture.

ALTERATION AND METAMORPHISM

Pervasive alteration of the primary lithological units is seen over large lateral and vertical distances. In the field the main alteration types recognized are: carbonatization, epidotization, potassic alteration, silicification, and sulphidation. The manifestation of individual or collective alteration processes is highly variable from one lithology to another.

Carbonatization and potassic alteration (both biotite and phlogopite) of the basaltic flows results in a brown-pink colouring. In places, the potassic alteration is preferentially concentrated along zones of the flows, and the rock takes up a banded appearance consisting of dark green and brown layers (Figure 3a). This is seen in relation to veins which in some cases display symmetrical halos. Extensive silicification and sulphidation of the tholeiitic pillow lavas gives rise to a whitish-buff coloured rock which, in the absence of pillow structures, does not resemble a mafic flow. The variolitic pillows show strong silicification and sulphidation manifested as a pink-rusty colour best seen in the varioles. The mafic parts of these pillows are dark to light green on weathered surfaces. On fresh surfaces these rocks are dark green-black and contain amphiboles, epidote, and chlorite.

Alteration of the schistose unit results in a green colour due to the presence of chlorite, epidote, and actinolite/tremolite. As seen in the mafic flows, preferential alteration along cleavage planes results in dark green-black and light green banding in the schistose rocks. In the majority of cases this banding is concordant with the foliation, but in places it has been observed to occur at an angle to it. In all cases it has been seen in close proximity to concordant and/or cross-cutting quartz-carbonate-sulphide veins.

In addition to chlorite in the groundmass, the schistose unit contains numerous 4 to 5 mm long chlorite clots. In hand specimen these chloritic clots appear to have overgrown the schistosity and do not show a penetrative cleavage. However, they do exhibit the same sense of crenulation as the schistosity. It appears, therefore, that the chloritic clots grew after the development of the schistosity and before the crenulation of this fabric. It is suspected that they replace amphiboles and therefore indicate a metamorphic retrogression.

The alteration of the felsic units (both intrusive and unsubdivided) is indicated by the presence of feldspars (mostly potassic), hematite(?), and sericite. The alteration fabric is typically a maroon-mauve matrix cut by quartz-carbonate microveinlets which carry bleached, apple green sericitic halos. In the case of a dense stockwork of veinlets, the maroon colour is only seen as

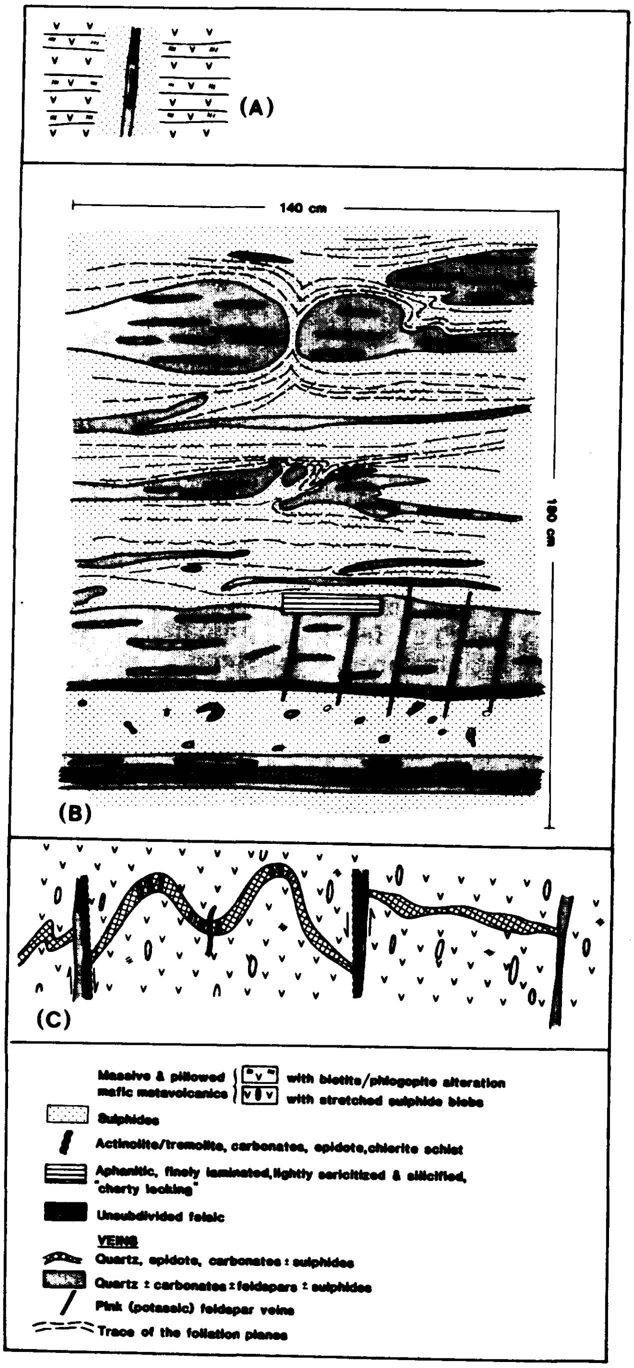

Figure 3. Schematic diagram of some of the veining and alteration patterns in the Main Ore Zone. (Project 44.)

small, irregular patches. In the extreme cases of alteration and deformation, a finely laminated, siliceous, aphanitic, salmon pink unit is developed which shows irregularly shaped bleached zones. This rock in most cases occurs as a potassic feldspar-sericitic alteration halo to quartz-sulphide veins. The aphanitic, bleached and finely laminated nature of this rock gives it a "cherty" appearance. Within it, the lamination and the colour banding, which resulted from alteration, are discontinuous and inconsistent along its strike length.

The metamorphic grade of the volcanosedimentary sequence in the open pit area is considered to be of upper greenschist-lower amphibolite facies. Primary lithologies have determined the metamorphic mineral assemblages which have been produced. Collectively, the following indicator minerals have been recognized as components of the main metamorphic assemblages:

1. Hornblende, black euhedral, 2 to 3 mm, best seen in the metasedimentary rocks and in the mafic flows
2. Garnet, bright red, euhedral, 1 to 2 mm, most prominent in the tholeiitic flows in close association with the sulphidized zones
3. Amphibole, monoclinic, black-green, euhedral, 3 to 4 mm, porphyroblasts grown over variolitic pillows
4. Actinolite/tremolite, black to light green, fibrous needles, both as the main constituent of the schistose unit and also as radial growth in veins
5. Phlogopite, iridescent, brown-pink, 3 to 4 mm

books, both as part of the alteration of tholeiitic flows and as vein material

6. Biotite, black-brown books, distributed throughout the tholeiitic pillow basalts and the felsic intrusions.

Field relationships have not yet yielded definite indications as to the timing of the regional metamorphism and contact metamorphism (from the felsic intrusion to the northeast and south of the supracrustal rocks). The relative timing of alteration and metamorphism may be clarified after petrographic examination. It is apparent, however, that a certain phase of metamorphism took place late in the history of the formation of the rocks (seen as hornblende recrystallization in altered and deformed variolitic pillows and metasedimentary rocks), and may have been contemporaneous with, or immediately preceded the mineralizing events.

VEIN MINERALOGY

Many mineral species constitute the veins. In hand specimen the most common minerals recognized are:

1. Quartz, which occurs both as white bull quartz and as a greyish-blue glassy quartz. It constitutes the largest volume of the majority of all vein sets.
2. Carbonates, which consist of beige-buff iron carbonate, chalky white calcite, as well as yellow, dogtooth calcite. The latter is seen in vuggy, quartz-sulphide-calcite veins.
3. Actinolite/tremolite, which in some cases occurs as radial, fibrous clusters of black needles.
4. Dark green chlorite, which occurs as pervasive alteration throughout the schistose unit and some of the mafic flows, as clots grown over the schistosity plane of the schistose unit, and as wisps and stringers along with quartz and carbonate veins.
5. Light green epidote, constituting a large percentage of the early folded quartz-carbonate veins.
6. Books of black biotite and brown-pink phlogopite.
7. Salmon pink-orange, potassic feldspar. This mineral occurs either as a vein constituent or as the main phase of vein/dike features. In the first instance, the fine-grained feldspar can occur at the margins of the quartz-carbonate-sulphide veins or it may occupy the central part of the veins. In some cases, it volumetrically exceeds the other vein constituents and occurs as pink feldspar veins.

   In the second instance, the pink potassic feldspar occurs in pegmatoidal vein/dike features, where it is very coarse-grained and euhedral, and is intergrown with lighter coloured albitic feldspars and quartz. In some cases it has brecciated its wall rock and contains angular fragments of the altered mafic flows. The dominant strike of these vein/dike features is north-south; they cut some of the vein sets and are in turn cut by some other vein sets. The pegmatoidal nature of these features more closely resembles that of a magmatic rock than a hydrothermal vein. This would suggest that they have been derived from either a very early or a very late, hydrous, potassic, volatile-rich phase of a felsic melt, rather than an aqueous hydrothermal fluid.

   Considering that pink feldspars are present throughout the alteration/mineralization system, both as vein material and as pervasive replacement in the host rocks, it could be of significance to determine their link with the pink feldspars in the pegmatitic dikes.
8. Sulphide mineralization, primarily pyrite, pyrrhotite, and chalcopyrite, which constitute a large volume of the veins and their immediate wall rock. Pyrite and pyrrhotite occur as fine- to coarse-grained, anhedral to euhedral crystals throughout the ore zone and extensively spread outside the main zone. In addition to pervasive dissemination (predominantly along the foliation plane) these sulphides form wisps, stringers, stretched blebs (most probably amygdule filling), pillow selvage filling, and massive bands that contain brecciated fragments of quartz and wall rocks. In some cases pyrite grows as radial concretional patches, best seen on the chlorite-coated joint surfaces of the felsic units and the chlorite-coated, slickensided shear planes in the mafic volcanic rocks. Less commonly the sulphides are euhedral and fairly coarse grained, suggesting that some recrystallization has taken place.

Chalcopyrite is more commonly a vein material rather than pervasively present in the wall rock. In addition to its occurrence as part of the vein sets, it occurs as cross-cutting stringers and wisps across the boudinaged veins. In this instance, the chalcopyrite is one of the latest mineral phases of the hydrothermal suite.

9. Gold, which is very fine-grained, hardly ever visible in hand specimen, and shows a distinct association with the sulphides, specifically chalcopyrite, suggesting that some of the gold mineralization occurred at a very late stage of the hydrothermal activity. In addition to the presence of gold as free grains, smears on slip planes, and associated with the sulphides, gold-bismuth tellurides have been observed in the quartz veins.

   Minor amounts of graphitic material and sphalerite have also been noticed in the more sulphide-rich veins. A full list of major and minor minerals will be available after microscopic studies.

STRUCTURE

The dominant structure in the open pit area is a near east-trending zone which hosts almost all of the known economic grade ore. It strikes 100° to 120°, dips steeply to the north, and has a moderate plunge of 40° to 45° to the west. This structure occurs at a sinuous, irregular contact of felsic units to the south, and mafic metavolcanic rocks to the north. Within it, concordant and discordant vein sets, numerous lensoidal, conformable slivers of schistose units, and felsic dikes are present. It is boudinaged along strike and down dip with individual boudins of up to 6 m in height and 3 m in width. The lateral and vertical extensions of this structure are not yet defined.

A crude assessment of the preliminary field data suggests that several intermittent stages of ductile and brittle deformation characteristic of a simple shearing process took place. Detailed analysis of the structural data will allow a more accurate assessment of the deformation styles and their timing with respect to the alteration, mineralization, and metamorphism.

A general pattern of deformation seems to indicate:

1. An early period of stretching and flattening which is manifested in:
   - development of a penetrative foliation in the tholeiitic basalts which strikes 090° to 110° and usually dips vertically, this foliation is most prominent and has obliterated any previous cleavages that may have existed
   - a very prominent foliation cleavage (schistosity)in the schistose unit; extensive slickensiding has occurred along the planes of this schistosity
   - thin, highly stretched tholeiitic pillows with short to long axes ratios of up to 1:30
   - rodded, highly stretched varioles in variolitic pillows
   - a strong lamination/foliation in some of the narrow felsic dikes that cross-cut the metasedimentary and the metavolcanic rocks; this cleavage is usually conformable with the contact of the felsic unit
   - a prominent cleavage in the metasedimentary rocks which strikes 100° to 120° and dips between 40° and 70°N; curvature in the layers or refractory cleavage going from the more rigid to the more plastic layers was not observed.
2. A brittle stage of deformation which allowed the formation of some early sets of quartz, epidote, carbonate (both calcite and dolomite), and pink potassic feldspar veins. At this stage a degree of pervasive potassic alteration had also taken place which is seen in biotite-phlogopite and sericite alteration along the foliation planes.
3. A second stage of ductile deformation consisting of folding which is evidenced by the following features:
   - contorted, folded metasedimentary rocks to the south
   - boudinaged layers within the metasedimentary rocks
   - highly contorted and folded foliation of the schistose units about a north-south axis
   - boudinaged contact zones of the felsic dikes
   - boudinaged quartz veins both within and outside the main ore zone
   - folded early epidote-carbonate-quartz veins
   - crenulated biotite-phlogopite-bearing schistose basaltic flows.
4. A second stage of brittle deformation which once again gave rise to rectilinear fractures and allowed the formation of many more sets of veins. This process was repeated sev-

eral times as most of the veins are ribboned and include rafts of the altered wall rocks, suggesting a "crack and seal" process (Figure 3b). The manifestation of this stage is best seen in quartz and sulphide mineralization filling tension cleavages in the nose of the folded, early veins (Figure 3c), and in sulphide stringers cutting the sulphide blebs that replace amygdules and coat foliation planes of the tholeiitic pillows.

5. A final stage of shearing and strike and dip slip movements which is seen as the following features:

- rotated boudins in the metasedimentary rocks
- folded epidote-quartz-carbonate veins dragged into closely spaced shears
- quartz and sulphide veins dragged into and displaced by sinistral shears
- two sets of kink bands trending 135° and 065° which cut the variolitic pillows and the dioritic feldspar porphyry dikes at the decline; these shears have given rise to a feathery looking, curved, spaced, and refracted cleavage; the 2 sets show opposite senses of movement suggesting the presence of a conjugate set
- displacement of the pillow selvages in the variolitic flows.

It should be pointed out that both sinistral and dextral movements have been noted and their timing with respect to the various stages of deformation is as yet uncertain.

The felsic units show a distinct block jointing, the surfaces of which are usually coated with chlorite. Flat, radial, concretional pyrite has grown over these slickensided chloritic joint planes. The pattern of joints indicates several sets; the relationship between the jointing pattern and other structures is not known. The felsic units are relatively massive and, with the exception of their contact zones and where they are cut by veins, normally do not show fissility or a penetrative cleavage. Along their joint planes mineral lineation is prominent; this usually consists of shallow westerly plunging structures.

ACKNOWLEDGMENTS

The author would like to thank the management of the Campbell Red Lake Mines Limited, Detour Lake Project, J. Rogers (Mine Manager), and J. Spiteri (Chief Geologist), who have agreed to this project. W. Valiant (Senior Geologist), P. Nakai, C. Poulet, and D. Rosser, of the geology department, and the surveying department provided support throughout the program. Special thanks are due to the pit foremen who made access to the pit exposures possible during their very busy daily schedule. Catering services were superb and the hospitality of the whole mine crew made the stay in the Detour Lake camp most enjoyable.

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45. Geology of the McLean Lake-Lundy Lake Area, Nipissing District

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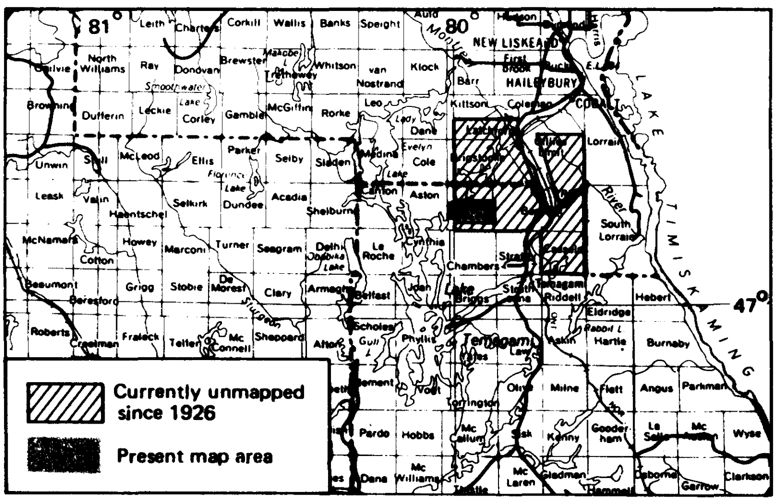
INTRODUCTION

Detailed mapping and sampling of an area located between the Cobalt and Temagami mining camps was initiated in 1983 (Owsiaki 1983). The program was continued in 1984 and with the conclusion of this mapping, the base and precious metal potential will be better defined in terms of structure, stratigraphy, and new mineral occurrences. The area is bounded by Latitudes 47°12'N and 47°10'N and Longitudes 80°01'W and 79°53'W and is located within Banting Township.

GENERAL GEOLOGY

The oldest rocks are of Archean age and include a sequence of mafic to intermediate, massive and pillowed volcanic flows and volcaniclastic fragmental rocks. These rocks are locally intruded by minor feldspar porphyry dikes and amphibolitic plugs. Facing directions, established from pillow top determinations, suggest the sequence youngs toward the north. Three relatively distinct units have been identified. The most southerly may best be described as a monolithic, mafic lapilli tuff/agglomerate. It is easily distinguished by a characteristic fine-grained mafic and schistose matrix which hosts distinctive white, rhyolite fragments. The fragments normally range in concentration from 2% to 5% but locally comprise up to 20% of the rock. Sizes vary from 1 cm to 2 m and shapes are commonly flattened or subrounded to rounded. Most fragments exhibit a cracked appearance with chlorite infilling the irregular fractures. Rarely, trace chalcopyrite is found as disseminations within the larger fragments. The matrix, although uniformly massive and schistose, sporadically exhibits features suggesting a pillow origin. Narrow irregular bands, comprised of pale felsic minerals, resemble pillow selvages and produce closed shapes that may be interpreted as distorted and stretched pillows. The enclosed cores of these structures contain concentrations of 1 to 2 mm, stretched, white amygdule-like forms. The rhyolite fragments occur both within and outside these structures.



LOCATION MAP

Scale: 1: 1 584 000 or 1 inch to 25 miles

A gradual upward transition through the sequence is reflected by a decrease in fragment concentration. The rock ultimately resembles a massive, schistose mafic flow. Numerous thin, and laterally discontinuous tuffaceous interbeds occur in the eastern portions of this unit. A series of well-formed pillowed and amygdaloidal flows define the top and occur primarily in the central map area (Figure 1).

The mafic flows are overlain in turn by a fairly distinct, heterolithic breccia unit, which is characterized by a 10% to 30% mixed fragment content within a banded schistose matrix of intermediate composition. The fragments are variable in size and bombs up to 3 m in length have been observed. A distinctive, green-weathering, siliceous variety of fragment is confined to this lithology and serves as a recognizable marker. The fragments are extremely flattened and commonly impart an irregular, banded appearance to the rock. Thin, mafic, and

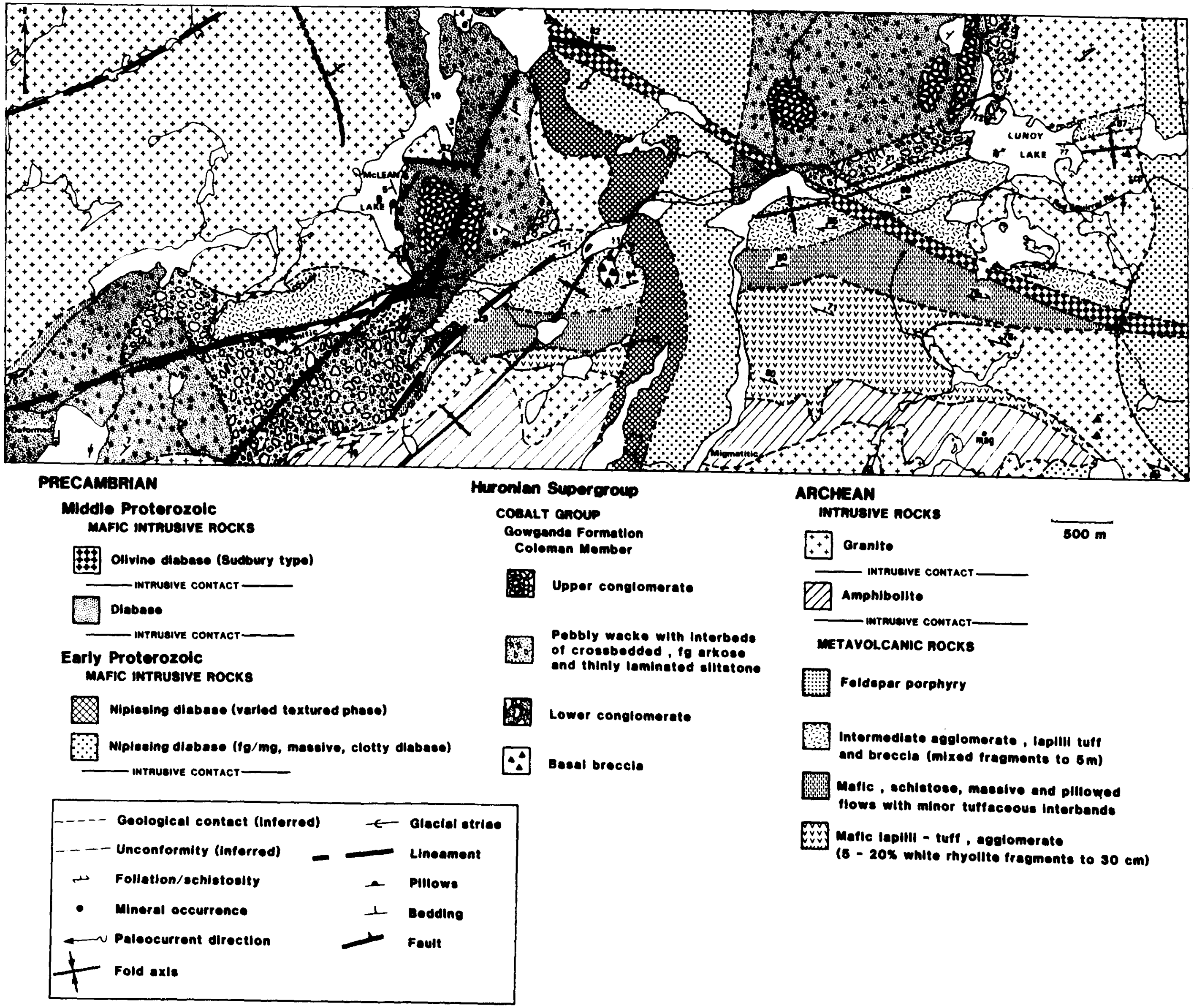


Figure 1. Geology of the McLean Lake-Lundy Lake Area, Nipissing District. (Project 45.)

schistose bands are intercalated within this unit.

During the late Archean, an amphibolite or diorite body intruded the volcanic rocks in the southern map area. Remnants of these volcanic rocks are preserved within much of this unit. Locally, mineral content within the intrusion varies dramatically and the rock ranges in composition from a diorite to hornblende syenite to hornblendite. Both magnetite and chalcopyrite mineralization have been identified within these rocks. The emplacement of medium-grained, pink granite subsequent to this event represents the major intrusive episode in this area. The granite underlies 60% of the map area and its exact relationship to the amphibolite as yet remains in question. The granite assumes a distinctly white colour where it is in contact with the amphibolite. The 2 rock types may represent the differentiation of a single parent magma and not separate intrusive events. The granite, in contact with the volcanic rocks, exhibits a gradual grain size change from approximately 1 mm adjacent to the contact to 8 mm, 10 cm away from it. Extensive rafting of intruded rocks occurs only in the southeastern map area. The rocks here resemble migmatites, as both the volcanic and amphibolitic units have been incorporated and deformed within the granite.

The only Proterozoic sedimentary rocks outcropping in the map area belong to the Coleman Member of the Huronian Gowganda Formation. The local stratigraphy closely parallels that found within the Cobalt mining camp (Owsiacki and Lovell 1984; Scammell 1984). Basal breccia exposed in Cobalt has been described as mechanically derived regolith (Donaldson and Munro 1982) and is found sporadically over the granitic basement rocks in the present map area. All fragments are granitic in composition and shapes reflect the effects of an in situ brecciation of the granite. Paleofracturing at the bedrock interface produced a blocky texture and open spaces were subsequently infilled with silt, sand and small rock fragments. This unit is more extensively developed as a clast-supported basal breccia in the central map area, where it overlies both granitic and volcaniclastic rocks. The fragments are unsorted, variable in size and comprised entirely of a mixture of the underlying rock types. The unconformity is exposed at only 2 locations and no basal breccia is developed in these areas. West of Lundy lake, the unconformity dips steeply north at 57° and suggests that the eroded basement topography is quite irregular.

A lower conglomerate unit is exposed sporadically along the unconformity and varies in thickness from 1 to 30 m. The rock is massive and includes a boulder and pebble concentration of 50% to 85%. Boulder types and shapes are extremely variable. A relatively thick sedimentary package immediately overlies the conglomerate. It consists of a lower, thinly laminated siltstone interbedded with thin (<1 m) fine-grained arkose and hosts up to 10% dropstones. The arkosic beds are commonly internally crossbedded and ripples are locally developed within the siltstone. Paleocurrent directions derived from the ripples imply a flow from the northeast. Pebbly wacke forms the upper portions of this package and includes a matrix which locally exhibits bedding and hosts 2% to 25% mixed pebbles of varying size and shape. In the southeastern map area, thin interbeds of orthoconglomerate and massive pebbly arkose are common.

An upper conglomerate unit is exposed on a few hilltops and closely resembles the lower conglomerate described previously. Differences include a slightly lower pebble and boulder concentration of 25% to 50% and a matrix which is sometimes bedded.

The sedimentary sequence appears to be infilling a shallow paleodepression which trends northeasterly and northerly across the map area and coincides, in part, with lineaments identified from LANDSAT photographs.

A Nipissing diabase sill cross-cuts all rock units and is exposed in the central and eastern map area. The central exposure is differentiated but in a slightly different manner from the sills described in Cobalt (Hriskevich 1952). The top of the sill dips westerly at 11°. Both contacts are characterized by massive and fine-grained quartz diabase up to 50 m in thickness. The upper third of the sill resembles varied textured diabase which has not been developed to the same extent as at Cobalt. The lower 2/3 of the sill is made up of fine-grained to medium-grained, massive diabase. It is characterized by a chloritic and clotty appearance on the weathered surface and differs from the hypersthene diabase zone which predominates in sills at Cobalt (Hriskevich 1952). The Nipissing diabase which outcrops in the eastern map area is similar and as such appears to represent the downward limb and base of the sill as it dips moderately to the east.

Narrow diabase dikes trend northeasterly and southeasterly and outcrop in the western part of the map area. They cross-cut both Archean and early Proterozoic formations. A very distinctive and wide (125 to 175 m) olivine diabase dike, described as Sudbury-type where it occurs near Temagami (Bennett 1978), trends northwesterly through the area. The dike exhibits a very strong linear aeromagnetic signature (GSC Map 1491G, 1965) and parallels a series of similar dikes exposed throughout this area (Card and Lumbers 1977). The rock weathers extremely easily and forms bulbous outcroppings which commonly disintegrate into an orange/brown gossany rubble. Dike margins are chilled, but minerals coarsen rapidly towards the centre where they produce an ophitic texture with crystals reaching 1 cm in size.

The most significant deformational event affecting the Archean rocks produced extensive isoclinal folding of the volcanic units and an accompanying well developed, axial planar schistosity. Younger intrusions of granite and amphibolite reflect this event through a moderate development of foliation. The foliation is produced by orientation of mafic minerals and linear stretching of quartz. In the coarse-grained central portions of the intrusions the foliation is difficult to discern, whereas at finer-grained contacts, it is quite strongly developed. Isoclinal folds occur at varying scales and manifest as folded fragments, matrix minerals, bands, and tuffaceous beds. The schistosity, foliation, and banding within the Archean rocks change dip about a northeasterly trending axis traversing the central map area (Figure 1) and define a synformal structure. In the eastern map area the volcanic rocks have been split into 3 divergent fingers by granitic lobes. The schistosity changes direction and parallels the trend of these fingers.

Major northeast-trending lineaments dominate this region but within the map area, numerous divergent northeasterly trending lineaments predominate and occur as subsidiary splays associated with the northwest-trending structures. One of these lineaments is marked by a series of elongated lakes comprising the Anima-Nipissing River system. In the granite, feldspars are broken down into smaller grains and quartz is stretched into long and extremely narrow rods. Pebbly wacke, located in the southwestern corner of the area, is extensively slumped over the projection of this lineament. Two narrow, easterly trending faults have been identified along the eastern shore of McLean Lake. Both dip steeply north at a similar angle to the olivine diabase dike which dips at 75°N.

ECONOMIC GEOLOGY

Although most rock types identified with the Cobalt silver camp are exposed in this area, including an apparent eroded arch of a Nippissing diabase sill, potential for discovery of silver-arsenide vein-type deposits is not considered to be high. During the mapping program, carbonate veins were not observed at any scale to cut either Nipissing diabase or Huronian sedimentary rocks. The extensive chlorite alteration spotting which is commonly developed in the rocks at Cobalt is absent. The spotting is associated with fluid migration related to diabase emplacement (Jambor 1971), emplacement of the ore veins (Thomson 1965), or a combination of the two. Mineralization was found in only one piece of float, used as base material for new lumber roads, which may have originated in nearby pits dug for this purpose. The float was a piece of fine-grained Nipissing diabase stained with pink erythrite and assayed 0.75% cobalt and 0.06 ounce silver per ton (Temiskaming Testing Laboratory, Cobalt).

Irregular, white quartz veins commonly cut granitic and volcanic rocks. Chip sampling along many of these veins was undertaken, but no mineralization was apparent. Gold assays for each of these samples produced insignificant values ranging from trace to a maximum of 0.005 ounce gold per ton (Temiskaming Testing Laboratory, Cobalt).

Minor occurrences of malachite staining and chalcopyrite mineralization were noted in Nipissing diabase, Archean granite, amphibolite, and volcanic rocks. The best sample was taken from the granite exposed in the northeastern corner, just north of Red Squirrel Road (Figure 1). Chalcopyrite occurs as disseminated clots to 2 mm in size within a quartz-poor phase of the granite. A large grab sample produced an assay of 0.1% copper (Temiskaming Testing Laboratory, Cobalt). All copper-bearing samples were analyzed for gold but nil values were obtained in all instances.

Massive magnetite bands were found in rocks rafted (?) within amphibolite exposed in the southwestern map area. About 300 m south of this showing, the amphibolite approaches a hornblendite in composition and contains up to 25% disseminated magnetite in scattered outcrop. Chalcopyrite was also observed along fracture surfaces in this area.

Although the 2 new mineral occurrences just described are the best found to date, sampling for gold within pyritiferous tuffaceous horizons in the volcanic rocks is yet to be undertaken. Mapping in future will concentrate on following the divergent fingers of volcanic rocks to the east.

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46. Age-Dating of Gold Mineralization in the Abitibi Belt, Northeastern Ontario

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INTRODUCTION

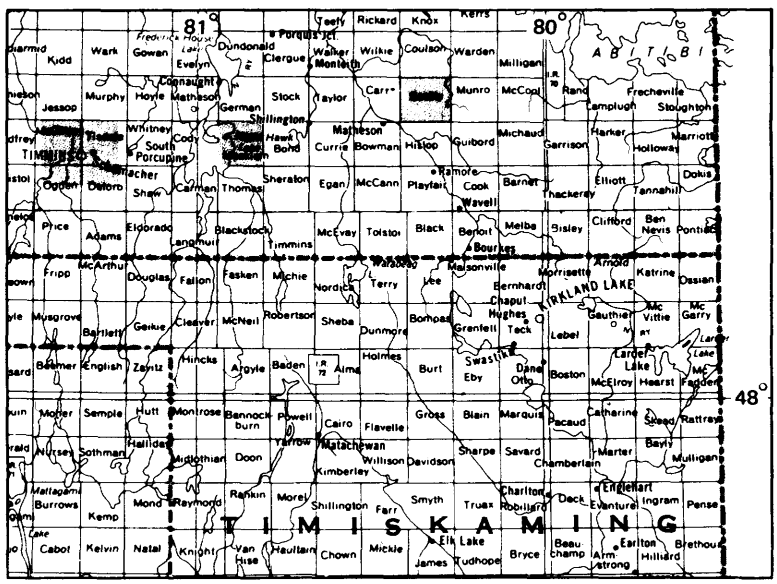
A program of age-dating, using the zircon U-Pb method, of gold associations in the Abitibi belt was initiated in 1983 (Marmont 1983). Five samples were collected from the Timmins and Kirkland Lake gold camps to: (1) verify some of the stratigraphic interpretations, and (2) to clarify the temporal relationship of gold mineralization with volcanism and felsic plutonism.

During the winter of 1983 and spring of 1984, the samples were processed at the Jack Satterly Laboratory, Royal Ontario Museum, Toronto. Suitable zircon fractions were extracted from each sample and analyzed for their U-Pb content. The results of this first phase of the program will be reported shortly.

During the 1984 field season, 6 more samples were collected from the Timmins area to better define the timing of gold mineralization in the Abitibi belt.

STATEMENT OF THE PROBLEMS

1. In the main part of the Timmins camp, many felsic porphyritic units are host to mineralization. Commonly, these "porphyries" lack characteristic petrological, geochemical, or geometrical features to allow their definite classification into either intrusive, extrusive flow, or pyroclastic categories. In some cases it has been reported that a fragmental pyroclastic unit "grades" into a quartz-feldspar porphyry (e.g. the Crown porphyry in the Hollinger Mine). This suggests the presence of an indigenous pluton (a comagmatic and coeval intrusive/extrusive complex) rather than 2 separate magmatic events wherein volcanism was followed by later intrusive activity. It is therefore important to establish the intrusive or extrusive nature of many of these "porphyries" and "fragmental" units which will allow a better reconstruction of the volcanic history, and elucidation of the link between volcanism, felsic plutonism, and mineralization. This will in turn aid better assessment of the synvolcanic (syngenetic) or epigenetic nature of the gold mineralization. In the absence of other means of identification (petrography, geochemistry), age-dating of these units is considered one of the better tools to achieve the above mentioned objectives.
2. In addition to the highly altered and fissile quartz-eye porphyries in the main part of the Timmins Camp, there are many felsic plutons which occur away from the Destor-Porcupine Break, are less deformed, and in some instances show relatively pristine features. Some of these plutons are host to gold mineralization, for example the Canadian Arrow trondhjemite, others have not been directly associated with mineralization but



LOCATION MAP   Scale: 1:1 584 000 or 1 inch to 25 miles may be pre-, syn-, or post-mineralization. In order to better define the role of the various types of felsic intrusions in gold mineralization, the temporal relationships between: (1) highly deformed and mineralized quartz-eye porphyries (e.g. Millerton porphyry), (2) less deformed and mineralized quartz-poor plutons (e.g. Canadian Arrow stock), (3) less deformed and mineralized quartz-rich plutons (e.g. Aquarius Mine), and (4) undeformed and unmineralized plutons (e.g. Adams pluton) have to be clarified.

3. Along the eastern section of the Destor-Porcupine Break many syenitic to quartz monzonitic plutons are present. In most cases these intrusions host shear zones within which extensive alteration and some mineralization are present. This style of mineralization can be equated with the geological setting of the Bourlamaque batholith, Val d'Or, Quebec, which is host to 2 mines (Belmoral and Bras d'Or), several significant prospects, and to the suite of syenitic intrusions in the Kirkland Lake area which host 7 major past and present producers. Although numerous companies are actively exploring several promising prospects in the eastern section of the Destor Porcupine Break, to date, no major gold deposits have been found in this part of the belt. Therefore, it may be significant to determine the timing of the emplacement of these intrusions, in order to establish their relationship with the intrusive event in the 2 other gold camps.
4. The establishment of the age of the felsic plutons and their relative timing with respect to volcanism will yield an older or maximum bracket for the gold mineralization. In order to obtain the duration of the mineralizing processes and the termination of the hydrothermal activity, it is necessary to obtain an age-date from a "post-mineralization" feature. Apart from the post-kinematic intrusions (e.g. Adams pluton) which may or may not be "post-mineralization", the only other rocks that show distinct "post-mineralization" relationships are those of the late Archean Matachewan diabase dike swarm. These dikes have been dated by Rb/Sr method (Gates and Hurley 1973) and yielded an age of 2690 ± 93 Ma. If they are "immediately post-mineralization", they can be used to indicate the end of the mineralizing event. If, however, they are younger than late Archean, they cannot be favourably correlated with the mineralizing event and other features have to be sought to define this episode.
5. The felsic metavolcanic units to the north and south of the Destor-Porcupine Break have been correlated by Jensen (1981) and Pyke (1982) and interpreted to be coeval flows. The "Krist fragmental", best seen on the northern limb of the Porcupine syncline, was sampled in 1983. Additional dates from the felsic metavolcanic rocks to the east of this location are needed to facilitate the interpretation and the temporal correlation of these flows.

PRESENT SURVEY

In order to overcome some of the above mentioned problems, 6 samples, weighing between 50 to 90 kg each, were collected from various mines and surface outcrops. Table 1 is a brief summary of these samples and Figures 1 and 2 show their location. The selection criteria for each of the samples are as follows:

1. *Millerton porphyry* — similar to the Pearl Lake, Preston, and Paymaster porphyries, this unit is one of the major hosts to gold mineralization in the Hollinger Mine. An age-date for this unit will allow its correlation with the aforementioned porphyries, as well as providing a maximum age for gold mineralization.
2. *Crown porphyry* — close examination of the "fragmental" unit in the Hollinger Mine revealed that this rock, although of a fragmental nature, is not a "pyroclastic" unit. It occurs as a cross-cutting breccia dike or fault breccia with the basaltic flows at the northern contact of the Crown porphyry, and does not exhibit a gradational contact with the Krist fragmental. Figure 3 shows these units on the plan of the 1700-foot level. The Crown porphyry is a quartz-feldspar porphyry which shows a distinct igneous texture. It is a granodioritic intrusion which, if coeval with the quartz-eye porphyries of

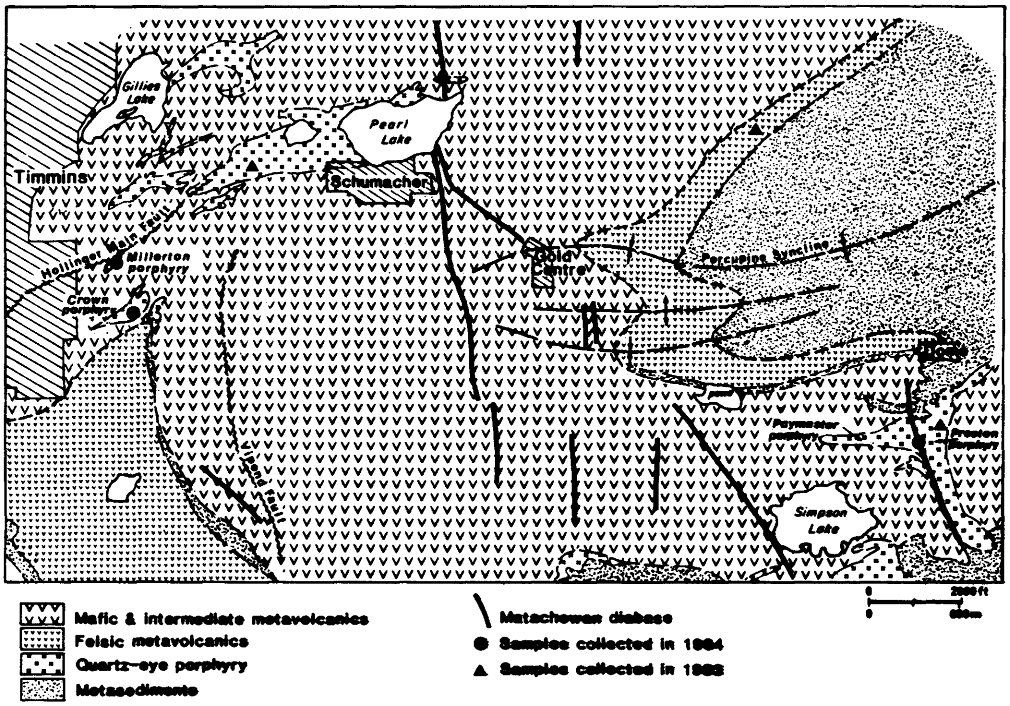


Figure 2. Simplified geology of the Timmins camp showing location of samples for zircon U-Pb age-dating. (Project 46.)

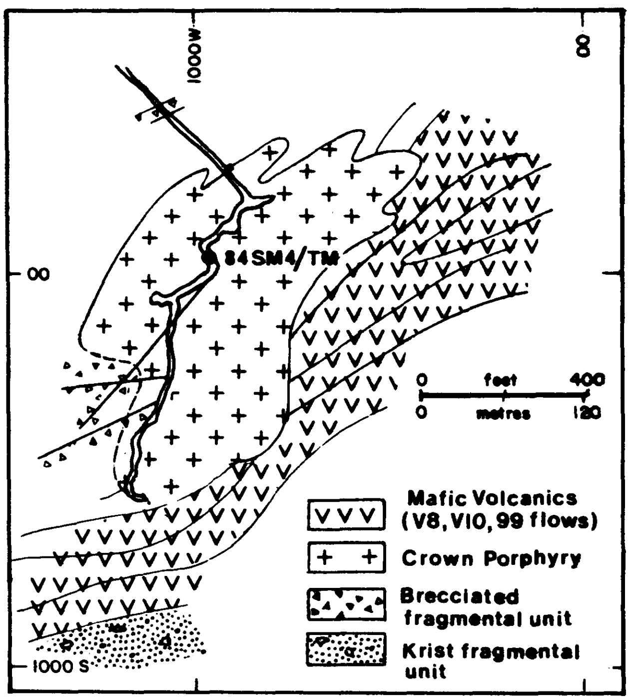


Figure 3. Plan of the 1700-foot level, Hollinger Mine (from Pamour Porcupine Mines Limited). (Project 46.)

eralized body may help in the interpretation of exploratory drilling results in the area.

4. *Garrison stock* — a small orebody occurring near the contact of this pluton has been mined by Kerr Addison Mines Limited. Recent exploration by this company has revealed the presence of further mineralization adjacent to the stock. An age-date from this monzonitic body may allow better correlation between the quartz-poor, more potassic, and the quartz-rich, more sodic suites of felsic intrusions in the study area (both suites host gold).
5. *Matachewan diabase dike* — throughout the Abitibi belt several sets of diabasic dike swarms are present. Each set has a distinct trend which, to date, has been

the basis for its chronological classification. The Matachewan diabase dikes trend north and are presumed to be late Archean. At the Dome Mine, a sample was taken from an 18 to 21.5 m wide diabasic dike which trends north and cuts the auriferous quartz-dravite-sulphide veins. This dike is clearly post-mineralization and, if proven to be Archean, will provide a minimum age for the deposition of gold. The combination of this data with age-dates obtained from the porphyries, which are the youngest units hosting gold, will allow calculation of the maximum "duration" of the mineralizing event.

6. *Beatty Township rhyolitic flows* — in order to verify the stratigraphic correlation between various felsic metavolcanic units in the area, several of these rocks will have to be dated. The data obtained from this sample will allow its correlation with the Krist fragmental and the rhyolitic flows in the Kidd Creek Mine area.

FUTURE CONSIDERATIONS

Depending on the outcome of results from the data collected to date, the future program of age-dating in the Abitibi belt will be planned accordingly. However, at the present time, obtaining an age for the following units is considered necessary for more definitive interpretations of the evolution of the Archean crust in the belt, as well as the timing of gold mineralization (*see* Figure 1):

1. Some of the major batholiths, e.g. Adams pluton, Lake Abitibi batholith, Round Lake batholith, and Watabeag batholith
2. Rhyolitic flows, both to the north and south of the Destor-Porcupine Break, in Coulson, Wilkie, Hislop, and Macklem Townships
3. Rhyolitic flows, to the south and north of the Kirkland Lake-Larder Lake Break, in Boston, and Gauthier Townships
4. Trachytic flows in the Kirkland Lake area, preferably in the Macassa Mine, where geological contacts and the relationship with the Macassa porphyry can be observed.

Age-dating of vein and alteration minerals using the $^{40}Ar/^{39}Ar$ method is also in progress and, combined with the Zircon U-Pb data, should provide a solid framework to elucidate the timing of gold mineralization in the Abitibi belt.

ACKNOWLEDGMENTS

The author would like to thank D. Rogers of Dome Mines Limited for his continuing support of the project by providing geological data and helping in sample collection. A. Brooks of Pamour Porcupine Mines Limited arranged for, and aided in the sampling of the Millerton and Crown porphyries. J. Sample of Asarco Exploration Company of Canada Limited suggested sampling of the Aquarius intrusion. Discussions with A. Green, Kidd Creek Mines Limited, Exploration Division, and R. Johnstone, Carleton University, regarding selection of suitable rhyolitic flows, are most appreciated.

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47. Geology and Placer Related Gold Potential of the Huronian Supergroup Along the Western Margin of the Cobalt Plain: A Preliminary Investigation

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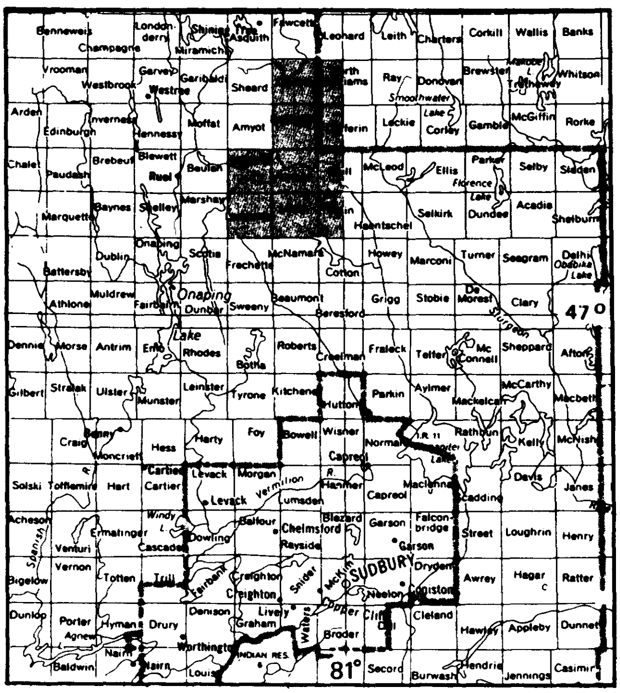
INTRODUCTION

The stratigraphy and sedimentology of the Early Proterozoic (Aphebian) Huronian Supergroup was investigated in a poorly exposed sector of the Cobalt Plain, including Lampman, Leask, Hodgetts, Unwin, Browning, and Ogilvie Townships, and parts of Amyot, Valin, Stull, Dufferin, and North Williams Townships. Interest in the gold potential of this area stems from the discovery of concentrations of gold in excess of 1 part per million (ppm) in a haematitic sandstone member of the Lorrain Formation by Colvine (Colvine 1981, 1982, 1983; Long *et al.* 1982). Colvine (1983) found that where mature haematitic quartz pebble conglomerates were present in this unit, gold concentrations were considerably above the background value of 2 parts per billion (ppb), with highs from 500 to 1200 ppb. The present investigation was aimed at delimiting the stratigraphy and structure of the Lorrain Formation in this poorly exposed area, with emphasis on the distribution of the haematitic sandstone member. An attempt was made to provide stricter stratigraphic and sedimentological control of gold-bearing intervals. To achieve this, detailed stratigraphic sections were established, where possible, to record bedform sequence and textural variations. This was combined with detailed sampling and paleocurrent analysis to provide a basis for future exploration in areas where high gold values are encountered.



LOCATION MAP

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or 1 inch to 25 miles

PREVIOUS WORK

The first regional compilation of the geology of the area investigated (*see* Location Map) was made by Collins (1917) who included it in his memoir on the Onaping map area. Collin's geological interpretations were incorporated into later compilation maps of the Sudbury-Cobalt area by Card *et al.* (1971) and Card and Lumbers (1975), produced at a similar scale of 1:253 400. Townships to the north and south have been mapped in greater detail by Meyn (1972a, 1972b, 1972c, 1976) and Carter (1973a, 1973b, 1977). The area to the east is included in maps of the Smoothwater Lake and Solace Lake areas, produced by Card *et al.* (1973) as part of Operation Maple Mountain.

Collins (1917) indicated that most of the area investigated is underlain by rocks of the Lorrain Formation, which are locally in erosional contact with underlying rocks of the Gowganda Formation and Archean basement. Most of the area is obscured by a veneer of Pleistocene deposits, including extensive tracts of fluvial and lacustrine strata (Boissonneau 1968; McIlwaine 1971) with superimposed aeolian deposits. Access to the area is along numerous forestry roads and hydro access roads.

STRATIGRAPHY

Collins (1917) suggested that the Lorrain in the western Cobalt Plain was between 610 and 915 m thick and could be subdivided into 3 members. The lower member was identified as a feldspathic sandstone of probable terrestrial origin, overlain by a less feldspathic middle member containing thin beds of resistate pebble conglomerate, in which most of the clasts were well-rounded quartz and chert pebbles, with only minor clasts of fine-grained igneous material. Collins noted that conglomerates commonly formed <5% of the sequence, were commonly <1 m thick and were laterally discontinuous. The upper member was described as a 'white quartzite' which lacked conglomerates and was characterized by better rounding of quartz grains and a greater abundance of ripples. Boundaries between these 3 members were described as indefinite. Collins noted that the Lorrain Formation was succeeded by a sequence of laminated "cherty" quartzites, 30 to 60 m thick, which is now ascribed to the Gordon Lake Formation, and a thicker sequence of plane and ripple laminated orthoquartzites, now known as the Bar River Formation. While Collins noted the presence of these stratigraphically higher sequences in the vicinity of Smoothwater Lake and the Lady Evelyn River (c.f. Card *et al.* 1973), he did not specifically identify them in the area of the present study.

Hadley (1968) examined the stratigraphy and sedimentology of the Lorrain Formation between Sault Ste. Marie, Ontario, and Ville Marie, Quebec. While Hadley made no specific studies in the area of the present study, he noted that Collins' (1917) stratigraphy could be applied throughout the Cobalt Plain and that the contact between the Lorrain and the Gowganda was conformable and gradational, at least in the central and eastern parts of the Cobalt Plain. Card *et al.* (1973), in their study of the Maple Mountain area, supported the latter observation and concluded that the Lorrain could be divided into 7 members. The basal member (a) was defined as a sequence of up to 610 m of interbedded sandstones and siltstones, which represents a transition zone from argillites of the Firstbrook member of the Gowganda Formation. The overlying lower feldspathic sandstone member (b) consists of several hundred metres of coarse-grained impure feldspathic sandstones, overlain by 457 to 910 m of green, medium-and coarse-grained pebbly sandstone, with minor interbeds of pink feldspathic sandstone, ferruginous sandstone, and white micaceous sandstone and argillite which were named the 'green sandstone member' (c). The green sandstone member is overlain by the 'ferruginous sandstone member' (d). This consists of 30 to 305 m of haematite-stained sandstone, with some white feldspathic sandstone and green sandstone units. This is overlain by the 'upper feldspathic sandstone member' (e), which consists of several tens or hundreds of metres of feldspathic sandstone with some interbedded haematitic and white sandstone. The upper feldspathic sandstone member is overlain by 305 to 457 m of medium-grained white micaceous sandstone ascribed to the 'white sandstone member' (f) and a further 30 to 60 m of fine-grained haematitic and white sandstone ascribed to the 'upper sandstone member' (g).

NEW OBSERVATIONS

Investigation of Huronian stratigraphy in the study area supports Collins' (1917) observation that the Lorrain lies in erosional contact with the Gowganda Formation or underlying Archean rocks. With the exception of the basal member (a) and the upper sandstone member (g) all of Card *et al.'s* (1973) members can be recognized in the field, although contacts between members are difficult to place as they all appear to be transitional. Further petrographic work is required to clearly define members, and to distinguish between strata of the green sandstone member (c), parts of the upper feldspathic member (e), the white sandstone member (f), and the upper sandstone member (g). It may be possible to distinguish the basal parts of the upper feldspathic member (e) from lower stratigraphic units on the basis of maximum grain size of the pebble fraction. While quartz pebbles are present throughout members b, c, d, and e, there appears to be a systematic decrease in maximum grain size from the base of the formation to the top of the green sandstone member (c). Maximum grain size increases to large, to very large pebble grade in parts of the ferruginous sandstone member (d) and achieves a maximum (very large pebble and locally area limit the near-surface distribution of this member.

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cobble grade) in the base of the overlying upper feldspathic member (e).

The haematitic or ferruginous sandstone member (d) which Colvine (1983) suggests is the preferred host for placer related gold deposits, was recognized at several locations along the hydro access road in Dufferin and North Williams Townships, in the eastern parts of Ogilvie and Browning Townships, and in a tract of Valin Township along and near the southern shore of Welcome Lake. The member may also be exposed in adjacent parts of Leask Township, but further work is required to delimit the distribution of the member in this area.

Rocks of the Gordon Lake and Bar River Formations were encountered in Valin, Stull, and Unwin Townships. The most extensive exposures of these formations are present in the core of a major east-trending synclinal structure which runs through Welcome Lake. The Gordon Lake Formation in this area consists of up to 660 m of laminated argillite with thin beds of very fine quartzose sandstone. Sandstone beds are predominantly massive to plane bedded, with local development of wavy bedding (oscillation ripples) and ripple cross lamination. Pseudonodule horizons are present locally where starved ripple trains have slumped into underlying mudrocks. Minor features include syneresis cracks, red chert nodules, intraformational conglomerates, and possibly hummocky cross stratification. The Gordon Lake Formation is conformably overlain by more than 125 m of white, predominantly massive and flat laminated, fine and very fine quartz sandstone, with minor intraformational conglomerate.

ECONOMIC GEOLOGY

Placer related gold concentrations have been encountered at several stratigraphic horizons within the Huronian Supergroup. Concentrations of gold have been identified in conglomerates at the base of the Huronian Supergroup in the area northeast of Sudbury (Meyn 1979; Long 1981, in press; Mossman and Harron 1981, 1984; Sauerbrei and Phipps 1983), and in related conglomeratic and arenaceous strata in the Elliot Lake Group (Long and Lloyd 1983; Meyer 1983) between Sudbury and Sault Ste. Marie. They have been identified in the Serpent Formation of the Cobalt Plain (Sauerbrei and Phipps 1983), and in the Lorrain Formation between Sault Ste. Marie and Sudbury (Innes and Colvine 1979; Tortosa 1984) and in the Cobalt Plain (Colvine 1981, 1982, 1983; Long *et al.* 1982).

Colvine (1983) suggests that in the Lorrain Formation of the Cobalt Plain the ferruginous sandstone member (d) has the best potential for sedimentary gold concentrations. Heavy mineral bands in this member are dominated by haematite, and apparently lack magnetite or ilmenite, which are conspicuous in other parts of the Lorrain, in subaqueous deposits in the Gowganda Formation (Long and Leslie 1983, in press), the Archean basement, and modern stream placers in this area. Feldspar in the ferruginous member and the underlying green sandstone member is extensively altered to sericite.

Gold in the pre-Gowganda units is normally restricted to fluvial units which contain concentrations of pyrite and show ample evidence of in situ alteration of associated detrital feldspar grains. The absence of magnetite and ilmenite in gold-bearing pyritic conglomerates in the basal Huronian strata of the Cobalt Plain led Long (in press) to suggest that gold mineralization was related to early diagenetic alteration of "black sand" placers by acid oxidized groundwaters (Long and Lloyd 1983), a model proposed earlier by Clemmey (1981) and Clemmey and Badham (1982) to explain the abundance of pyrite in uraniferous conglomerates in the Elliot Lake Group. A similar mechanism, involving groundwater under slightly different Eh and pH conditions may explain concentration of gold in the Lorrain. The sequence below the ferruginous member indicates a progressive increase in the degree of weathering of the stratigraphic pile, both in the provenance area and during transport (shown by a progressive increase in the quartz content) and after deposition (shown by more extensive in situ alteration of feldspar grains). Conglomerates in the member may indicate tectonism in the provenance area, or more likely an increase in rainfall, which would permit reworking of parts of the underlying sequence and allow transport of coarser material.

While no specific comments can be made on the gold distribution in Huronian rocks in the study area until completion of chemical analysis, the discovery of new areas of outcrop of the ferruginous member in Ogilvie, Browning, and Valin Townships is encouraging. Steep dips in rocks of the Huronian Supergroup in this

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48. Granite and Anorthosite as Ceramic Raw Materials

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INTRODUCTION

Sand, clay, and limestone are historically the basic raw materials of ceramics. The natural oxides in these resources lend themselves to partial or total vitrification upon heating. The durable, corrosion and weather resistant products of heat treatment are familiar to the public in the form of glass, earthenware, and whiteware ceramics in home, factory, and laboratory, as crockery, bathroom fixtures, containers for liquids and chemicals, electrical insulators, and construction materials.

The behaviour of a ceramic raw material upon heating is determined by its composition: a combination of refractory oxides (SiO_2, Al_2O_3) and fluxes (K_2O, Na_2O, CaO, Na_2CO_3). Transparent glass is obtained by adding ~15% feldspathic material to the silica batch. The material has to be free of iron, chrome, or cobalt compounds to prevent discolouration. Essential is the alumina content, which makes the molten glass more ductile and prevents crystallization upon cooling.

In pottery or whiteware the correct composition and granularity of the raw material are even more crucial. Here the form is established before firing and has to be retained in the firing process. Only partial melting and vitrification are allowed. The producer depends on consistent behaviour of the raw material from one firing to the next, and is therefore extremely reluctant to experiment with different compositions or substitute materials. Pure kaolinite clay and feldspathic fluxes of consistent composition are the preferred ceramic raw materials.

The exciting prospect of entering a new ceramic age calls for reassessment of mineral raw material resources. Ceramics are gaining prominence in such basic industries as building construction and car manufacture. An energy conscious future may see conventional building materials like brick, concrete and cement replaced by synthetic zeolites or other structural compounds with particularly engineered insulation and energy storage capacities. The demand for kaolinite clay and feldspar, from which the zeolites are made, will increase accordingly. Polymerization of mineral-based liquids to provide a bond in natural aggregates was successfully practiced by the early pyramid builders in Egypt, according to Davidovits (1983) who studied these structures more than 2000 years after their construction.

Energy constraints are also prompting increased use of transparent glass in building construction, either in walls and roofs to provide direct sunlight or in solar panels to actively gather and store energy for future use.

Use of ceramics in car engines and parts is developing on several fronts. Although in an experimental stage now, predictions are that the ceramic engine will save in fuel and maintenance costs by being lightweight, energy efficient, and durable (Bell 1984). While a variety of ceramic raw materials are being investigated, pure silica in all likelihood will keep playing a large part in the future of high technology ceramics (e.g. optic wave conduits or silicon chips in computers).

POTENTIAL SOURCES OF CERAMIC RAW MATERIAL

In providing feldspathic materials for the ceramic industry present producers rely on hard-rock mining. The development of a flotation technique which effectively separates feldspar, quartz, and mica after crushing of a granitic rock, has made it possible to turn to this source for feldspar. The bulk mining of a homogeneous body of granite is more efficient than the selective mining of pegmatite veins. Therefore the present reassessment of potential resources is primarily concerned with identifying homogeneous igneous rocks with an adequate percentage (60%) of feldspathic material of sufficient purity (<0.05% Fe_2O_3).

In Ontario, selective mining of pegmatites has not been practiced since 1953, except for some experimental efforts. Instead, the needs for feldspar in glass manufacture have been met by mining nepheline syenite in the Peterborough area. In North Carolina, alaskite is mined for its content of feldspar, quartz, and mica. The products of these sources have replaced a large part of the traditional pegmatite markets.

Since the main function of feldspar in a glass batch is to provide the necessary aluminum, calcic feldspar typical of anorthosite would be equally suitable. The bulk mining of anorthosite as a ceramic raw material must be considered, therefore, provided the anorthosite is sufficiently pure and lacks the finely dispersed iron compounds which are so hard to eliminate.

The North Carolina alaskite, a large body of granitic rock with a high feldspar content of constant composition, is interesting for its quartz and mica by-products in the flotation process. At least one company is beneficiating the quartz to meet optic fibre specifications; the mica is sold as a filler and reinforcing agent in plastics. An approximate modal analysis of the alaskite is given by Brobst (1962, p.A10) as follows: oligoclase 40%, microcline (perthitic) 20%, quartz 25%, muscovite 15%, and accessories <5%.

Pegmatites are left to fill the need of local markets in the southeast and midwestern states of the United States. They are the only source of high potassium feldspar required in the manufacture of electric insulators for high tension wires. The high potassium content makes these ceramic insulators more resistant to extreme temperature conditions. In Ontario a market of approximately 10 000 tonnes per year of high potassium feldspar has been identified, dependent on construction of planned hydro lines. Potassium feldspar is now imported to Ontario from the United States or Quebec.

PRESENT STUDY APPROACH

Field work for the ceramic raw material survey consisted of examination of potentially suitable igneous rocks in selected areas of the province. Sufficiently leucocratic granites or syenites were sampled. Chemical analyses will further determine the ceramic potential of the contained feldspar and quartz.

Examination of some anorthosites near Parry Sound showed a content of ferromagnesian minerals higher than expected from literature research, and they were, therefore, eliminated from the survey.

A search for muscovite- or 2-mica granites led to several granites in the Madoc-Bancroft area. Here also, the lack of sufficiently leucocratic granites caused elimination of many bodies initially considered on the basis of literature descriptions. Even if the deleterious iron content can be eliminated with the ferromagnesian silicates in the beneficiation process, the diminution from amount of material initially mined and crushed to amount of product will destroy the competitive edge these rocks may have.

The following areas were examined and sampled in the field:

1. Westport map area (Wynne-Edwards 1967)
2. Deloro batholith (Saha 1957)
3. Three Duck Lakes area (Laird 1932)
4. dune sands, Westree area, Sudbury District (Guillet 1983)
5. King's Island syenite and anorthosite, Parry Sound District (Quirke 1929)

WESTPORT MAP AREA

Leucocratic pegmatite granite and syenite at Long Lake (approximate Latitude 44°32'N, Longitude 76°24'W), Red Horse Lake (approximate Latitude 44°33'N, Longitude 76°05'W) and Charleston Lake (approximate Latitude 44°35'N, Longitude 76°01'W) were examined. In the Long Lake granite body the medium- to coarse-grained white granite alternates with coarse-grained white marble. Sufficiently large areas of granite are exposed, however, to make this rock potentially interesting for bulk mining.

White pegmatites are common both in the Long Lake and Charleston Lake areas. Granites here contain samples with a high content of desirable potassium feldspar (50% or more according to preliminary staining tests).

Samples of rock from the Westport map area will be analysed to confirm the indicated preferred composition and mineralogy.

DELORO BATHOLITH

The medium- to coarse-grained, granitic to syenitic rock sampled in this area is part of a relatively homogeneous body. A certain amount of iron in the feldspar is indicated by the brown colour. Laboratory analysis will determine the feldspar composition and lithologic classification of this granitic rock. The ceramic potential of the Deloro granite appears low, and will depend upon the composition of the feldspars.

An additional use of the granite would be building stone; however, a former quarry in the area shows a multitude of joints and fractures and the batholith would not lend itself to production of large blocks.

THREE DUCK LAKES AREA

Alaskite in the Three Duck Lakes area occurs as the central part of an extensive batholithic intrusion into metavolcanic and metasedimentary rocks, which are surrounded by older Archean gneisses. The area is noted for gold, copper, and iron mineralization (Laird 1932). Laird described the alaskite as the younger part of the batholith on the basis of its fresher appearance, but stated that whether it is of igneous or sedimentary origin is not always clear, even under the microscope. He noted that the alaskite consists largely of quartz and orthoclase with minor amounts of plagioclase, hornblende, chlorite, ilmenite, leucoxene, and pyrite. Blue quartz, in the form of blebs locally attaining the size of a bean, is characteristic.

A series of samples across the contact of metasedimentary rocks with granite of the batholith was complemented with several samples of light grey granite from the central part of the intrusion. Few samples were sufficiently leucocratic to justify extensive analysis.

The ceramic potential of this rock depends on the composition of both quartz and feldspar. Quartz will be analysed for its chemical purity.

DUNE SANDS, WESTREE AREA

Pleistocene outwash sands in glacial moraine in the Westree area have been studied with encouraging results. Guillet (1983) concluded that a feldspathic sand chemically suitable for the making of fiberglass and coloured container glass can be obtained without excessive losses during removal of deleterious material in the beneficiation process. The quartz component of this feldspathic sand is of high purity but generally is too low in volume to be of economic interest. Guillet (1983, p.14) suggested that samples of active sand dunes in the area be evaluated for purity and quartz content. For this reason some dune sands were collected by the author in Invergarry and Garvey Townships. The samples were taken at a depth of 1/2 to 1 m, from roadside exposures. In a preliminary analysis it was established that some samples contain from 50% to 70% free quartz. The sands are generally well sorted, with sizes in Garvey Township samples peaking at -80 to -120 mesh (U.S.A. standard sieve). The relatively fine grain size may be acceptable in modern glass melting techniques and sorting in this size range would guarantee use of most of the material processed. Samples of this interesting source of potential glass sand will be subject to further chemical analyses.

KING'S ISLAND SYENITE–ANORTHOSITE

The King's Island area, between the Main and Western channels of the French River on Georgian Bay, has not been mapped in detail. On geological maps, a central area of anorthosite is shown surrounded by granitic to syenitic rocks, and samples of both rock types were collected. Dikes and lenses of pink, fine-grained, aplitic rock or felsite are common; larger bodes of this aplite tend to cross-cut the foliation of the surrounding gneisses. A high content of potassic feldspar in rocks at this location, with access from Lake Huron, would make it potentially a very interesting source of ceramic raw material. Anorthosite gneisses of the central area are generally tan to brown, and coarse-grained. They contain some hornblende and/or pyroxene and the brown colour indicates a potentially deleterious content of iron in the feldspar. To the east of the anorthosite coarse-grained augen gneiss with feldspar porphyroblasts up to 1 inch in diameter is common. The porphyroblasts have quite rectangular cross sections in some locations, and elsewhere retain a typical oval shape. Whether this feldspathic material is of the desired purity, and amenable to beneficiation to remove iron compounds distributed in or between mineral grains, remains to be determined by further chemical analyses.

DISCUSSION

Production of ceramic raw material from alaskite or anorthosite in Ontario is economically determined by its competitive position with respect to nepheline syenite. A favourable geographic location, e.g. King's Island, with easy access to markets in the Chicago area, which are now supplied from the Blue Mountain deposits, or a special composition (high potash) are required to gain a competitive edge over nepheline syenite. Development of alternative resources in Ontario will be subject either to a substantial increase in demand, due to expansion in the production of glass and ceramics, or to the eventual depletion of present resources of nepheline syenite. At existing rates of mining, the deposits near Peterborough are estimated to have sufficient reserves for more than 40 years.

The possibility of providing material to existing markets for high potash feldspar and/or quartz of extreme purity from Ontario granitic rocks requires further investigation. Although limited at present (the market for fibre optic quartz in North America is approximately 30 000 tonnes per year (G. Minnes, Policy Analyst, Industrial Minerals

Section, Ontario Ministry of Natural Resources, personal communication, 1984)), the markets for high technology ceramics may be expected to increase substantially in the near future.

ACKNOWLEDGMENTS

The author wishes to acknowledge the able and dedicated assistance in field and laboratory work by student Joe Horawski.

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INTERDISCIPLINARY PROGRAMS

The Opapimiskan Lake Project

The Black River - Matheson (BRIM) Program

S49. Opapimiskan Lake Project: Precambrian Geology, Quaternary Geology, and Mineral Deposits of the North Caribou Lake Area, District of Kenora, Patricia Portion

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This project was funded by the Ontario Ministry of Northern Affairs (Opapimiskan Lake Survey).

INTRODUCTION

In the summer of 1984 the Ontario Geological Survey began a 3-year integrated study of the North Caribou Lake area involving field work by staff of the Precambrian Geology, Engineering and Terrain Geology, and Mineral Deposits Sections. This program, known as the Opapimiskan Lake Project, was prompted by recent gold exploration activity in the Opapimiskan Lake area which sparked wide interest in the gold potential of the region and in turn created a demand for an updated and expanded database.

With some exceptions, the North Caribou Lake "greenstone" belt is poorly exposed, hence indirect methods of establishing bedrock geology are being integrated with Precambrian mapping at a scale of 1:15 840. Towards this end a study of the dispersal of supracrustal lithologies in glacial sediments is being carried out down-ice from the greenstone belt. This type of analysis should provide valuable information on the geology of completely drift-covered portions of the area, and may prove to be an effective exploration tool.

A study to characterize mineral deposits and determine controls on local mineralization within the belt was started in the latter part of the 1984 field season. During the next 2 years, Mineral Deposits staff will be involved in additional studies to classify these deposits within the tectonostratigraphic framework of the belt as established by Precambrian mapping.

Because of the strong positive economic and social impacts that mineral exploration and mining activity in this region would have on communities nearby, the program has been supported and funded by the Ontario Ministry of Northern Affairs. The geological maps and reports that will be published over the next 4 years as a result of the Opapimiskan Lake Project will help sustain private sector interest and investment in this relatively remote part of northwestern Ontario.

This summary deals with all current field components of this interdisciplinary project. Although the results of Precambrian and Quaternary geology surveys and Mineral Deposits Section's examinations are described under separate headings, the interdependence of these studies is readily apparent, and demonstrates the many advantages of such integrated work.

LOCATION AND ACCESS

The North Caribou Lake Belt, which extends in "dog-leg" fashion from Weagamow Lake in the northwest to Neawagank Lake in the southeast (*see* Figure 1), is about 150 to 100 km north of Pickle Lake. The settlement on the northern side of Weagamow Lake lies just to the west of the project area.

Access to most of the area is by float- or ski-equipped aircraft from Pickle Lake. Regularly scheduled air service also exists between Pickle Lake and the Weagamow Lake Indian Reserve. An all-weather, gravel-surfaced road extending from Pickle Lake to Windigo Lake passes about 40 km south of Opapimiskan Lake. This road, and the Musselwhite Gold Property on the southern side of that lake, are linked by a recently constructed winter road.

The western part of the project area, where most of the field activity took place, is readily accessible by watercraft using the Weagamow-Eyapamikama-North Caribou Lake system. Most of the canoe routes and portages described by Satterly (1941) were found usable by the field crew in 1984.

PREVIOUS WORK

The North Caribou Lake metavolcanic-metasedimentary belt was first mapped by Satterly (1941), at a scale of 1:63 360 (1 inch to 1 mile). The area was later remapped at a reconnaissance level during geological compilation by Emslie (1962) and by Thurston *et al.* (1979). The Forester Lake area in the southeastern part of the belt has only been examined during the reconnaissance mapping by Emslie (1962) and Thurston *et al.* (1979). Andrews *et al.* (1981) undertook a preliminary reconnaissance of the belt and described the Musselwhite Gold Property on Opapimiskan Lake. The belt was also re-examined at a reconnaissance scale by R. Hall to complement detailed mapping conducted in the Opapimiskan Lake area, as part of his Ph.D. research study at Queen's University, Kingston, Ontario.

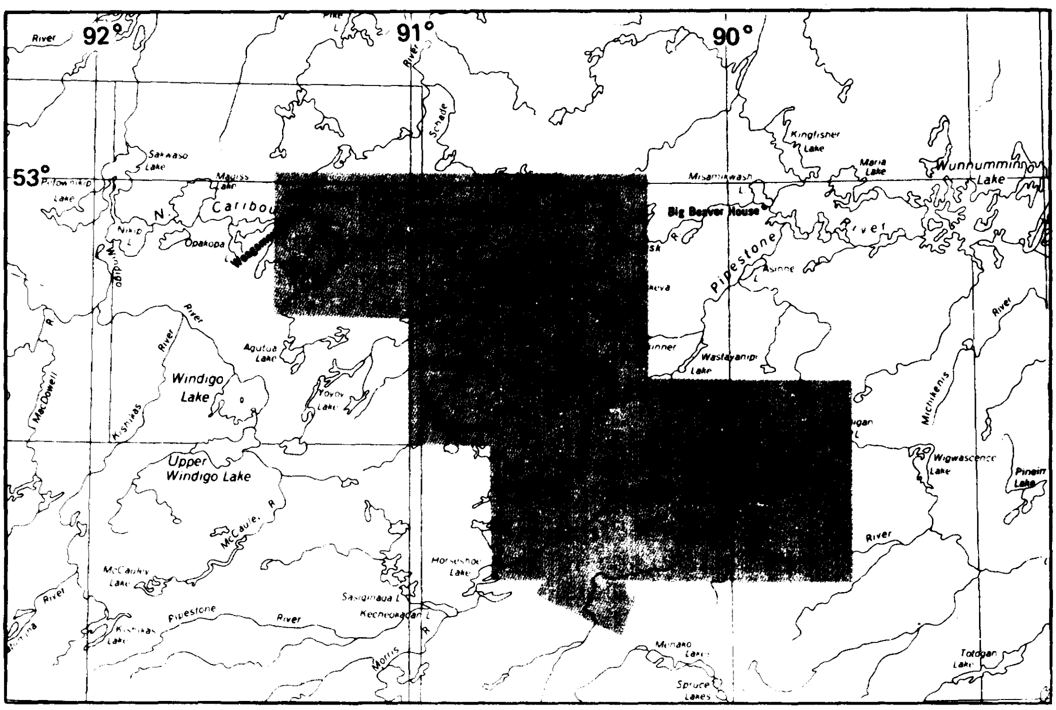
The area was covered by an airborne magnetometer survey on a scale of 1:63 360 (1 inch to 1 mile) in 1960 (ODM-GSC 1960).

A number of property scale geological, geophysical, and geochemical surveys have been undertaken by exploration companies within the belt. Some of their results are in the Assessment Files, both in the Mining Recorder's Office, Sioux Lookout, and the Assessment Files Research Office, Toronto.

PRECAMBRIAN GEOLOGY

REGIONAL GEOLOGICAL SETTING

The North Caribou Lake "greenstone" Belt forms part of the Sachigo Subprovince which consists of several relatively small arcuate and irregularly shaped metavolcanic-metasedimentary belts surrounded mainly by younger granitoid rocks. Lithological similarities in the stratigraphic



LOCATION MAP

Scale : 1 : 1 548 000 or 1 inch to 25 miles

make-up of several of these isolated belts (e.g. the North Caribou Lake, Windigo Lake, North Spirit Lake, and Wunnummin Lake belts) suggest that they share several important evolutionary features; they may well represent remnants of a single, once continuous "megabelt". Some of these features are quite distinct from developmental stages recognized in supracrustal belts to the south in the Uchi and Wabigoon Subprovinces.

Within the North Caribou Lake Belt, a thick metasedimentary sequence consisting of conglomerates, arenites, wacke-mudstones, and chemical metasedimentary rocks is flanked on both sides by predominantly mafic metavolcanic sequences. The metasedimentary rocks have been interpreted as overlying the metavolcanic rocks, thus forming a large syncline, possibly coaxial with Eyapamikama Lake (Satterly 1941; Thurston *et al.* 1979). The supracrustal rocks are bounded to the north and west by migmatized rocks, mainly sedimentary in origin, and to the south by felsic intrusive rocks.

GENERAL GEOLOGY

Field work in 1984 concentrated mainly on that part of the North Caribou Lake Belt between Weagamow Lake and the eastern end of Eyapamikama Lake.

Agutua Arm Metavolcanic Rocks

The oldest stratified rocks in the map area occupy the extreme southwestern part of the North Caribou Lake Belt (Figure 1). These comprise mainly massive mafic flows. A gross southwest-striking stratigraphy is suggested by 2 felsic and intermediate pyroclastic/volcaniclastic intercalations situated near the northeastern end of Agutua Arm of Weagamow Lake. These units dip shallowly to the southeast, however, their stratigraphic relations within the Agutua Arm metavolcanic rocks are tenuous due to the absence of top indicators.

The most extensive felsic and intermediate pyroclastic/volcaniclastic sequence, situated between the mouth of the North Caribou River and the western end of Eyapamikama Lake, is largely undocumented except for shoreline exposures mapped previously by Satterly (1941) and Thurston *et al.* (1979). Both fragmental sequences are composed mainly of monolithic tuff and lapilli-tuff. Coarser fragmental rocks, mainly heterolithic, are commonly too deformed to determine the method of fragmentation, and are hence termed "volcaniclastic"; these occur locally throughout the fragmental sequences.

Where discernible, bedding thickness in pyroclastic rocks is on the order of 1 to several metres, in places up to 10 m or more. Internal stratification is generally lacking or crudely developed. These features suggest that these are mainly air-fall pyroclastics deposited in a proximal, probably subaerial environment.

Keeyask Lake Metasedimentary and Metavolcanic Rocks

Southeast from the extreme western end of Eyapamikama Lake to south of the North Caribou River lies an east-facing, 8 km long metavolcanic-metasedimentary sequence with a maximum thickness of 800 m; it thins gradually to the north where it is probably less than 200 m thick. An unconformable contact with the underlying pyroclastic/volcaniclastic rocks of the Agutua Arm metavolcanic sequence is exposed at 3 localities, and marks the beginning of an early episode of sedimentation in the North Caribou Lake greenstone Belt. The metasedimentary unit does not exceed 18 m in thickness, and comprises, in ascending order: trough cross-stratified quartz arenite exhibiting bimodal to random paleocurrent directions; massive quartz arenite; marlstone (possibly stromatolitic); very thinly bedded to laminated siltstone; lean chert-magnetite iron formation; and intraformational marlstone breccia.

The presence of mature, cross-stratified quartz arenites containing well-rounded grains suggests a tectonically stable, shallow water shelf environment; the possible presence of stromatolites is consistent with this interpretation. Quartz-rich metasedimentary rocks also occur in the nearby North Spirit Lake Belt, and were interpreted by Wood (1977, 1980), and Donaldson and Ojakangas (1977) to signify a period of early crustal stability in the Archean, as yet undefined chronologically.

Directly overlying the Keeyask Lake metasedimentary rocks is a sequence comprising ultramafic rocks interpreted by the authors as volcanic. These rocks are best exposed northeast of Keeyask Lake, where the maximum exposed thickness is about 100 m. Although now converted to talc + carbonate ± amphibole ± serpentine schists, primary textures including spinifex and polysuturing are well preserved. Pillowed flows, some

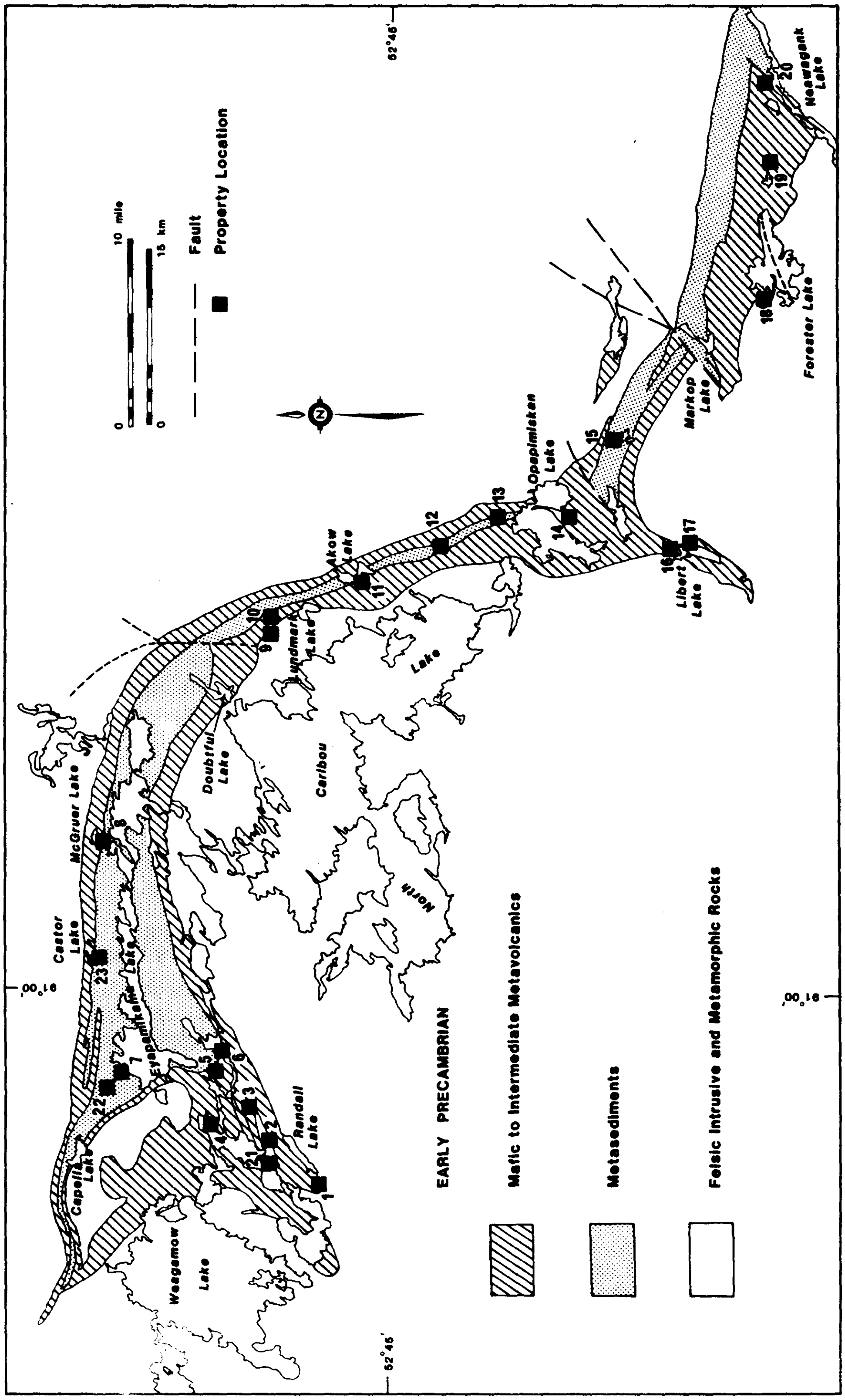


Figure 1. Location map for mineral properties in the North Caribou Lake Belt; location numbers are indexed to Table 1. (Project S49).

intensely variolitic, occur locally. Autoclastic breccias are common in the northern part of the unit. Flow thickness is generally at least several metres.

Minor interdigitation of the ultramafic metavolcanic rocks overlying mafic metavolcanic rocks may be the result of mesoscopic folding or it may reflect a facies transition northwestward from predominantly mafic to predominantly ultramafic metavolcanic rocks. The mafic metavolcanic rocks appear to pinch out north of Keeyask Lake and are best exposed northeast and east of Keeyask Lake, and south of the North Caribou River.

Mafic metavolcanic rocks in this area include massive and pillowed varieties. Fine-grained massive flows commonly exhibit medium- to coarse-grained flow centres. Pillows are generally little deformed, range in length from 40 to 150 cm, and commonly display a zonation of vesicles toward their tops. Moderate to high concentrations of vesicles in the pillows indicate that these rocks were deposited in a relatively shallow marine environment.

Varioles up to 20 cm in diameter are common in mafic flows east of Keeyask Lake; locally they have coalesced to form sub-metre-scale masses. Minor mafic autoclastic breccias occur north of Keeyask Lake, generally in association with ultramafic breccias.

North Rim Metavolcanic Rocks

North of Eyapamikama Lake, a 0.4 to 1.7 km thick metavolcanic sequence is continuously bounded throughout the map area by tonalitic intrusive rocks to the north and clastic metasedimentary rocks to the south. Its relationship with the Keeyask Lake mafic and ultramafic metavolcanic sequence is enigmatic because of poor exposure between Miskeesik and Eyapamikama Lakes.

The North Rim metavolcanic rocks comprise massive and pillowed mafic flows with minor intercalations of mafic and intermediate volcaniclastic rocks, chemical metasedimentary rocks, and metamorphosed ultramafic rocks of unknown origin.

In most areas, the North Rim mafic metavolcanic rocks are moderately to intensely deformed; length-to-width ratios of preserved pillows (in sections normal to dip) commonly vary between 1:10 and 1:25. Intense attenuation of pillows is notable in the Atikomik Lake and Castor-Pollux Lakes areas. Pillow shape and packing arrangement can be used only rarely as facing indicators, as in the McGruer Lake area (*see* also Satterly 1941, p.13). Pillows locally contain abundant vesicles, indicating a shallow marine environment of deposition.

Small deformed pods and lenses of calcsilicate material characterized by the assemblage plagioclase + diopside ± grossularite ± quartz ± epidote ± tourmaline, occur within mafic metavolcanic rocks between Atikomik and Capella Lakes.

South Rim Metavolcanic Rocks

The South Rim metavolcanic rocks form the southern limit of the North Caribou Lake Belt from the eastern part of the map area to the sixth portage on the North Caribou River above Agutua Arm (*see* Satterly 1941, Map 48h). Their relationship with the Agutua Arm and Keeyask Lake metavolcanic successions is unknown due to a presently undefined component of movement along the Staunton Lake Fault Zone.

Like the North Rim metavolcanic rocks, the South Rim sequence is between 0.4 and 1.7 km thick. As in the North Rim, massive and pillowed mafic metavolcanic rocks predominate, with only local intercalations of felsic and intermediate tuff, chert, and chert-magnetite banded iron formation. The best exposed section through the South Rim metavolcanic sequence is on the shores of the channel between Eyapamikama and Seeseep Lakes. There, massive and pillowed mafic flows alternate on the scale of several metres to tens of metres; minor pillow breccia layers are commonly less than 2 m thick and are typically strongly foliated (sheared?). Hyaloclastite is preserved in pillow interstices. Some pillows contain highly vesicular zones. In general, the South Rim metavolcanic rocks are less deformed than those of the North Rim.

Eyapamikama Lake Metasedimentary Rocks

A major episode of clastic sedimentation is represented by the rocks occupying the core of the North Caribou Lake Belt. These rocks unconformably overlie the Keeyask Lake mafic and ultramafic metavolcanic rocks, and appear to be at least in part gradational with the North Rim metavolcanic rocks; their contact relationship with the South Rim metavolcanic rocks is not well understood due to poor outcrop exposure. Deformation of the metasedimentary unit is generally most pronounced away from the centre of the belt, in close proximity to the North and South Rim metavolcanic rocks. The best preserved section of the metasedimentary unit follows the length of Eyapamikama Lake. At the western end of the lake these metasedimentary rocks fine upward from conglomerate through arenite to an arenite-mudstone assemblage, and thence to mudstone, which predominates to the eastern end of the lake.

The base of the clastic metasedimentary sequence is characterized by matrix-supported and, less commonly, clast-supported conglomerates containing a wide variety of cobble to boulder sized clasts derived from relatively local plutonic, volcanic, subvolcanic and sedimentary sources. Overlying, and to a lesser extent interstratified with the conglomerates are commonly massive, immature, coarse wackes and feldspathic arenites. Rare graded arenite 15 to 150 cm thick, exhibits basal scour structures marked by lag deposits.

Interbedded mudstone-arenite or wacke commonly exhibits a variety of primary structures including graded bedding, flames, slump features, scours, and clast rip-ups. As these sedimentary rocks display various combinations of the Bouma cycle, they are interpreted to be turbidites.

Most of the clastic metasedimentary unit comprises thinly to very thinly bedded, fine-grained mudstones characterized by a well-developed slatey cleavage. These rocks are considered to be derived from sediments deposited in a low energy, deep water environment.

Chemical Metasedimentary Rocks

Chemical metasedimentary rocks such as chert and banded iron formation commonly occur as local accumulations contained within all metavolcanic-metasedimentary sequences described above. Grunerite-quartz banded iron formation is notable in the Castor-Pollux Lakes area where tectonic enclaves of this rock are contained within a highly deformed, transposed assemblage of metapelite, metawacke, mafic metasedimentary rocks, fine-grained mafic metavolcanic rocks, and rare sericite schists. Exposures of grunerite-quartz iron formation are up to 12 m thick, however, thicknesses have probably been significantly increased by tight folding.

Metaplutonic Rocks

The North Caribou Lake Belt is bounded by 3 felsic intrusive masses. As emphasis in this survey was placed on the metavolcanic-metasedimentary rocks of the belt, only cursory examination was made of the bordering plutons.

The North Caribou Lake Batholith marks the southern limit of the greenstone belt. Near the contact it comprises moderately foliated biotite tonalite, and, less commonly, granodiorite. Xenoliths of mafic volcanic rocks are common, suggesting that the volcanic rocks predated emplacement of the pluton.

The intrusive body bounding the northern side of the belt is compositionally and texturally varied, ranging from massive tonalite and granodiorite, to foliated biotite granite, to gneissic granite and granodiorite, to foliated, layered tonalite and plagioclase megacrystic tonalite. Mafic xenoliths occur at least 1.8 km from the volcanic-plutonic contact.

The Weagamow Batholith bounds the belt to the west. At its eastern limit north of Keeyask Lake its character varies from massive, equigranular hornblende granodiorite to a felsic quartz-phyric rock which may be subvolcanic. Many felsic plutonic clasts in the conglomerate at the western end of Eyapamikama Lake bear at least superficial resemblance to the rocks composing the Weagamow Batholith. Hence this pluton may have predated the major episode of sedimentation in the North Caribou Lake Belt.

STRUCTURAL GEOLOGY

Two major folding events are recorded in the rocks of the Eyapamikama Lake area. The first, D_1, is characterized by: (1) mesoscopic and macroscopic tight to isoclinal folding about east-striking, subvertical axial planes; (2) a penetrative mineral and mineral aggregate foliation (S_1); (3) transposition of bedding and original fabric elements (S_0) into parallelism with S_1; and (4) flattening of pillows and conglomerate clasts. A strong mineral lineation (L_1) occurs in the hinge zones of D_1 folds. L-S fabric is typically most pronounced in metavolcanic rocks adjacent to the granitoid bodies to the north and south.

Opposing stratigraphic top indicators throughout the study area, but particularly in the rocks north of Eyapamikama Lake, suggest the presence of large amplitude D_1 folds having wavelengths of up to 1000 m or more. Repetition of stratigraphy is thus likely in many parts of the area, including those where facing criteria are not available.

Bedding and S_1 foliation are in turn deformed about open to gentle (D_2) folds with northeast-striking, shallowly to moderately southeast-dipping axial planes. The intersection of D_2 foliation/cleavage (S_2) with S_0/S_1 fabric results in a crenulation lineation (L_2), most pronounced in slatey mudstones on the shores of Eyapamikama Lake. In most other rocks, effects of D_2 folding are poorly developed or absent.

Narrow brittle deformation zones are distributed throughout the Agutua Arm metavolcanic rocks. These west- to southwest-striking fault zones are mainly sinistral and vary in width from 3 to 6 m. The most prominent fault zone mapped is the Staunton Lake Fault, which is intermittently traceable for 18 km from the Staunton Lake outlet southwest to Agutua Arm of Weagamow Lake. This zone is characterized by a strong penetrative foliation where mafic and ultramafic metavolcanic rocks are overprinted; and by shallowly to moderately plunging, west-trending mineral and fold axis lineations. Talc-carbonate schists, commonly fuchiste-bearing, and associated quartz-carbonate layers are contained within parts of the fault zone, as are rare tectonic enclaves of massive quartz arenite.

These fault zones have economic importance, serving as hosts for Cu-Ag-Au mineralization, as at the Teal Occurrence (described below). Arsenopyrite-bearing carbonate-quartz veins up to 30 cm wide also occur within these zones.

A zone characterized by a more ductile style of deformation extends along the northern side of the belt at least as far east as the eastern end of Eyapamikama Lake. Deformation within this zone is most evident along the contact between metavolcanic and metasedimentary rocks where lithologies of contrasting competency are intercalated. On a mesoscopic scale, competent layers are boudinaged; indeed this may account for the intermittent nature of banded iron formation units in this area. Tight and isoclinal east-plunging folds with subvertical axial planes are best seen in chemical metasedimentary rocks. Dislocation of fold limbs resulting in "fish hook" structures is common, and results in very complex features on outcrop scale.

METAMORPHISM

Metamorphic zones are roughly parallel to the boundaries of the North Caribou Lake Belt. A large area of low grade metamorphism is asymmetrically disposed between Agutua Arm and the eastern limit of the study area. Metamorphic rank increases to medium grade north and east of this chlorite zone as established by the appearance of biotite, and localized andalusite, cordierite, and staurolite. A distinct biotite isograd, as delineated in mudstones of the central clastic metasedimentary sequence extends for 30 km along Eyapamikama Lake. Biotite porphyroblasts, probably formed at the expense of chlorite, gradually coarsen northwards, attaining 3 mm diameters as on Stanley Lake. Roughly 2.5 km north of the biotite isograd, the appearance of garnet is favoured in certain mafic metavolcanic and iron-rich metapelite compositions. The garnet isograd was traced for at least 16 km between McGruer Lake and west of Castor Lake.

Metamorphic subdivision of mafic metavolcanic rocks is more difficult in the field due to a prevailing fine grain size and imperceptible megascopic difference between actinolite and green hornblende. However, within 150 m of tonalitic batholiths positioned along the northern and southern contacts of the North Caribou Lake Belt, mafic metavolcanic rocks are characterized by black hornblende + plagioclase ± quartz ± biotite assemblages.

Impressive cordierite zones are developed in metapelitic rocks at the eastern end and near the northwestern extremity of Eyapamikama Lake. The former locality contains ovoid cordierite porphyroblasts up to 3 by 2.5 by 1 cm which make up 40 to 50% of the rock. Noteworthy here is an eastern transition (over 2 m) from andalusite to sillimanite zones marked by the following quartz + plagioclase - bearing metapelites:

(1) biotite + muscovite + andalucite + cordierite

(2) biotite + muscovite + andalucite + staurolite + cordierite

(3) biotite + muscovite + sillimanite + cordierite

The andalusite-sillimanite isograd is also observed at Miskeesik Lake in the northwestern part of the North Caribou Lake Belt. Andalusite locally coexists with staurolite and also can occur as large pink masses within deformed quartz veins associated with andalusite-bearing metapelites in this area.

Kyanite-bearing metapelite was encountered near Miskeesik Lake and may represent the first such occurrence in the Sachigo Subprovince in northwestern Ontario.

ECONOMIC GEOLOGY

Approximately 300 specimens were submitted to the Geoscience Laboratories, Ontario Geological Survey, Toronto, for analysis of Au (2 ppb sensitivity), Ag, As, and in some cases W, B, Li, Cu, Pb, and Zn. The material currently being analyzed includes metavolcanic and metasedimentary rocks mineralized with sulphides, banded iron formation, quartz veins containing sulphides and/or tourmaline and/or carbonate, barren quartz veins, and fuchsite-bearing carbonate rocks from layers in shear zones.

Gold is associated with banded iron formation at the nearby Musselwhite Property on Opapimiskan Lake (Andrews *et al.* 1981; *see* also Musselwhite Property below). A similar association should be considered for certain parts of the study area as exemplified at Castor-Pollux Lakes where highly deformed grunerite + quartz ± magnetite ± garnet lean banded iron formation is exposed. Preliminary results indicate that localized sulphide concentrations, occurring as massive arsenopyrite lenses concordant to banding, contain 0.04 ounce gold per ton (Geoscience Laboratories, Ontario Geological Survey, Toronto) as on Castor Lake. Veins of massive pyrrhotite, up to 2 cm wide and mainly disposed normal to the banding of the iron formation host, occur south of the eastern end of Pollux Lake.

Banded iron formation in the Castor-Pollux Lakes area has probably been overlooked to date as a potential gold exploration target because the magnetic signature is only subtley distinguishable from surrounding units on regional aeromagnetic maps (ODM-GSC 1960). These banded iron formation units probably extend, albeit discontinuously, from west of Castor Lake to McGruer Lake and it is highly recommended that this area be explored in detail. Further gold potential in this area is indicated by quartz-tourmaline veins which locally contain appreciable arsenopyrite as evidenced 150 m south of the eastern end of Pollux Lake, and 200 m south of McGruer Lake. The latter occurrence registered 10.9 ppm gold (0.022 ounce gold per ton) (Geoscience Laboratories, Ontario Geological Survey, Toronto).

The intense ductile deformation evident along the northern part of the belt may be genetically associated with the presence of gold concentrations in this area.

QUATERNARY GEOLOGY

Quaternary investigations during the summer of 1984 included the North Caribou Lake map sheet (NTS 53 B/15) and the eastern half of the Weagamow Lake map sheet (NTS 53 B/14).

PHYSIOGRAPHY

The study area lies wholly within the Canadian Shield and it is part of the Severn Upland division of the James physiographic region (Bostock 1969). The Uplands are relatively flat to gently rolling, strongly reflecting the widespread distribution of glacial drift. Drumlins and drumlinoid ridges are the most common geomorphic features in the study area, seldom exceeding 20 m in height and 1.5 km in length.

Bedrock commonly occurs as isolated knolls or ridges, surrounded by Quaternary deposits. However, there is an extensive zone of shallow drift-covered (to exposed) bedrock that extends from Atikomik Lake eastward to Erichsen Lake, a distance of about 45 km. This zone rises between 20 and 60 m above the surrounding countryside and is part of the North Caribou Lake metavolcanic-metasedimentary belt. Similar zones of shallow drift-covered bedrock occur northwest of and parallel to Randall Lake (Satterly 1941).

QUATERNARY DEPOSITS

The study area contains a variety of Quaternary deposits that represent the last major ice advance and its subsequent retreat during the Wisconsinan. Till, mainly lodgement till, was deposited during the advance of glacial ice, and a variety of ablation deposits, including glaciolacustrine sediments of glacial Lake Agassiz, were deposited as the glacial ice front retreated northward.

Ice movement was generally in a southwesterly direction as suggested by various ice flow directional indicators. Cross-cutting striae were observed along the southern shore of Eyapamikama Lake in 2 localities. At each locality, the cross-cutting striae are remarkably consistent, the oldest set trending about 205°, and the younger and more regional set trending 226°. The 2 localities are about 8 km apart suggesting that a local readvance may have occurred in this area.

Till is the most common Quaternary deposit in the study area. Texturally, the till ranges from a stony and gritty, silty, fine to very fine sand. It is usually moderately compact, fissile, and massive and occurs in the form of drumlins, end moraine, and ground moraine. Till colour varies from a yellowish brown to brown near the surface; fresh unoxidized exposures are olive or olive-grey. In most locations, fines have been winnowed from the upper 0.5 m of the till by the action of glacial Lake Agassiz.

Glaciofluvial deposits in the form of esker ridges occur in several localities, the most prominent being an esker system that extends southwestward from Hodgson Lake, a distance of about 25 km. Kames are commonly associated with esker systems in the study area.

Glaciolacustrine or fluvial deposits of gravelly sand to sand commonly occupy the low ground between drumlins and similar features. These sediments may be the result of wave action of glacial Lake Agassiz.

Glaciolacustrine silts and clays deposited in glacial Lake Agassiz are found in the western part of the study area, between Weagamow and Eyapamikama Lakes. These sediments commonly occupy low sheltered areas between bedrock knolls and ridges.

Varved silts and clays were found between till units near Staunton Lake. This, combined with the presence of cross-cutting striae to the northeast (described above), suggests that a glacial readvance probably occurred in the study area. A readvance described by Prest (1963) in the North Caribou Lake map area may correlate with this event.

Well developed terraces on drumlins were noted in several localities in the study area. Lag concentrates of boulders were also noted on drumlins as well as around the perimeter of most lakes. All of the above features are presumably the result of wave action in glacial Lake Agassiz.

Accumulations of organic matter in the form of peat and muck are widespread. The thickness of the peat is variable, and it commonly overlies till.

BEDROCK DISPERSION STUDIES

As noted by Andrews *et al.* (1981), the study area is particularly well suited for bedrock dispersal studies since glacial ice movement was transverse to the strike of the Weagamow-North Caribou Lakes metavolcanic-metasedimentary belt. Also, there is abundant coarse glacial drift exposed at the surface and the belt consists of easily recognized and spatially distinct bedrock types (Andrews *et al.* 1981, p.212). Thus, the occurrence and distribution of boulders were examined and samples of essentially unweathered lodgement till were systematically collected down-ice from the greenstone areas.

Based on the presence of gold mineralization within iron formation units in the vicinity of Opapimiskan Lake, particular attention was given to the occurrence and distribution of iron formation float. Numerous boulders of iron formation and associated chemical sediments were found north of the portage between Eyapamikama Lake and North Caribou River. The boulders were strongly concentrated on a small ridge-shaped feature, the core of which is believed to be an in situ bedrock feature. Several samples of iron formation float were submitted for gold assay and thus far, only 1 sample yielded minor amounts of gold (0.01 ounce gold per ton; fire assay determination, Geoscience Laboratories, Ontario Geological Survey, Toronto). Subsequent investigations nearby led to the discovery of iron formation in bedrock.

Based on the discovery of iron formation bedrock south of Castor and Pollux Lakes, dispersion studies were conducted southwest (down-ice) of these localities. Numerous sulphide-rich boulders, including some iron formation, were found along the northern shore of Eyapamikama Lake. Thus far, 2 boulders have assayed 0.01 ounce gold per ton (fire assay determination, Geoscience Laboratories, Ontario Geological Survey, Toronto). Data from other samples are not yet available.

Many mineralized (sulphide-rich) boulders including relatively high concentrations of iron formation float were found in the northern part of Agutua Arm. The iron formation may have originated from either the Eyapamikama Lake-North Caribou River area (discussed above), or from a drift covered source.

Data on till samples are not yet available.

AGGREGATE RESOURCES INVENTORY

The objective of this part of the Opapimiskan Lake Project is to provide information on aggregate resources suitable for highway and general construction, much of which may be required if a potential mining operation goes ahead. Prior to this study, the general area was perceived to lack any appreciable resources of good quality construction aggregate. The area studied for this purpose extends along a 10 to 15 km wide corridor, within the Opapimiskan Lake project area, which straddles the route of a winter road running south from Opapimiskan Lake to the gravel surfaced road leading to Pickle Lake, some 100 km away (*see* Location Map).

The field investigation involved the examination of potential aggregate deposits, natural and man-made exposures, and existing pits. Test pitting, soil probing, and hand augering techniques were used to assess subsurface materials in areas of limited exposure. Deposits with good potential for extractive development were studied in greater detail. Representative samples were taken from several of these deposits to ascertain the quality and workability of the aggregate.

The topography of the southern part of the project area is dominated by the presence of the Agutua Moraine (Prest 1963) which is a major glacial feature in northwestern Ontario. This northwest- to southeast-trending moraine is approximately 4 to 5 km wide. It consists dominantly of sand and gravel and is a major source of aggregate in the southern part of the project area. Several pits have been opened in the moraine, exposing material ranging in composition from medium sand to coarse gravel. Crossing the moraine at several locations are northeast- to southwest-trending esker and ice-contact deposits which increase the potential aggregate resources in the area.

From the Agutua Moraine to approximately 10 km south of Opapimiskan Lake, the terrain is of low relief with numerous swamps. Bedrock exposures are common but large areas of glacial till also occur. Aggregate resources in this part of the project area are limited although localized deposits of ice-contact material may be of use.

In the vicinity of Opapimiskan Lake, aggregate resources are relatively abundant. Several eskers, some of which exceed 30 m in height, traverse the area. The material exposed at the surface of the ridges varies from sand to coarse gravel and should be suitable for the production of a variety of aggregate products. Ice-contact sand and gravel often flanks the eskers, enlarging the resource potential. A prominent east-trending morainic ridge is also located in the Opapimiskan Lake area—just to the north of Zeemel Lake. This morainic ridge, in contrast to the Agutua Moraine to the south, consists predominantly of sandy till which, although useful for fill, is not too well suited for aggregate use.

In general, the sand and gravel in the Opapimiskan Lake area is of high quality. Deleterious materials appear to be insignificant with only minor occurrences of chert and no significant content of fines. The available aggregate should meet the specifications for most road-building and construction products, including crushable aggregate for use in structural concrete. A major concern in the area is that whereas aggregate supplies appear adequate in the vicinity of Opapimiskan Lake and the Pickle Lake road, resources are scarce in the central part of the study area.

MINERAL DEPOSITS

As part of the Opapimiskan Lake Project, field inspection was conducted on a number of mineral showings in the North Caribou Lake Belt. Attention was focused on the western Eyapamikama Lake-Agutua Arm area to augment work being done by Precambrian Geology field crews. A brief visit was also made to the Musselwhite Gold Property on Opapimiskan Lake.

PROPERTY DESCRIPTIONS

Figure 1 is a location map for all properties located in the belt that are either described in this report and/or in the Assessment Files Research Office, Ontario Geological Survey, Toronto (AFRO), or are properties that were recently staked for which no assessment work has been submitted.

Each map location number refers to a property described in Table 1, which is a compilation of property information taken from the Assessment Files (AFRO) and from referenced geological studies.

The following descriptions are of properties that were visited by the authors during this field season. Although they are based primarily on field observations, they do include information from company reports. Especially drill logs in the Assessment Files (AFRO).

Teal Cu–Au–Ag Occurrence

The claims covering the Teal Occurrence were acquired by St. Joseph Exploration Limited (now Sulpetro Minerals Limit-

TABLE 1. MINERAL PROPERTIES IN THE NORTH CARIBOU LAKE BELT (PLOTTED ON FIGURE 1). DATA COMPILED FROM INFORMATION IN THE ASSESSMENT FILES OFFICES, ONTARIO MINISTRY OF NATURAL RESOURCES. (PROJECT S49).

Map Location	Property/Name	Location Long./Lat.	Property Descriptions
1	Grid 1, 2, & 3 Properties; St. Joseph Exploration Ltd. (now Sulpetro Minerals Ltd.)	91°14′ 52°49′	Located at margin of greenstone belt, metasedimentary and metavolcanic rocks are migmatized and intruded by granites. Three conductive, magnetic anomalies located by airborne and ground EM and Mag surveys, not tested.
2	Grid 4 Property; St. Joseph Exploration Ltd.	91°12′ 52°50′	*see* text and Thurston *et al.* (1979)
3	Randall Lake Property; Moss Resources Ltd.	91°09′ 52°52′	Claims underlain by a suite of predominantly mafic volcanic rocks, with few felsic intercalations and metasedimentary rocks including banded iron formation (BIF). They have been intruded by granitic rocks and are cut by a throughgoing, intensely deformed shear zone. Mineralized areas subjected to ground EM and Mag surveys, extensive pitting and trenching, and about 1500 m of diamond drilling. Property includes the St. Joseph Grid 5 and 6 areas described in the text; also *see* references in Thurston *et al.* (1979).
4	Keeyask Lake Property; Moss Resources Ltd.	91°11′ 52°53′	En echelon quartz veins occurring in andesitic mafic metavolcanic rocks. Mineralization consists of arsenopyrite, pyrite, chalcopyrite, and tetrahedrite. Stripping, trenching and diamond drilling undertaken on property (Thurston *et al.* 1979). Current owners have no assessment work filed.
5	Grid 5 Property; St. Joseph Exploration Ltd.	91°06′ 52°53′	*see* text
6	Grid 6 Property; St. Joseph Exploration Ltd.	91°03′ 52°53′	*see* text
7	Molybdenite Occurrence; Not claimed	91°06′ 52°57′	*see* text
8	McGruer Lake; Dunlop Exploration Ltd.	90°48′ 52°58′	Mainly andesitic, mafic metavolcanic rocks overlain by metasedimentary rocks including BIF. Cut by 2 sets of pyrite±arsenopyrite-bearing quartz veins. No assessment work submitted.
9	G & F Claims; Canadian Occidental Petroleum Ltd., Minerals Div.	90°34′ 52°51′	Claims over contact area between metavolcanic and metasedimentary rocks including outcropping BIF. V.L.E.M. and ground Magnetic survey outlined 4 conductors associated with sulphide facies BIF and at the metavolcanic-metasediment contact. BIF assayed geochemically anomalous Au and As. More prospecting, geochemistry, and soil sampling recommended.

TABLE 1. CONTINUED (PROJECT S49.)

Map Location	Property/Name	Location Long./Lat.	Property Descriptions
10	North Caribou Lake Properties; Eldorado Nuclear Ltd.	90°32′ 52°51′	Claim underlain by metavolcanic and metasedimentary rocks including BIF and is on the southern limb of the regional syncline. Ground Mag and EM surveys done on the property, also geological mapping, soil sampling, and lithogeochemistry—no anomalous Au, Ag, or As areas.
11	Akow Lake Property; Cominco Ltd.	90°29′ 52°47′	Claims underlain by basic metavolcanic and metasedimentary rocks including BIF. Sixty Wacker-type overburden holes drilled to acquire basal till samples at or near the bedrock-overburden interface—low base metal values but geochemically anomalous Au values show systematic increase along southwestern shore of Akow Lake.
12	Opapimiskan North Property; Canadian Nickel Co. Ltd.	90°26′ 52°43′	Property underlain by foliated to massive basaltic flows with lenses of dacitic tuffs and volcaniclastic sediments, and metasedimentary rocks including sulphide and lean oxide facies BIF. Mag and EM surveys outline 2 anomalies in basic metavolcanic rocks on both sides is a synclinal fold axis. Basaltic units with quartz veining and traces of arsenopyrite and pyrite, and dacitic tuffs with quartz veining, both assayed anomalous Au.
13	Opapimiskan Lake Property; Van Horne Gold Explorations Inc.	90°23′ 52°40′	Property underlain by sequence of north- trending metavolcanic and metasedimentary rocks, including oxide/silicate facies BIF; lying in the axis area of a regional fold. Ground Mag and EM surveys, and geological mapping outlined 2 conductive anomalies in folded BIF. Trenching in contorted magnetite-chert BIF yielded a sample over 11 feet that assayed 0.09 ounce Au per ton. More geophysics and diamond drilling planned.
14	Musselwhite Occurrence, Opapimiskan Property; Dome Syndicate	90°24′ 52°37′	*see* text and Andrews *et al.* (1981).
15	Graff Lake Project; Canadian Nickel Co. Ltd.	90°17′ 52°35′	This property is underlain by mostly basaltic metavolcanic and metasedimentary rocks including 2 zones of BIF, which are intruded by gneissic granites and diabase dikes. Chip channel samples were taken on all exposed outcrops of BIF—anomalous with respect to Au in ppb range but not sufficient to warrant further work.
16	Libert Lake Property; Van Horne Gold Explorations Inc.	90°26′ 52°32′	These claims are underlain by mafic to intermediate metavolcanic and metasedimentary rocks including BIF; ground Mag and EM surveys were done on the property and a sericitic quartz-bearing shear zone with weak magnetic-sulphide BIF has been trenched; samples taken over 2.8 m assayed 0.19 ounce Au per ton.
17	Libert Lake Property; Armstrong, Reid and Best	90°26′ 52°31′	This property area is underlain by felsic, intermediate, and mafic metavolcanic and intercalated metasedimentary rocks including BIF. Five diamond-drill holes totaling 547 m intersected deformed garnetiferous sulphide and oxide facies banded iron formation containing pyrite and pyrrhotite, no assays were reported.

TABLE 1. CONTINUED (PROJECT S49.)

Map Location	Property/Name	Location Long./Lat.	Property Descriptions
18	Forester Lake Properties; Van Horne Gold Explorations Inc.	90°06′ 52°27′	This property is underlain by metavolcanic and metasedimentary rocks that are intruded by pegmatites, aplites, porphyries, and later peridotite sills, and is bounded by granites. Property has numerous gossanized shears and fractures containing 10 to 35 mm wide quartz veins associated with aplite dikelets and pegmatite bands that are mineralized with py, po, cp±mo. Two short diamond-drill holes on airborne detected, EM conductors yielded massive po + graphite assaying trace to 0.02 ounce Au per ton. The ultramafic sills have Mag signature and contain significant nickel and cobalt.
19	Sage Lake Area Properties; Canadian Nickel Co. Ltd.	89°56′ 52°28′	This property is underlain by intermediate to basic lava flows with intercalated metasedimentary rocks and widely developed migmatites. In 1941, grab samples from quartz vein within a shear zone assayed 5 ounces Au per ton. Extensive trenching has explored a number of these quartz veined shear zones mineralized with massive to disseminated asp, py, cp, and galena—most of these zones have anomalous Au.
20	Neawagank Lake Group; Van Horne Gold Explorations Inc.	89°56′ 52°28′	This property is underlain by mafic metavolcanic and metasedimentary rocks, which host a number of quartz veins, and is cut by felsic intrusive rocks. Mag and EM surveys have outlined 2 well defined conductors along a magnetized zone that could be sulphides within iron formation or shear zones. The area supposedly includes one of the high grade gold showings in quartz veins that was discovered in the 1940s.
21	Dunlop Exploration Ltd.	91°13′ 52°50′	This property is underlain by predominantly mafic metavolcanic rocks which have been intruded by felsic intrusive rocks, mainly diorites and granodiorites. In the neighbouring Teal Property this intrusive contact is a mineralized shear zone. Mag attractions are common in the region. A number of quartz, calcite, and ankerite veins have been sampled in the area. No assessment work has been submitted by claim owners.
22	Dunlop Exploration Ltd.	91°07′ 52°57′	This claim is underlain by mostly metasedimentary rocks including wackes, arenites, mudstones and cordierite-biotite schist. The area is to the northwest of the tonalite dike hosted, molybdenite, pyrite, fluorite, tourmaline mineralization. No assessment work has been submitted by claim owners.
23	Dunlop Exploration Ltd.	90°27′ 52°58′	These claims cover the contact area between metasedimentary rocks, mostly wackes, and metavolcanic rocks, mostly amphibolites. A Mag attraction in the area may be related to BIF. No assessment work submitted by claim owners.

ed) in 1976. In 1977, 1335 line km of airborne electromagnetic survey were flown over the property area with follow-up ground reconnaissance and geological mapping; claims were staked on 6 properties named Grid 1 to 6 (map locations 1, 2, 5, and 6, Figure 1) with detailed mapping and subsequent diamond drilling on 3.

Grid 4 Property

This anomaly coincided with the original Teal Cu-Au-Ag Occurrence (map location 2, Figure 1) and consists of localized mineralization along an extensive northeast-trending shear zone occurring at the contact of a diorite intrusive body and mafic metavolcanic rocks. It is located 630 m east of the Agutua Arm of Weagamow Lake and 900 m north of Randall Lake. The exposed mineralized zone, which is 195 m long by 12 m wide, consists of highly sheared dioritic material, highly silicified, and locally totally replaced by silica. A dense network of irregular, locally brecciated, quartz-ankerite veins are mineralized with chalcopyrite, pyrite, pyrrhotite, tetrahedrite, and bornite. A fuchsite-quartz vein marks the footwall margin of the shear zone.

Thurston *et al.* (1979) describe the geology of the showing in some detail, including a pre-1971 exploration and development history of the occurrence.

St. Joseph Exploration Limited mapped the area at a scale of 1:2400 (1 inch to 200 feet), subsequent to which 3 diamond-drill holes totaling 365 m were drilled to test the down dip extension of the mineralized zone. The structure was found not to persist at depth and no significant Cu, Au, or Ag mineralization was found in the drill intersections that were assayed.

Grid 5 Property

Grid 5 (map location 5, Figure 1) is located to the south and east of the Portage Trail between the most southerly arm of Eyapamikama Lake and the Agutua Arm of Weagamow Lake. The area is underlain by a suite of predominantly mafic metavolcanic rocks with few felsic, mostly rhyolitic, intercalations. Cherty banded iron formation occurs associated with a highly sheared quartz-eye rhyolite and a massive sugary textured grey quartzite. To the north of the claim area, near the Portage Trail, a 6 m thick, thinly laminated and strongly oxidized banded iron formation outcrops, and is associated with a massive grey quartzite and relatively undeformed rhyolitic felsic metavolcanic rocks. This would suggest an increase in intensity of structural deformation as one proceeds south. Rayner (1978) suggests that the banded iron formation lies within the core of an overturned syncline which plunges to the north. Rayner (1978) also suggests that the metavolcanic sequence is intruded by a highly fractured, tourmaline- and pyrite-bearing, quartz feldspar porphyry.

St. Joseph Exploration Limited drilled 5 diamond-drill holes, totaling 350 m, to test geologically favourable electromagnetic conductors. Variable thicknesses of cherty, banded sulphide iron formation with massive and disseminated pyrrhotite, pyrite ± chalcopyrite were intersected. Most of these assayed trace to *nil* gold. A 1.53 m drill intersection of a "cherty interflow material consisting of fine grained, grey, locally finely bedded reworked tuffaceous sediments", (St. Joseph Exploration Limited drill logs, Assessment Files Research Office, Ontario Geological Survey, Toronto) containing an average of 20% pyrrhotite and pyrite with trace chalcopyrite and sphalerite, assayed 0.02 ppm gold, and a 1.22 m section of porphyry/granodiorite with tourmaline - quartz - pyrite ± arsenopyrite veinlets, assayed 0.4 ppm gold.

Grid 6 Property

This group of claims, located north and south of the North Caribou River (map location 6, Figure 1), is underlain by predominantly mafic metavolcanic rocks. Ground magnetic and horizontal loop electromagnetic surveys located a conductive anomaly at the contact between pillowed andesitic metavolcanic rocks and cherty rhyolite. This anomaly was tested by a 94 m deep diamond-drill hole which intersected a massive sulphide breccia zone containing 60% pyrrhotite and 10% pyrite with traces of chalcopyrite; a 2.43 m drill intersection assayed 0.025 ppm gold. This unit contacted a cherty magnetite banded iron formation with 5% magnetite and 1 to 2% pyrrhotite which assayed 0.06 ppm gold over a 1.53 m drill intersection.

St. Joseph Exploration Limited allowed all of their claims, except for those covering the Teal Occurrence, to lapse. The claims were subsequently restaked for Van Horne Gold Exploration Incorporated/Moss Resources Limited in the spring of 1984.

Molybdenite Occurrence

Satterly (1941) mapped 2 outcrops of a grey biotite granite on the western shore of Eyapamikama Lake. He interprets these as being related to concordant intrusive bodies at the margin of the larger Weagamow Lake batholith. The intrusive bodies consist of a pinkish-white, coarse-grained, equigranular rock containing mostly plagioclase, with minor quartz and variable amounts of green muscovitic mica. A 50 by 16 m outcrop (map location 7, Figure 1) exposes a tonalitic dike striking 067°, intruding a foliated metasedimentary sequence consisting of interbedded mudstones, wackes, and cordierite-biotite schists. The dike is cut by numerous fracture-filling quartz veinlets which do not persist across the intrusive contact. The quartz veins host disseminated flecks of molybdenite and fluorite; at the margin there is a peripheral zone of green muscovitic mica enrichment with more abundant fluorite, molybdenite, and pyrite. The dike rock itself is compositionally variable, with zones of quartz, K-feldspar, and biotite enrichment (making it more granodioritic), with attendant depletion in the green muscovitic mica, the sulphides, and fluorite. The more tonalitic parts of the dike, with abundant green muscovitic mica, have disseminated fluorite, pyrite, and molybdenite in zones with no quartz veining. In outcrops adjacent to the larger dike, numerous dikelets, possibly feeders from the main body, varying from 5 to 30 cm wide, with subparallel strike, were found crosscutting the bedding of the metasedimentary rocks. Some of these dikelets grade laterally into 3 to 6 mm wide tourmaline and albite veins, suggesting a volatile-rich igneous system. The dikelets were unusually tonalitic in composition and contained the green muscovitic mica and hosted molybdenite, fluorite, pyrite, and tourmaline mineralization.

A number of samples of the mineralized rocks from this area have been submitted for assay.

Musselwhite Property, Opapimiskan Lake

The Musselwhite Property on Opapimiskan Lake (map location 14, Figure 1) was discovered by Harold and Al Musselwhite in 1962. In 1973 the Musselwhite brothers formed a grubstake to assess the property with the participation of several major mining companies, and Dome Mines Limited as operator. Following several extensive diamond drilling programs on the property, the Grubstake has published resources for the deposit of 3.2 million tons at a cut grade of 0.169 ounce gold per ton (Northern Miner, February 9, 1984). During 1984, the operating company began driving a decline into the West Anticline Zone, which has indicated reserves exceeding 1.0 million tons at 0.18 ounce gold per ton (Northern Miner, February 9, 1984) to further assess the mineralization. The decline descends at -15°, under the lake to a depth below surface of 92.6 m. A ramp then ascends at + 2°, designed to intersect the mineralized zone.

PROPOSED FUTURE INVESTIGATIONS

It is hoped that once the West Anticline Zone on the Musselwhite Property is exposed, the relationship between mineralization and host lithology may be investigated, with the operating company's consent. A detailed Ph.D. research study of the Musselwhite Property area, by R. Hall, will be released during 1984-85. Hall describes the nature of the mineralization and whether it is a sedimentary component of the host iron formation or a feature superimposed at a later date. This research will also identify the salient features of the mineralizing system and aid in determining the course of future research. Potentially similar properties in the southern segment of the belt will be compared with the Opapimiskan Lake deposit to determine whether there are similarities in style of mineralization.

In the northern and northwestern portion of the belt, several properties will be further investigated to assess the significance of regional distribution of metals. In addition in this area, the potential sources of mineralizing systems will be studied. The molybdenite-fluorite showing (map location 7, Figure 1) will be investigated in some detail to determine the local potential for gold mineralization in view of the common association between molybdenite and gold (e.g. Campbell Red Lake, Lake Shore, Geraldton). Fluorite and gold are not common associates, although both occur together at Bachelor Lake Mine in Quebec (Buro 1984).

There appears, to date, to be little massive sulphide potential in the Weagamow-North Caribou Lake Belt and it is anticipated that most efforts by the Mineral Deposits Section of the Ontario Geological Survey will be directed towards a 2-fold approach: (1)

description of known gold properties, and (2) assessment of the potential of those parts of the belt containing no known mineralization.

ACKNOWLEDGMENTS

We would like to thank the Musselwhite Grubstake, particularly the operating company, Dome Mines Limited, for permission to visit the Opapimiskan Lake property and for the hospitality afforded us at the campsite. Special thanks are due to Dave Rigg for introducing us to the property and providing us with an opportunity to investigate the recent underground exposures. We are also very grateful to L. Halliday of Dome Exploration (Canada) Limited for facilitating our visit to the property and for valuable discussion concerning the mineralization. T. Mann of Dome Mines Limited and J. Sparling of Environmental Applications Group Limited provided valuable information on the surficial geology of the Opapimiskan Lake area.

We also wish to thank H.J. Hodge (Moss Resources Limited, Van Horne Gold Exploration Incorporated) for describing to us the several interests he holds in the Weagamow-North Caribou Lakes area.

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Summary of Activities 1984, BRIM Program

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This program is part of Operation Black River-Matheson (BRIM) which was funded equally by the Ontario Ministry of Northern Affairs and the Ontario Ministry of Natural Resources.

INTRODUCTION

The Black River-Matheson (BRIM) Program is an interdisciplinary, multiyear activity with the general aim of stimulating mineral exploration, discovery, and development in a 40 township area north of Kirkland Lake and northeast of Timmins. The program commenced in 1982 with Precambrian mapping and the organization of airborne geophysical surveys for the whole 40 township area. In 1983 a Quaternary mapping component was added. During 1984 the scope of the program was increased to include study of mineral deposits and other occurrences and to include an interdisciplinary overburden drilling project involving Quaternary geology, geochemistry, geophysics, and Precambrian geology.

PRECAMBRIAN GEOLOGY

During the 1982 season, the Precambrian Geology field work included activity in Stock, Taylor, Carr, Currie, Beatty, and Bowman Townships (Trowell 1982). In the following year this work was extended to include field work in Munro, McCool, Hislop, Guiboard, and Michaud Townships as well (Trowell and Johnstone 1983). Additional field work was completed during the summer of 1984 which is reported by Johnstone and Trowell (Project S50.). As a part of the overburden drilling project, the Precambrian Geology Section of the Ontario Geological Survey will produce a 1:100 000 compilation map of bedrock geology for the 16 townships situated at the western end of the BRIM area.

QUATERNARY GEOLOGY

Quaternary geological mapping of parts of the BRIM area still unmapped was commenced in 1983 at a scale of 1:50 000 with the mapping of the Matheson (NTS 42 A/9) and Lightning River (NTS 32 O/12) sheets by Vagners (1983). In 1984 the mapping continued with the Porquis Junction (NTS 42 A/10) and Watabeag River (NTS 42 A/7) areas as described by Richard (Project S51.).

GEOPHYSICS

Airborne geophysical mapping is an essential component of a geoscience database required for mineral exploration. Consequently, airborne magnetic and electromagnetic coverage of the 40 township area was commenced in the first year of the program (1982). In the spring of 1984 a series of 40 1:20 000 geophysical maps were released by the Ontario Geological Survey. Each map included both magnetic and electromagnetic data overprinted on a photo mosaic for a single township. The methodology used to complete this survey is described by Barlow and Pitcher (Project S52.).

DATA FOLIOS, ECONOMIC GEOLOGIST

In 1984, 2 projects were initiated by staff of the Kirkland Lake Resident Geologist Office, Ontario Ministry of Natural Resources. The activity at Kirkland Lake involves the compilation of recent exploration information (made available for the area included in BRIM) on a township basis together with field studies of selected occurrences and deposits. Data folios derived from this activity are currently available for inspection by explorationists at the Kirkland Lake core library. In addition an economic geologist has been attached to the Resident Geologist's staff with responsibility for providing liason and consultation with prospectors and companies centred in the Matheson area. The economic geologist will also collect and log drill core from previous exploration programs to improve the database for interpretation of the bedrock geology and mineral deposit potential of the area. A report of progress for this multiyear project will appear in an Ontario Geological Survey publication early in 1985.

MINERAL DEPOSITS

The work initiated in 1984 for the study of mineral deposits in the BRIM area is of 2 types. One involves the assembly of a computerized database for all mineral occurrences and deposits in the 40 township area as described by Whittaker and Malczak (Project S53.); the other is the development of a metallogenetic model for the area including base, precious, and industrial minerals integrated within a comprehensive geological database including stratigraphy, lithology, structure, alteration, and metamorphism.

BASAL TILL

The BRIM program combines multidisciplinary components which contribute to the program as a whole, and which also involve integrated geoscientific disciplines in the planning, conduct, and conclusions of a single project. An example of such a project was the "basal till" study within the Kirkland Lake Initiatives Program (KLIP). The BRIM basal till interdisciplinary project in 1984 includes elements of Quaternary geology, geochemistry, geophysics, and Precambrian geological mapping in 16 townships located at the western end of the BRIM area, particularly in the vicinity of the Destor-Porcupine Fault System.

On completion of the KLIP "basal till" study in 1983, a broadsheet (Fortescue and Gleeson 1984) and an Open File Report (Fortescue *et al.* 1984) were prepared to provide an overview of the project, and a workshop, "Till Tomorrow" (sponsored jointly by the Canadian Institute of Mining and Metallurgy and the Ontario Geological Survey), (CIM-OGS 1984) was held in Kirkland Lake in May 1984. The workshop attracted over 200 explorationists and interested scientists for discussions centred upon methods of exploration in overburden for gold and other mineral deposits.

As a result of the workshop discussions, the plan for the BRIM overburden drilling project in 1984 was modified in 3 ways. First, the project was rearranged to include a geophysical component which would provide information concerning the spotting of drillholes in the 16 townships selected for study; second, the sampling technique selected for Quaternary formations and proving bedrock in deeply covered areas was sonic drilling in place of the reverse circulation technique used in the KLIP project; and third, the geochemical analysis of samples of tills and related materials was broadened to include both major and trace elements. In addition, gold will be determined in the sample fines as well as in the nonmagnetic heavy (specific gravity ≥3.3) mineral fraction of the materials. The use of a backhoe for sampling tills and related materials in areas of shallow overburden remained unchanged although the samples were to be analyzed geochemically by the same techniques as those selected for the drill core samples. The backhoe sampling field component is described by Baker, Steele, and Fortescue (Project S54.).

The geophysical component of the basal till drilling project is described by Pitcher *et al.* (Project S55.) and a complimentary ground electromagnetic study, designed to check the validity of the airborne geophysics interpretation, is described by Barlow and Pitcher (Project S52.).

In order to complete the study of tills and related deposits in parts of the 16 township BRIM area selected for study in 1984, 2 departures from previous practice of till study by the Ontario Geological Survey were included. These were the use of geophysics to estimate the relative thickness of a layer of massive and varved clay overlying the till material and the use of the sonic drill.

The geophysical survey data provides evidence for the existence and location of buried valleys below the clay cover (which may be several tens of metres thick). Consequently, in order to provide the most complete Quaternary sections from below the clay layer to the bedrock surface, the location of buried valleys is studied prior to spotting holes. Unlike the reverse circulation drill which provides a sample of till in a slurry of air and water, the sonic drill obtains a 4 inch (10 cm) diameter solid core from Quaternary materials and may also be used to provide a 2 m bedrock core from the bottom of a hole. This core provides information on the geochemistry, mineralogy, structure, and stratigraphy of the material. From the exploration viewpoint the sonic cores provide benchmarks for the interpretation of reverse circulation data.

SUMMARY

The BRIM interdisciplinary program has been conducted since 1982 with the aim of collecting data on the Precambrian bedrock, the Quaternary geology, and regional geophysics for the whole 40 township area, or for those parts which required new coverage. In 1984 the interdisciplinary aspect of the program was enlarged with the addition of studies of mineral deposits, an integrated till study project, and provision of economic geologist services and exploration data folios. These projects will provide important information to those engaged in mineral exploration in this area of thick overburden. The geophysical methodology developed for the measurement of clay layer thickness using a reworking of the airborne electromagnetics database is a new application in exploration geophysics and may be applicable to many areas where a thick layer of lake clay impedes mineral exploration.

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S50. Precambrian Geology of the Black River-Matheson (BRIM) Area, District of Cochrane

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This project is part of Operation Black River-Matheson (BRIM) which was funded equally by the Ontario Ministry of Northern Affairs and the Ontario Ministry of Natural Resources.

INTRODUCTION

Field work done during the 1984 field season represents the third year of a multiyear program to conduct detailed, synoptic, and stratigraphic mapping along the Destor-Porcupine Fault from east of Timmins to the Quebec border (Trowell 1982; Trowell and Johnstone 1983).

The mapping of Beatty and Munro Townships and much of the western half of McCool Township was completed in 1984.

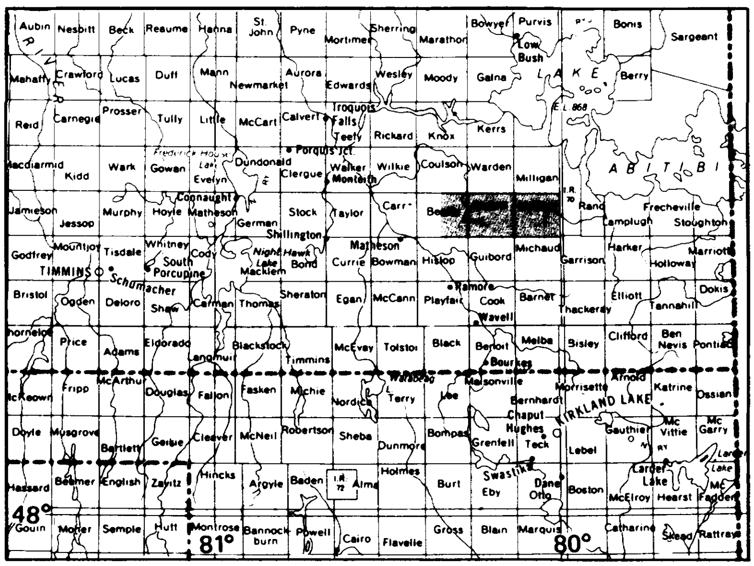
Munro and McCool Townships are situated east of the Town of Matheson. The area is accessible by Highway 101 and by lumber and mining roads. Northwestern Munro and central to northeastern McCool Townships are best accessed by helicopter.

MINERAL EXPLORATION

Unless otherwise stated, the exploration information reported here was obtained from the Resident Geologist Files, Ontario Ministry of Natural Resources, Kirkland Lake, or the Assessment Files Research Office, Ontario Geological Survey, Toronto (AFRO).

Exploration, primarily for gold but also for base metals and asbestos, that began at the turn of the century, usually initially involved geophysical surveys, usually magnetic and often electromagnetic, with follow-up diamond drilling of anomalies, *see* data series maps of Beatty (Lovell *et al.* 1973), and Munro (Ploeger and Grabowski 1980) Townships. A compilation of assessment work and mineral exploration for Stock, Taylor, Carr, Bond, Currie, and Bowman Townships is given by Trowell (1982) and for Beatty and Munro Townships by Trowell and Johnstone (1983).

In the western part of the area, the majority of the exploration has been directed towards the delineation and selection of anomalies in the vicinity of the Destor-Porcupine and Pipestone Faults. Diamond drilling along these structures indicates the presence of a sequence of ultramafic and mafic rocks which are locally cut by gold-bearing quartz-carbonate veins and stringers. These rocks were likely originally komatiitic volcanic flows. Sulphide minerals, specifically pyrite and arsenopyrite but also galena, sphalerite, and chalcopyrite, are reported to accompany the gold. Metasedimentary rocks, including chert, graphitic horizons, and conglomerates and wackes of ultramafic composition, situated along these faults are also reported to contain gold mineralization. Exploration in Beatty to McCool



LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

Townships, in addition to being directed towards these fault structures, has been directed to the search for base metals and asbestos as well as gold. There are 6 past producers in the area mapped (*see* Trowell and Johnstone 1983). Further work has been completed on the property of Maude Lake Gold Mine Limited (Trowell and Johnstone 1983). A substantial open pit has been completed and a bulk sample removed. Drilling is continuing to outline the mineralized structures. Work is continuing on a gold prospect in McCool Township east of the present area of mapping by a consortium of Placer Development Limited, Belore Mines Limited, and Huronian Mines Limited.

GENERAL GEOLOGY

The townships were the subject of 3 early Ontario government reports (Hopkins 1915; Satterly 1952, 1953) and in more recent years, portions of Munro Township have been sites for numerous petrological, mineralogical and geochemical studies (Freeman 1956; MacRae 1969; Pyke *et al.* 1973; Fleet and MacRae 1975; Arndt 1975, 1976, 1977; Coad 1976; Arndt *et al.* 1977; Arth *et al.* 1977; Zindler *et al.* 1978; MacRae 1982; Saunders 1982).

Apart from a single Abitibi Dike Swarm (Keweenawan) diabase dike which trends northeast across the area, the metavolcanic-metasedimentary assemblage exposed within the map area is of Early Precambrian (Archean) age.

The metasedimentary rocks fringing the southwestern edge of Munro Township are part of an east-trending belt bordered to the south by the southern branch of the Destor-Porcupine Fault and to the north by the Pipestone Fault. In Munro Township and eastern Beatty Township the northern edge of the belt is marked by the east- to southeast-trending Contact Fault. This fault appears to die out along strike to the southeast and the metasedimentary/metavolcanic contact is conformable upon entering Guibord Township (Prest 1953). This north-facing metasedimentary assemblage belongs to the Beatty Formation of the Porcupine Group of metasedimentary rocks and consists of a sequence of medial and distal turbidites separated by 2 horizons of more proximal wackes and conglomerates (Lorsong 1975).

Jensen and Langford (1983) have suggested that these rocks represent a metasedimentary facies of the Hunter Mine Group which lies stratigraphically below the Stoughton Roquemaure Group to which they have assigned the metavolcanic rocks of Munro and southern McCool Townships.

Interflow metasedimentary rocks in the form of graphitic horizons, argillite, and black chert, some of which contain pods of massive fine-grained pyrite, make up a small percentage of the remaining metavolcanic package. At the northern edge of Munro Township are thin units (10 to 100 m thick) of laminated chert and bedded tuffs which may belong to the Hunter Mine Group.

North of the Contact Fault, the base of the north-facing metavolcanic sequence consists of a thick sequence of predominantly iron-rich variolitic pillowed and massive tholeiitic flows. This sequence is overlain by a 300 to 500 m thick sequence of intercalated rhyolitic, dacitic, and andesitic lava flows and breccias.

The overlying flow sequence, which appears to be intercalated thick and thin layered tholeiitic and komatiitic lava flows, marks the base of an approximately 1000 m thick komatiitic flow sequence which occupies the Munro Fault zone, as it is represented by Satterly (1952). Significant shearing was observed only in the ultramafic rocks in the northern half of the zone. The Munro Fault likely exists but may not be as wide as previously believed.

The 3000 m thick tholeiitic succession above the fault-zone komatiites consists primarily of normal to high-magnesium tholeiitic flows and flow breccias with a few bands of iron-rich tholeiites and, towards the base, of a number of basaltic komatiite flows in the Deadman's Hill area.

At the top of this succession north of the Centre Hill Complex, komatiitic flows are overlain by a clast-supported volcaniclastic unit with a composition between a tholeiitic olivine basalt and a picritic basalt (Coad 1976). Subsurface data from the Potter Mine indicates that the fragmental unit is overlain by more komatiitic lava flows which contain 3 more volcaniclastic units that host the Potter Mine (Coad 1976).

The south-facing metavolcanic assemblage in the northern third of Munro Township is described by Arndt (1975) as comprising a thick basal sequence of tholeiitic basaltic and andesitic lava flows and fragmental rocks, interlayered with a few andesitic komatiites towards the top, and overlain by either a thick layered peridotite/gabbro flow of tholeiitic affinity (referred to as Theo's Flow, Arndt 1976) or thinner tholeiitic flows. This group is overlain by a series of komatiitic lava flows, starting with another thick, layered flow (komatiitic) referred to as Fred's flow (Arndt 1976).

Large discordant gabbro bodies that intrude this assemblage tend to be elongated parallel to the stratigraphy and concentrated in the northern half of the township. It appears that they have intruded east-trending zones of weakness, perhaps a major strike fault which repeats a portion of the stratigraphy.

A large mafic intrusion, the Centre Hill Complex, intrudes a dominantly komatiitic flow sequence in central Munro Township. The sill has a gabbroic upper half, a rhythmically layered pyroxenite/gabbro core, and a basal zone of alternating peridotite and pyroxenite layers.

The Centre Hill Complex may correlate with: (1) the tholeiitic, layered peridotite/pyroxenite/gabbro sill known as the Munro-Warden Complex situated along the northern Munro Township line (MacRae 1969); and (2) a layered gabbro/peridotite/pyroxenite body, McCool Hill, situated in south central McCool Township.

A chain of small outcrops indicates that there may be either 1 large elongate diorite intrusion or a string of small discordant intrusions stretching from just south of the Centre Hill Complex west across the centre of the township. A few small outcrops found in the area south of the Centre Hill Complex indicate that this body has been intruded in turn by a discordant quartz diorite. This intrusion contains large xenoliths of diorite and metavolcanic flows, and the dikes which radiate from it contain xenoliths.

The grade of metamorphism in the area is low, ranging from prehnite-pumpellyite to lower greenschist facies. For the most part, primary mineral textures and mineralogy are well preserved. Carbonatization is most common in the fault zones, particularly in ultramafic rocks. Much of the Contact Fault is marked by a green fuchsite-rich carbonate rock formed by the carbonatization of both metasedimentary and metavolcanic rocks. This zone is also characterized by a patchy sericitization of the more siliceous metasedimentary rocks. Sericitization is also common in the more felsic metavolcanic rocks of the area. Partial or complete serpentinization of olivine and orthopyroxene affects both mafic and ultramafic lavas (Arndt 1976).

STRUCTURAL GEOLOGY

The stratigraphy throughout Munro Township and the immediate area strikes between 100° and 120° with only local deviations due to some minor late stage open folding about north-south axes. The bedding tends to be subvertical with only shallow dip values being recorded in fold crests and troughs. The earlier group of folds in the map area are double-plunging isoclinal folds which run for short distances (generally less than a few kilometres) parallel to the stratigraphy. The main fold structure in the area is a syncline, the axial trace of which trends approximately 100° across Munro Township with an axis passing just north of the Centre Hill Complex and a fold closure located at McCool Hill. West and west-northwest of Centre Hill the stratigraphy is disrupted by a group of closely spaced isoclinal folds which plunge west-northwest into north central Beatty Township and southeastern Coulson Township after being displaced dextrally by a group of north- and northeast-striking faults. These steeply dipping folds are common throughout the Black River-Matheson area and can be considered unique in that they display little or no internal deformation despite rapid reversals of stratigraphy and closely-spaced axes. The axial regions display only minor shearing.

Most of the cross-faults in the area are steeply dipping, strike north to northeast, and tend to be concentrated in 2 areas; northern and southwestern Munro Township. Apart from a few northeast-striking faults in the north central part of the township, with horizontal displacements of a few hundred metres, the horizontal and probably the vertical displacements along these faults is quite low. The north-striking faults are late, and most have a dextral sense of displacement. They may be related to the Matachewan swarm of diabase dikes which have intruded a region-wide system of north-striking fractures.

The only major, low angle strike fault indicated is in north central Munro Township where a large section of the northern limb succession is repeated. The fault has been intruded by a discordant gabbro. Satterly (1952) suggested that a thrust fault coincides with a synclinal axis in the centre of the township.

Apart from an east-striking valley, no evidence was found to support the existence of the Camrose Fault mentioned by Satterly (1952).

The Contact Fault, and the more significant Munro Fault Zone, have had a largely vertical direction of displacement. Slickensides plunge at approximately 75° west along shear faces within these zones. Based on age relationships and the manner in which the Munro Fault passes between an anticlinal and synclinal axis along part of its length, it is thought that the block of rock between the 2 faults has down-dropped relative to the neighbouring fault blocks within this portion of the Destor-Porcupine Fault Zone.

Most of the faults in the area show little if any lateral ductile deformation which reflects a high level, brittle regime.

ECONOMIC GEOLOGY

Both the ultramafic and associated mafic rocks, and the metasedimentary rocks along the Destor-Porcupine and Pipestone Faults, represent viable exploration targets, especially for gold mineralization. Paucity of outcrop and impermeable clay cover preclude geological and some geophysical (for example Induced Polarization) exploration techniques. Overburden drilling with chemical and mineralogical analysis of basal till could be an effective prospecting method. As well, vertical-gradient magnetometer surveys combined with a knowledge of drift thickness might be useful in defining and thus screening out the effects of overburden cover, and thus allow for more accurate delineation of structures and lithological distribution.

In northern Beatty Township, hyaloclastite, pillow breccia, and interpillow hyaloclastite invariably contain 1% to uncommonly 3% sulphide mineralization consisting of pyrrhotite, pyrite, and locally chalcopyrite, and warrant exploration for both base and precious metals (*see* Trowell and Johnstone 1983).

At this time, exploration for asbestos is probably not warranted. Because the past producers of gold and precious metals in the map area are situated in fracture-controlled gold-bearing quartz veins, attention should be directed towards accurate delineation of the fracture patterns in the area to possibly predict the location of those areas where quartz stockworks could have developed.

While minor pyrrhotite ± pentlandite mineralization was locally observed by the field party in basal sections of some komatiitic flows, their nickel potential is at present unknown.

Exploration should be directed towards the cherty interflow tuffaceous units in northern Munro Township for potential precious metal mineralization. The felsic metavolcanic rocks of Beatty and Munro Townships may be potential base metal exploration targets.

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S51. Quaternary Geology of the Porquois Junction (42 A/10) and Watabeag River (42 A/7) Map Areas, District of Cochrane

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This project is part of Operation Black River-Matheson (BRIM) which was funded equally by the Ontario Ministry of Northern Affairs and the Ontario Ministry of Natural Resources.

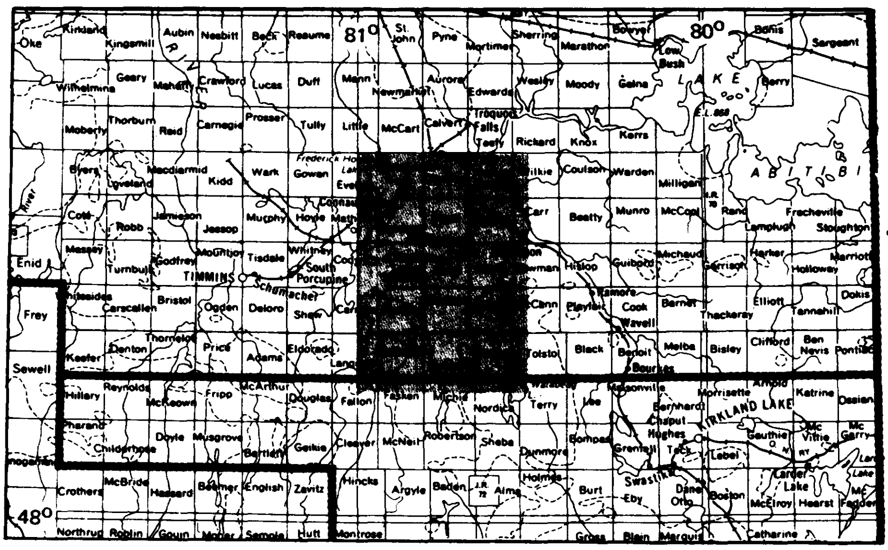
INTRODUCTION

The Porquois Junction and Watabeag River map areas are bounded by Latitudes 48°15'N and 48°45'N, and by Longitudes 80°30'W and 81°00'W. The combined map areas cover a total of 2040 km^2 and are situated between the City of Timmins (Night Hawk Lake) to the west, and by the communities of Iroquois Falls and Matheson to the north and east respectively.

Detailed Quaternary mapping (1:50 000 scale) and stratigraphic studies were completed during the 1984 field season. The project's objective was to create a geological database which would complement reconnaissance till surveys being carried out by the Geophysics/Geochemistry Section under the integrated BRIM program. Previous Quaternary mapping of the Porquois Junction-Watabeag River area was completed at reconnaissance scales by Hughes (1959a, 1960), Boissonneau (1965) and Lee (1979a, 1979b).

BEDROCK GEOLOGY

Detailed and semidetailed geological mapping has been completed over much of the present map area and has been summarized by Pyke *et al.* (1973) and MERQ-OGS (1984). Archean rocks of the western Abitibi subprovince underlie the Porquois Junction-Watabeag River area with east-striking formations of ultramafic, mafic, and intermediate metavolcanic rocks forming the most prevalent bedrock units. Bands of similarly striking felsic metavolcanic rocks are found in: (1) Evelyn, Dundonald, and Wilkie-Walker Townships; (2) the south Night Hawk Lake area; and (3) across Bond, Currie, and Bowman Townships. A 7 to 10 km swath of metasedimentary rocks (Porcupine Group) extends across the area, bounded



LOCATION MAP

Scale: 1: 1 584 000 or 1 inch to 25 miles on its southern margin by the Destor-Porcupine Fault. This structural feature, to which most of the gold mineralization in the Timmins camp is linked, runs along the northern shore of Night Hawk Lake, and eastward towards the hamlet of Watabeag. Ultramafic intrusive rocks occur as localized bodies in Langmuir and Dundonald-Clergue Townships. Granitic and syenitic stocks are confined to the southern half of the Watabeag River map sheet. Early Precambrian diabase dikes trend north while Late Precambrian dikes of the Abitibi swarm trend northeast.

PHYSIOGRAPHY

Most of the Porquois Junction and Watabeag River map areas lies between 275 to 290 m elevation. As a part of the Great Northern Clay Belt, it is characterized by flat to gently rolling tracts of glaciolacustrine varved clays deposited by proglacial Lake Ojibway. Bedrock promontories and esker complexes punctuate the otherwise monotonous topography, creating local relief on the order of 15 to 20 m. In the Egan Township area, exceptionally large granite bosses abruptly rise 60 to 100 m above the surrounding landscape. Along the southern margin of the Watabeag River map area, the glaciolacustrine plain gives way to irregular, till-covered bedrock uplands (335 to 380 m above sea level) as the regional topographic gradient rises toward the continental drainage divide immediately to the south.

QUATERNARY GEOLOGY

Surface glacial deposits and features of the Porquois Junction - Watabeag River area record the movements of Late Wisconsinan ice and the subsequent deglaciation phase. Morphologic ice-flow indicators such as striae, groovings, and facetting indicate that a late glacial lobation crossed the area moving towards 155° to 165°. Cross-cutting relationships show that this movement postdates the 175° to 180° trend which is generally assumed to represent the main phase of Late Wisconsinan glaciation. The western limit of this south-southeasterly lobation is situated in the Night Hawk Lake area, west of which the 175° to 180° trend predominates.

Striae displaying the main 175° movement overcut an older protected 240° set at Twin Falls in Teefy Township. This southwestward movement may belong to an early advance of Labrador ice, evidence for which has recently been uncovered at the Detour Lake mine site to the northeast. This older ice advance could be related to till formations that are found at depth in Stock, Bond, and Currie Townships and elsewhere in the Timmins area.

Within the map area, surface exposures of till, informally referred to as the Matheson or Lower till by Hughes (1959b, 1965), are generally limited to leeside bedrock accumulations located below 305 m elevation. Larger outcropping deposits are found at Val Gagne, northern Stock Township, and Matheson Township, west of Frederick House Lake. In Blackstock Township, a number of till-covered ridges up to 3 km in length protrude above the clay plain. Exposures typically reveal pebbly to bouldery, sandy silt till facies that occur both in basal meltout and lodgement varieties. Thin, discontinuous till deposits mantle the bedrock uplands above 305 m elevation in Fasken, Michie, and Timmins Townships.

Although local Archean metavolcanic lithologies comprise the bulk of till clast content, exotic indicator lithologies readily observed in the till suggest that a considerable amount of debris has been englacially transported from sources up to 800 km away. Included in this category are Paleozoic carbonate rocks from the James Bay Lowlands, and Proterozoic lithologies such as redbed clastic rocks, oolitic jaspers, and Omarolluk Formation wackes derived from the Belcher Islands Group and Richmond Gulf sequences in eastern Hudson Bay.

Clayey Cochrane till of the late glacial Cochrane readvance was not mapped within the Porquois Junction map area. However, isolated pods of probable ice-rafted Cochrane diamicton were noted atop some promontories in the northern part of the map area, indicating close proximity to the readvance limit.

Six esker complexes, herein informally named the Kettle Lakes, Porquois, Taylor, Twin Falls, Ice Chest (Richard 1983), and Watabeag (Baker *et al.* 1980) eskers, approximately traverse north-south across the map areas. Each exhibits characteristics typical of esker sedimentation in the Barlow-Ojibway basin, i.e. large subglacial cores composed of coarse, planar-bedded gravel and sand reflecting conduit conditions, flanked and/or overlain by varying volumes of sandy subaqueous outwash. Large nodes of kettled sand plain situated along esker crests denote the locations of marginal ice reentrants developed during static phases of glacial retreat. Esker crests typically rise 15 to 30 m above the surrounding terrain, although in places, glaciolacustrine sediments have virtually buried them under as much as 4 m of silt and clay.

Varved silts and clays of the Barlow-Ojibway Formation (Hughes 1965) and lesser shallow-water (sandy) sediments comprise a ubiquitous surficial unit in the map area. Stratigraphic studies indicate that this unit mantles underlying formations to an average thickness of 30 to 40 m. Large continuous sections (some described by Hughes 1959b) are exposed along the shorelines of Night Hawk and Frederick House Lakes.

Numerous strandlines observed as wash limits and shoreline terraces occur throughout the map areas, recording the static levels of proglacial Lake Ojibway. Regressive shallow-water sands mantle the flanks of reworked esker complexes and typically extend out over the adjacent varved clays.

Large parabolic dunes, ranging up to 20 m in height, form conspicuous features in the southeastern quadrant of the map area surrounding Watabeag Lake. Similar eolian reworking of glaciolacustrine shallow-water sands is common on surfaces above 305 m elevation.

STRATIGRAPHIC COMPILATIONS

In an ongoing study of the subsurface Quaternary stratigraphy of the Timmins region, all available overburden drill-hole logs on file with the Resident Geologist Offices in Timmins and Kirkland Lake have been compiled for the present map areas. Correlated stratigraphic profiles indicate that in the Stock, Bond, and Currie Township areas, 2 or more subsurface till formations separated by thicknesses of nonglacial sands and clays are present. Of particular significance are the sequences of in situ organic lacustrine clays and paleosols, one occurrence of which has been previously described by Brereton and Elson (1979). Clearly, a more complicated pre-Late Wisconsinan history of the area is just beginning to emerge. Compiled stratigraphic data of the Timmins region will be included in a final report now in progress.

ECONOMIC GEOLOGY

Large reserves of granular aggregate are still available within the Watabeag and Kettle Lakes esker systems in the Watabeag River map area. In the Porquois Junction map area, the Kettle Lakes and Porquois Junction eskers are the largest and most easily exploited aggregate sources. While reserves are still available in the smaller esker systems, thick overlying sequences of fine-grained sands and glaciolacustrine deposits make extraction and exploration for future reserves costly and difficult. Beach gravels derived from till deposits, such as those in Blackstock Township, provide locally important sources of road-building material.

ENGINEERING GEOLOGY

Glaciolacustrine silts and clays of the Barlow-Ojibway Formation demonstrate severe slope stability problems. Mass movements in the form of rotational block slumping and earthflows are common. Severe shoreline erosion by slumping is evident around cottage areas on Frederick House Lake and on Night Hawk Lake. Large-scale earthflows of liquified Barlow-Ojibway Formation have occurred along the Frederickhouse and Abitibi Rivers. The largest scar, noted southeast of Twin Falls in Teefy Township, encompassed an area of approximately 12 ha.

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S52. An Airborne Electromagnetic-Magnetic Survey of the Black River-Matheson (BRIM) Area, District of Cochrane

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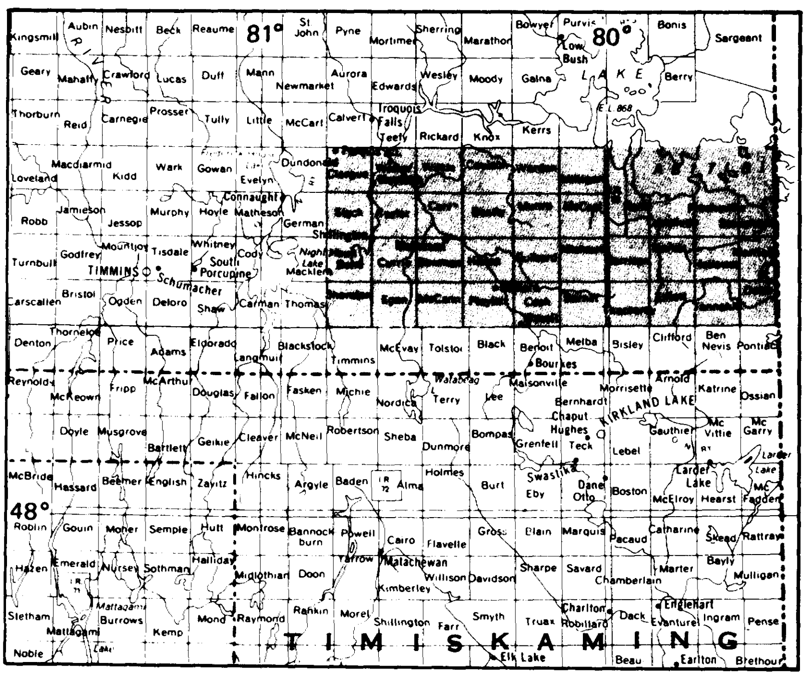
This project is part of Operation Black River-Matheson (BRIM) which was funded equally by the Ontario Ministry of Northern Affairs and the Ontario Ministry of Natural Resources.

INTRODUCTION

An airborne electromagnetic-magnetic survey was flown for the Ontario Geological Survey during the Spring of 1983 and the results publicly released in May, 1984 (OGS 1984). The survey (*see* location map) covers an area of approximately 3550 km^2 of high mineral potential.

The bedrock geology of the area is, in large part, covered by a complex glacial sequence of ice-contact stratified deposits consisting of eskers, kames, deltas, and ice-retreat lacustrine lake sediments, most notably sequences of varved and massive silty clay. The latter is most prevalent and thickest in parts of the western half of the BRIM area.

The survey was composed of 18 747 line kilometres of alternate north-south flight lines flown at a nominal terrain clearance of 120 m and having a mean line spacing of 200 m.



LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

SURVEY INSTRUMENTATION

The electromagnetic-magnetic survey was flown by Questor Surveys Limited using a Skyvan (C-GDRG) aircraft equipped with a modified Barringer/Questor Mark VI INPUT® airborne EM system, a Sonotek PMH 5010 proton precession magnetometer, and a Sonotek SDS-1200 Series Data Acquisition system.

The electromagnetic transmitter employed on this survey evolved from several years of research and development which was partially sponsored by the Exploration Technology Development Fund (ETDF). Design changes were made to the primary pulse repetition rate (211 per second), the pulse width (2.0 ms) and the dipole moment of the transmitting coil (6 turns x 300 amperes x 190 m^2) yielding 3.42 x 10^5 ampere-metres^2. The modified system was tested over the Night Hawk Lake Geophysical Test Range and the results showed considerable improvement in attentuation rate with altitude compared to the standard configuration of this airborne EM transient system.

Slight modifications to the transient receiver gate widths and centre positions were made for the 6-channel system (*see* Table 1) so that advantage could be taken of the longer measuring duration in the "off-time".

A standard 0.5 s sample interval and 1.1 s integration time constant were used.

The receiver bird position was 93 m behind the aircraft and 67 m below the aircraft at an average flying speed of 110 knots. Figure 1 illustrates the change in bird position relative to airspeed.

TABLE 1. RECEIVER GATE CENTRES AND WIDTHS. (PROJECT S52.)

CHANNEL	GATE CENTRE (μs)	GATE WIDTH (μs)
1	300	200
2	500	200
3	800	400
4	1200	400
5	1700	600
6	2300	600

RESULTS

BEDROCK CONDUCTORS

In general, bedrock conductors such as sulphides and graphite have a relatively high conductance (conductivity-thickness product), exhibit long rates of decay, and are classified as 4-, 5-, or 6-channel anomalies.

POSSIBLE OVERBURDEN/BEDROCK RESPONSES

Overburden features of limited dimensions or clay filled narrow valleys often exhibit response profiles that are similar in shape to those over bedrock conductors. A number of these anomalies have been clearly identified with an asterisk on the geophysical anomaly maps (OGS 1984) at the lower left hand corner of the plotted symbol and have been interpreted as possible overburden responses.

1 – TO 3 – CHANNEL RESPONSES

A large portion of the 3550 km^2 survey area contains non-conductive overburden cover; in these areas weaker responses of 1 to 3 channels are indicative of bedrock conductors. On the other hand, 1- to 3-channel responses due to bedrock conductors in areas of conductive overburden cannot be easily recognized and were quite often not selected.

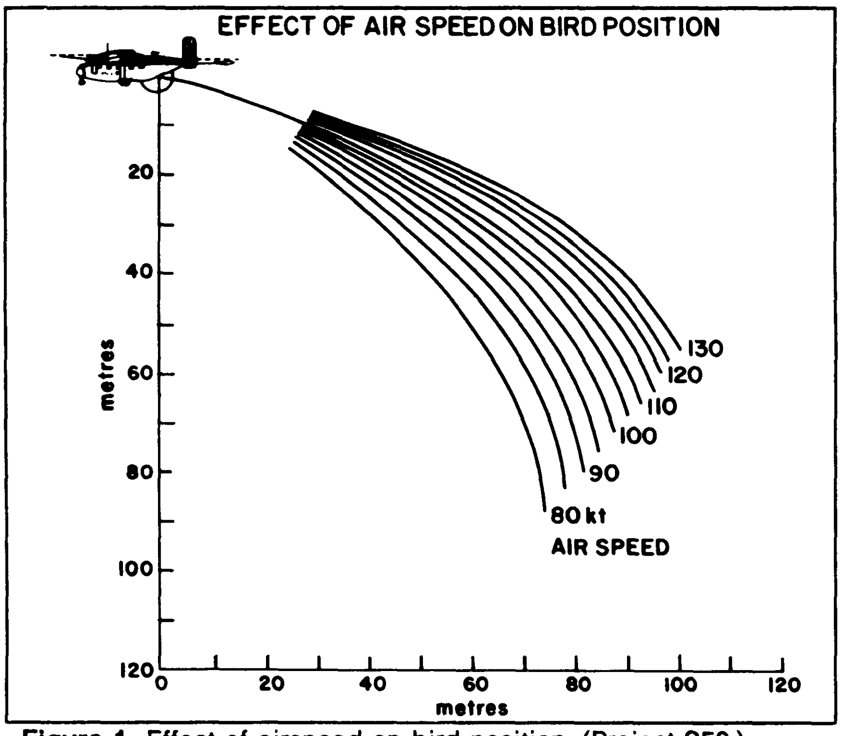


Figure 1. Effect of airspeed on bird position. (Project S52.)

CULTURAL CONDUCTORS

Cultural anomalies are also plotted on the geophysical anomaly maps (OGS 1984) and are designated with a square symbol. These anomalies are due to artificial sources in the vicinity of paved roads, power lines, railroads, pipelines, buildings, and fences and have been distinguished from natural conductors by their relative position to cultural sources on the flight path film and by the on-board 60 Hz monitor. In some cases, a cultural anomaly coincides with a sub-surface geological conductor and wherever possible has been selected as a bedrock conductor.

OVERBURDEN RESPONSES

Parts of the survey were flown over the Abitibi clay belt, which contains conductive clays commonly up to 30 m thick with resistivities on the order of 30 ohm-metres. The electromagnetic responses of these features can be recognized by their broadness, asymmetry, and fast decay rate and were not interpreted as originating from bedrock conductors.

These conductive sediments, which are thickest in the vicinity of Black River in the western part of the survey area, cause notable responses on up to 3 "early time" channels. A discussion on the application of mapping these conductive overburden features using the "early time" data is presented in another article by Pitcher *et al.* (this volume).

CONCLUSIONS

In summary the survey was quite successful in identifying some 2732 anomaly intercepts, of which 18.0% were 6-channel responses, 8.2% were 5-channel responses, 14.6% were 4-channel responses, 33.6% were 3-channel responses, 21.6% were 2-channel responses, and 4.0% were 1-channel responses.

The release of these airborne electromagnetic-magnetic survey results has added significantly to the overall geoscience database of the Black River-Matheson area and has been a stimulus to mineral exploration.

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S53. Mineral Deposits Investigations in the Black River-Matheson (BRIM) Area, District of Cochrane

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This project is part of Operation Black River-Matheson (BRIM) which was funded equally by the Ontario Ministry of Northern Affairs and the Ontario Ministry of Natural Resources.

INTRODUCTION

During the 1984 field season the Mineral Deposits Section of the Ontario Geological Survey initiated projects as components of Operation Black River-Matheson (BRIM), a geoscience study in 40 townships straddling the Destor-Porcupine Fault Zone between Night Hawk Lake and the Quebec border. The objectives of these mineral deposits projects are to develop a regional metallogenetic framework, with emphasis on gold mineralization, which will be of assistance in mineral exploration, and to assess the potential of the BRIM area for industrial minerals development.

Metallogeny of gold and other metals within the BRIM area involves numerous local variations in the style of mineralization and host rocks. Projects will be designed to examine localities of mineralization in detail and, together with consideration of regional geology, evolve a working model, or models, to account for observed field, petrographic, and geochemical relationships.

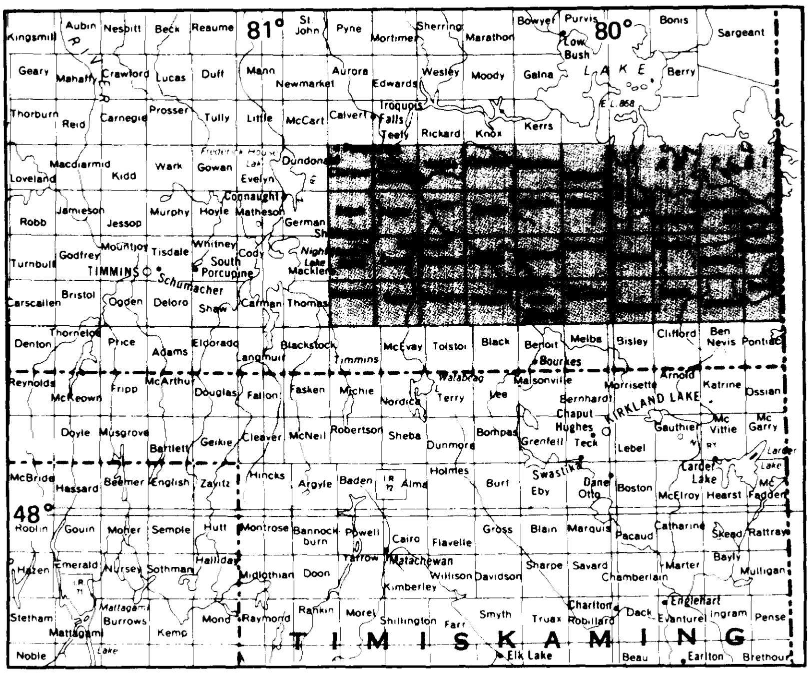
Individual deposits examined in 1984 are shown on Figure 1 and briefly described on Table 1. More complete descriptions of selected properties follow.

The Mineral Deposits Section's involvement is part of the multidisciplinary program designed to provide a database for mineral resources development in the development in the BRIM area as described in the Introduction by J.A.C. Fortescue. Compilation of information on mineral deposits from assessment files is being carried out by G. Troop and J. Malczak, who will also be conducting a preliminary study of the St. Andrew Goldfields Deposit. Previous and present work by the Precambrian Geology Section, and by the Geophysics/Geochemistry and Engineering and Terrain Geology Sections are providing additional information for this component of the BRIM program.

HEDMAN MINE

The Hedman Mine is an open pit industrial mineral (serpentine) deposit owned and operated by Hedman Resources Limited of Timmins, Ontario. It is situated in the southern part of Warden Township in a claim group straddling the Munro-Warden Townships boundary (Figure 1). Access is provided by an 11 km all weather gravel road which runs north from Highway 101, approximately 25 km east of Matheson.

The Timmins-Kirkland Lake geological compilation map (Pyke *et al.* 1972) indicates that the Hedman deposit is at the northern side of an interlayered series of west-northwest-trending, ultramafic-mafic rocks in McCool, Munro, and Warden Townships. At a more local



LOCATION MAP Scale : 1 : 1 548 000 or 1 inch to 25 miles

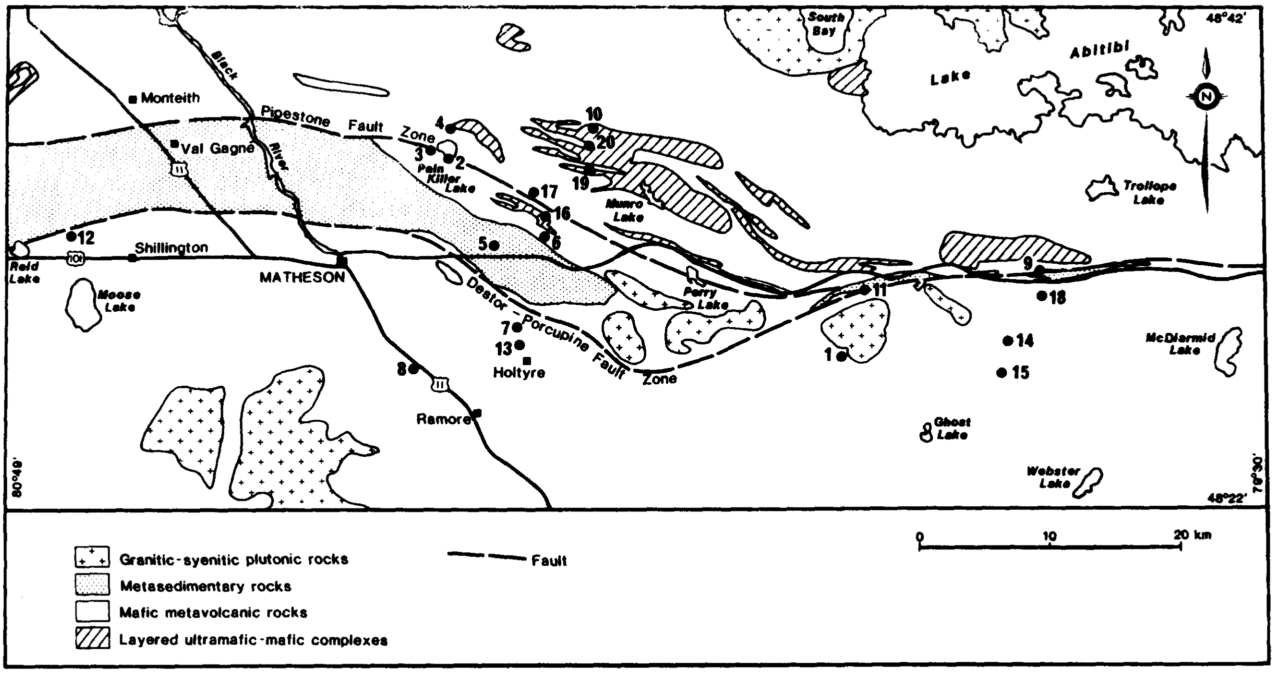


Figure 1. General geology of the BRIM area, and mineral deposit localities visited in 1984. (Project S53.)

TABLE 1: SUMMARY OF MINERAL DEPOSITS VISITED DURING 1984. (PROJECT S53.)

	Mineral Deposit	Commodity	Host Rock	Alteration
1*.	Murphy Garrison Mine	Au	m.v.	Carb, Py
2.	Blue Quartz Deposit	Au	m.v.	Sil, Py
3.	Lucky Ben Deposit	Au	m.v.	Sil, Py
4.	Aljo Deposit	Au	m.v.	Carb, Sil, Py
5.	Stewart-Abate Deposit	Au	gabbro	Sil, Ep
6.	Croesus Deposit	Au	m.v.	Carb, Sil, Py, Ser
7.	New Kelore Deposit	Au	syenite	Sil, Py, Hem
8.	Vimy Ridge Deposit	Au	Carb breccia vein cutting m.v.	Carb, Hem, Py
9.	Teddy Bear Valley Deposit	Au	m.v.	Carb, Sil, Py
10.	Hedman Deposit	Serpentine	dunite	Serpentinization
11.	Garrcon Deposit	Au	v.m.	Carb, Sil, Py
12.	St. Andrew Goldfields Mine	Au	u-m & m.v.	Carb, Sil, Py, Ser
13.	Ross Mine	Au	m.v.	Carb, Sil, Py, Hem
14.	Harlight Deposit	Au	m.v.	Sil, Py
15.	Golden Harker Deposit	Au	m.v.	Sil, Carb, Py
16.	Munro Deposit	Asbestos	dunite	Serpentinization
17.	Barton Creek Deposit	Ni	u-m & m.v.	Ep
18.	McDermott Deposit	Au	u-m & m.v.	Sil, Ser, Carb, Py, Hem
19.	Potter Deposit	Cu, Pb, Zn	m.v.	Ep, Py
20.	Potterdoal Deposit	Cu, Pb, Zn	m.v.	Ep, Py

Abbreviations:

m.v.	- mafic metavolcanics	Sil	- silicification
u-m	- ultramafic	Ep	- epidotization
v.m.	- volcanogenic metasediments	Ser	- sericitization
Carb	- carbonatization	Hem	- hematization
Py	- pyritization		

*Numbers correspond to localities on Figure 1 scale, the deposit occurs within serpentinized dunite north of the Munro-Warden ultramafic complex mapped by Arndt (1975). The dunite may represent part of the layered complex which forms an east-trending, south-facing succession of interlayered peridotites, pyroxenites, and gabbros.

Serpentinized dunite is exposed in the pit area over a width of about 125 m and a length of 300 m; drilling indicates a length of 600 m and a depth of 225 m. Within the pit, serpentinized dunite is relatively homogeneous and consists of massive lizardite (platy serpentine) with minor veinlets of magnetite and chrysotile. A few rodingite dikes, up to 20 cm wide, cut the dunite in 1 locality and minor faults of various orientations are abundant. The serpentinite is characterized by a light grey to white weathered surface with fine, dark green to black veinlets defining a polygonal pattern. In hand specimen, weathered surfaces have a fine-grained, equigranular texture. Fresh surfaces are typically black-green, hackly, and dull. Magnetite, chrysotile, and coarse-grained lizardite (variety picrolite) form veinlets in fractures around massive parts of the rock.

The Hedman open pit is roughly rectangular in form and covers an area at least 60 m wide and 200 m long. All production is currently derived from 1 level of development. The material is transported by truck to the 600 ton/day Hedman mill in Matheson.

An average of 59% of the mill feed is extracted to the form the product, Hedmanite. Standard specifications recorded by Hedman Resources Limited indicate that the product is composed of about 86% lizardite and 14% chrysotile with minor magnetite (J.J. Mangan, Hedman Resources Limited, personal communication, 1984). It is a natural material which contains no amphibole, free silica or additives. The average fibre length is 2.5 microns, which is within a size category determined by medical research studies as being devoid of pathogenic potential. Hedmanite is a bluish-white powder with a specific gravity of 1.8 and a dry bulk density of 300-500 ml/100 g. The material has an electropositive charge and is capable of absorbing 32% of its weight in oil. The mineral components of Hedmanite impart 2 important properties; the lap shear strength of prismatic laths, and fibre reinforcement.

Hedmanite has a number of uses, particularly as a filler for plastics and paper. In the plastics industry, it is used in phenolic and polyester molding compounds and gelcoats as a reinforcing filler. It can also be used in vinyl flooring, vinyl acetate, epoxy adhesives, acrylic, melamine, mylar, polypropylene and polyethylene. Hedmanite is an extender of cellulose fibres in paperboard, construction, and cover paper. It can be used in newsprint and other printing papers for improvements in print quality and opacity. The pulp and paper industry utilize the absorption property of the product for pitch control. Other general uses include refractory compounds for steel production, welding rod flux coatings, texture and rust proof paints, stains and primer paints, friction materials, asphalt paving, sealants, grease, and wood preservatives.

TEDDY BEAR VALLEY (SEAGER'S HILL) DEPOSIT

The Seager's Hill Deposit is located in the western part of Holloway Township (Figure 1, 9). Host rocks consist of intensely altered mafic flows which form part of a fault-bounded block approximately 650 m wide (Satterly 1954). The block dips steeply south, strikes easterly, and is part of the Kinojevis Group (Jensen 1982). Porcupine Group metasedimentary rocks are in contact with the metavolcanic rocks to the north of the property and are cut by the north boundary fault. Detailed mapping of quartz veining at Seager's Hill serves to illustrate the complexity of quartz vein systems close to the Destor-Porcupine Fault Zone (DPFZ).

Intensely carbonatized mafic volcanics at Seager's Hill (Figure 2) are cut by several sets of sharply defined quartz veins. Free gold occurred in the earliest, shallowly dipping set of veins in the vicinity of the prospect shaft. Although gold mineralization was of limited extent in the quartz veins, the complex array of veining illustrates at least 2 episodes of brittle deformation.

The shallowly dipping vein set, Q_1, consists of composite quartz-carbonate veins. The presence of ankeritic carbonate (ferroan dolomite?) in these veins may suggest that emplacement of Q_1 veins was contemporaneous with carbonatization of the host rock. The Q_1 veins range in thickness from 2 to 7 cm and because of their shallow dip form part of the outcrop surface. They consist of white to grey translucent quartz and approximately 15% coarse-grained ankeritic carbonate. The Fe-carbonate weathers

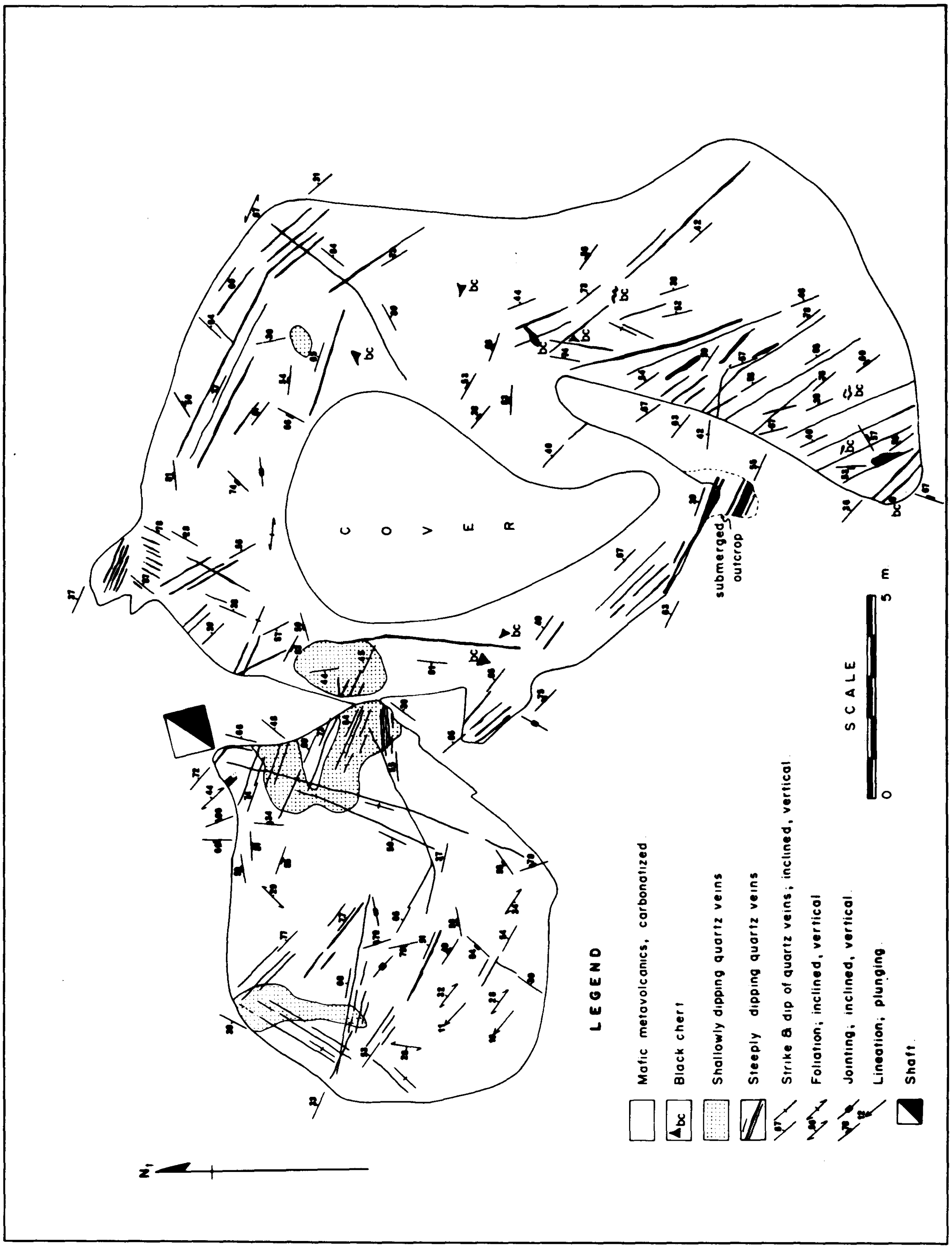


Figure 2. Geology of the Teddy Bear Valley gold deposit. (Project S53.)

buff brown and, where it is weathered out, leaves a vuggy texture in the composite veins. Shallowly dipping Q_1 veins are cross-cut by a second set of white quartz veins, Q_2. The Q_2 veins are steeply dipping (Figure 2) and consist of only quartz. They are 5 mm to 2 cm wide and cross-cut both the host rock and the Q_1 veins with sharply defined, unaltered contacts.

Steeply dipping Q_2 veins form the predominant veining and become more closely spaced towards the prospect shaft. Here the Q_2 veins are part of an east-southeast striking set, are planar and continuous for 3 to 5 m, or occur as 50 cm to 1 m *en echelon* veinlets. In addition to more closely spaced veining in this zone is the development of a friable or fissile texture in the rock. This fabric parallels the Q_2 veins and exhibits waxy brown-green sericitic foliation surfaces.

A summary of events at Seager's Hill is:

1. Development of F_1 and F_2 foliations with contemporaneous carbonatization
2. L_1 lineation
3. Emplacement of shallowly dipping, auriferous quartz-carbonate veins (Q_1)
4. Development of steeply dipping, barren quartz veins (Q_2), which cross-cut Q_2 veins
5. Late brittle jointing, barren of any veining.

CONCLUSIONS

A metallogenetic study of the eastern Abitibi Belt within the BRIM area will examine gold and associated metals in the Hunter Mine, Stoughton-Roquemaure, Kinojevis, and Blake River Groups and in the Destor-Porcupine Complex of Jensen (1982). Selected deposits from these groups, related to the DPFZ, will be examined in detail with respect to alteration, metamorphism, and structural controls.

ACKNOWLEDGMENTS

Thanks are due to O. Kukal for able field assistance and to G. Troop for additional help and discussion. M.E. Cherry similarly contributed many helpful suggestions towards initiation of this project. The cooperation of numerous company geologists is also gratefully acknowledged.

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S54. Reconnaissance Till Sampling Program in the Matheson Area, District of Cochrane

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This project is part of Operation Black River-Matheson (BRIM) which was funded equally by the Ontario Ministry of Northern Affairs and the Ontario Ministry of Natural Resources.

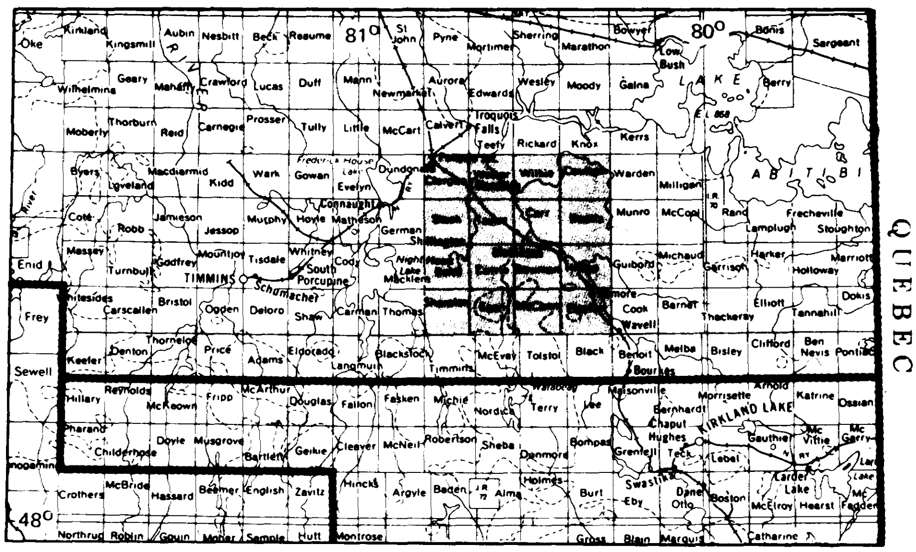
INTRODUCTION

During the 1984 summer field season the Engineering and Terrain Geology Section and the Geophysics/Geochemistry Section began an applied program of Quaternary and geochemical studies in the Matheson area. This work is part of the Black River-Matheson (BRIM) geoscientific studies being undertaken by the Ontario Geological Survey. The program is designed to provide a regional mineral exploration-oriented geoscientific database. Funding for the program is provided by the Ontario Ministries of Natural Resources and Northern Affairs, and is administered by the Geophysics/Geochemistry Section.

LOCATION

The BRIM area consists of a rectangle of 40 townships extending from Night Hawk and Frederick House Lakes eastward to the Quebec border. Highway 101 serves as the main access route and bisects the area in an east-west direction. The corner townships of the BRIM area are (clockwise from the southwest): Sheraton, Clergue, Stoughton-Lake Abitibi, and Dokis.

The 1984 field work was carried out in the western 16 townships of the BRIM area which are centred on the village of Matheson (*see* Location Map). These 16 townships encompass an area of approximately 1540 km^2. The area lies within the Hudson Bay (Arctic) drainage basin and is



LOCATION MAP

Scale: 1: 1 584 000 or 1 inch to 25 miles referred to physiographically as the Great or Abitibi Clay Belt.

RECONNAISSANCE SAMPLING PROGRAM

Experience has shown that the till in the area is essentially a reflection of the local bedrock composition. Till sampling is an effective method of evaluating the mineral potential of this area at either the reconnaissance or local scale.

In the study area, till occurs at the base of the overburden stratigraphic sequence. The till is in turn overlain by: (1) glaciofluvial deposits, the majority of which are contained in narrow north-trending esker complexes; and (2) glaciolacustrine clay, silt, and sand deposited in glacial Lakes Barlow and Ojibway.

Where the glaciofluvial and glaciolacustrine deposits are thin or absent the till may be sampled by backhoe trenching. Backhoe sampling of till could gainfully be carried out around rock knobs that protrude through the clay plain at scattered locations and in the bedrock highlands located along the southern edge of the study area.

BACKHOE SAMPLING PROGRAM

A backhoe sampling program has several advantages:

1. The equipment is mobile and can be moved quickly over large distances.
2. Trenches up to 2 m in depth can be dug rapidly with minimal disturbance to the surrounding ground surface.
3. Large samples of fresh material are easily obtained.
4. A stratigraphic section is exposed in the trench wall.
5. Compared with hand digging or drilling, this method is a highly cost effective way of obtaining, shallow till samples in bulk.

Limitations of a backhoe sampling program on the clay plain are:

1. The equipment can only be used along roads or on cleared land that has a moderately firm surface.
2. It is practical to trench only in those locations where the till is exposed at the surface or around bedrock outcrops where the probability of finding till is high.

SITE SELECTION

A list of potential sample sites was compiled through a review of several sources of information both published and unpublished. These included township-scale bedrock geology maps and Quaternary geology maps and reports (Baker *et al.* 1980; Vagners 1983; Richard, this volume). Positions of outcrops located near roads or in cleared areas were obtained from the bedrock maps. Surficial maps provided locations of till exposures and areas of bedrock-drift complex where till was likely to be near the surface. Air photographs were examined to identify new roads, which were then plotted on base maps.

Potential sampling sites were field checked to ensure ready accessibility, and that power, gas, or telephone lines were not in the way. New roads were also traversed so that any additional bedrock outcrops or till exposure not previously known would be included in the trenching program.

Field checking was completed over a period of 3 days. The majority of the time was spent in obtaining permission from private landowners to work on their land.

Surficial mapping and previous backhoe sampling (Thomson and Wadge 1980, 1981) have shown that till is most frequently found on the up-ice or stoss side of bedrock knobs. For this reason, sites were chosen on the northern (stoss) side of bedrock outcrops whenever possible.

EQUIPMENT

A Case 580B backhoe-loader (with an extendahoe option), was employed for 118 hours. In addition, a John Deere 410 backhoe with a 6 cubic foot bucket was used for 37 hours. This equipment was contracted locally. A wheeled, rubber tired backhoe-loader, as opposed to a skidder mounted backhoe, was selected because of reduced rental charges and ease of movement between sites.

Over a 16 day period, 135 sites were trenched. On the average, approximately 1.2 hours were required to dig, sample, and backfill a trench and move to the next site. At each site, if till was not found in the first trench, up to 3 additional trenches were dug.

The backhoe was driven between sites for approximately 70% of the moves. Where the distance between sites was more than 5 km the backhoe was loaded onto a small float and towed by a truck.

SAMPLING RESULTS

Pit depth varied from site to site and was controlled primarily by the topography of the bedrock surface. To obtain fresh till, samples were taken below a depth of 1 m whenever possible. Sampling depths

TABLE 1. DEPTH OF TILL SAMPLES IN BACKHOE TRENCHES (PROJECT S54.)

Depth (in metres)	Number of Samples
0.0-0.5	2
0.5-1.0	10
1.0-1.5	41
1.5-2.0	19
2.0-2.5	14
2.5-3.0	5
3.0-3.5	2
Total	93

TABLE 2. DISTRIBUTION OF BACKHOE SITES. (PROJECT S54.)

Township	Number of Sample Sites	Clay or Till as Surface Material		Sand As Surface Material	
		Till Present	Till Absent	Till Present	Till Absent
Sheraton	4	1	0	2	1
Egan	0	NA	NA	NA	NA
McCann	12	2	2	2	6
Playfair	25	19	3	1	2
Hislop	20	17	2	0	1
Bowman	11	4	2	1	4
Currie	12	7	2	0	3
Bond	0	★	★	★	★
Stock	1	1	0	0	0
Taylor	7	6	1	0	0
Carr	2	1	1	0	0
Beatty	7	2	2	1	2
Coulson	3	0	0	1	2
Wilkie	2*	2	0	0	0
Walker	13	10	3	0	0
Clergue	16	11	1	2	2
Totals	135	83	19	10	23

NA -No access
★-Uniform deep overburden
*-Samples dug by hand, river access

ranged from 0.5 m to 3.2 m, with the mode being 1.5 m. Safety considerations rarely permitted in-trench sampling below 3 m. Sampling depths are summarized in Table 1.

When till was found in a pit, a 6 to 8 kg sample was taken using a stainless steel sampling tool. The favoured sampling position in a pit was within 0.5 m of the till-bedrock interface. Circumstances often dictated, however, that samples be taken higher in the section. In addition to the till, a sample of the underlying bedrock was taken or, when this was not feasible, a pebble count of approximately 100 clasts was collected. The samples taken should allow a better understanding of till geochemistry and up-ice incorporation of bedrock. Till seen in the pits generally was massive and compact. At most sites subglacial deposition of the till was indicated by: (1) the abundance of locally derived clasts; (2) the overconsolidated nature of the material; (3) clast shape; and (4) surface markings, such as striae, on the clasts. Texturally the till has a silty sand to sand matrix and contains 20 to 40% +10 mesh (2 mm) material. Typically, clast angularity ranges from angular to subangular, although subrounded intrusive lithologies are not uncommon.

Till samples are to be processed and the following fractions analyzed geochemically: (1) -10 mesh total till; (2) -250 mesh total till; and (3) >3.3 specific gravity nonmagnetic heavy minerals. Selected samples are to have size analysis, carbonate determination, and a visual scan of heavy mineral assemblages.

DISTRIBUTION OF BACKHOE SAMPLES

The number of backhoe sites per township is listed in Table 2. A total of 93 till samples were taken from 135 sites; an average success rate of about 70% in obtaining a sample. This rate could be improved but cultural features prevented extensive digging at some locations.

At sites where till outcropped or clay onlapped a rock knob, fresh till was recovered in more than 80% of the cases. At the 33 sites where sand was the surface material, only 10 yielded till at depth; a recovery rate of 30%. In most instances the sand was associated with esker systems and was too thick to be penetrated with the equipment used.

Additional data from the survey will be published following completion of the chemical, analyical, and mineralogical stages of the program. At that time results of the overburden drilling to be completed in the fall of 1985 will also be available.

ACKNOWLEDGMENTS

This program was designed and completed by the authors with the aid of P.J. Dowds, summer student assistant. The authors wish to thank the numerous individuals, companies, and institutions who provided access to properties and allowed sampling by trenching. Particular thanks are extended to the Corporation of the Township of Black River-Matheson, and the Ontario Ministry of Transportation and Communications, for permission to work on road right-of-ways. Information on the surficial geology and the distribution of materials in the study area was obtained through discussions and field trips with J.A. Richard, Geologist, Ontario Geological Survey, Toronto.

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S55. Mapping the Overburden in the Black River-Matheson (BRIM) Area, District of Cochrane, Employing an Airborne Time-Domain System

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This project is part of Operation Black River-Matheson (BRIM) which was funded equally by the Ontario Ministry of Northern Affairs and the Ontario Ministry of Natural Resources.

INTRODUCTION

The Black River-Matheson (BRIM) area is located within the Abitibi Upland physiographic division of the Canadian shield (Bostock 1970) as well as being within the Great Clay Belt. The overburden in the area is comprised of tills, glaciofluvial deposits such as eskers, glaciolacustrine deposits consisting largely of clay, and of various types of organic swampy terrain. This summary outlines the feasibility of using a large scale airborne time-domain electromagnetic system to map the nature and aerial extent of the conducting overburden in the area, due to its variation in electrical properties. Such information is useful for Quaternary geologists who are interested in sampling the overburden using overburden drilling techniques in areas of thick cover associated with bedrock valleys.

PREVIOUS WORK

As part of the overall BRIM initiative to stimulate exploration in the Black River-Matheson area, the Geophysics/Geochemistry Section of the Ontario Geological Survey, on behalf of the Ministries of Northern Affairs and Natural Resources, contracted an airborne electromagnetic-magnetic survey to Questor Surveys Limited employing the INPUT® system. This survey covered an equivalent 40 township area (3550 km^2) utilizing a 200 m line separation with a nominal north-south flight line direction. The results of this survey are reported by Barlow and Pitcher (this volume) as well as in the form of a series of geophysical maps (OGS 1984) depicting bedrock anomaly locations and contours of the magnetics, plotted relative to the flight lines on a photomosaic base.

Apart from the application of locating bedrock conductors for base-metal exploration and geological mapping, airborne electromagnetic data can also be used for mapping surficial geology. This has been demonstrated previously for a fixed wing aircraft frequency-domain system by Seigel and Pitcher (1978) and for a helicopter frequency-domain system by Fraser (1978). DeMoully and Becker (1984) have also been successful in employing an earlier version of the time-domain INPUT® system for the mapping application.

ELECTROMAGNETIC RESULTS

MODEL

Figure 1 shows a simplified model of the system configuration and the subsurface model used to represent conducting overburden situated on very resistive Precambrian bedrock. This model is often referred to as the thin sheet model where only the product of conductivity and thickness can be determined, and not the conductivity and thickness separately. In the Black River - Matheson area the overburden consists of a glaciolacustrine unit composed mainly of varved and massive clay overlying prelacustrine glacial units made up of till, sand, and gravel. Frequently the terrain is overlain by organic materials composed of peat, silt, and swamps.

DATA

A selected computer-generated profile of the electromagnetic results from the digital data for Line 11080S which traverses Wilkie, Carr, and Bowman Townships is presented in Figure 2. The location of this profile can be determined from electromagnetic anomaly maps 80 574, 80 584, and 80 594 (OGS 1984). The results have been computer generated in a form that is reasonably consistent with the standard analog presentation. The various parameters have been time advanced to correct for the time delays associated with the system. In summary the computer profile presentation depicts the following:

1. The anomaly location is at the top, identified by a number to indicate the number of channels. The C is used to define cultural anomalies due to powerlines, metal fences, pipelines, railroads, etc.
2. The top trace is the 60 Hz monitor profile to detect powerlines.
3. The next 6 profiles are the 6 channels of INPUT data, which for the 2 ms pulse system employed for the present survey represent time gates of 200-400, 400-600, 600-1000, 1000-1400, 1400-2000, and 2000-2600 μs. The increasing positive-downwards convention is employed.
4. The altimeter trace represents the terrain clearance of the aircraft..
5. The 2 dashed lines, employing stepping scales of 1000 gammas and 500 gammas, full-scale, represent the coarse and fine scale magnetometer profiles, respectively. A 10:1 ratio of sensitivities is used to represent both large and subtle anomalies on the same profile.
6. The number and arrow at the bottom of the profile represents magnetic coincidence with the corresponding INPUT anomaly.
7. The 2 profiles at the bottom are artifacts of the Channel 1 and Channel 2 responses. The solid line is the straight difference of the 2 responses, whereas the dashed line is the optimally low-pass filtered difference. Again, responses are increasing positive downwards to follow the standard convention.

DIFFERENCE PARAMETER

When employing the INPUT system for the overburden mapping application, both bedrock conductors and cultural anomalies can be considered as sources of unwanted signal. The difference parameter (Channel 1 - Channel 2) was devised to reduce the contributions of these 2 sources of noise from the Channel 1 response, which, in the BRIM area, is the most useful for mapping the overburden. For example, the cultural anomalies near fiducials 64 and 65 have been reduced by 50 to 80% as well as the 5-channel INPUT anomaly near fiducials 53 and 54 by approximately 50% (Figure 2). It should also be noted that the overburden response has been reduced by only up to 25% along the entire profile. The reason for this is that good bedrock conductors generate slower decay rates than less conducting overburden features, so their responses will be suppressed. Cultural anomaly responses are quite erratic, particularly those associated with powerlines, and the degree of suppression of these features is rather unpredictable.

Figure 3 illustrates the behaviour of the difference parameter as the product of the overburden conductivity times thickness (i.e. its conductance) increases. In the BRIM area, the maximum thickness of the most conductive materials, the various clays, of the overburden is of the order of 50 m, which have conductivities in the range of 30 to 40 millisiemens/metre. Hence, the maximum conductance is only 1.5 to 2.0 siemens which, from Figure 3, would result in only a 25% reduction in the Channel 1 amplitude by computing the difference function. This

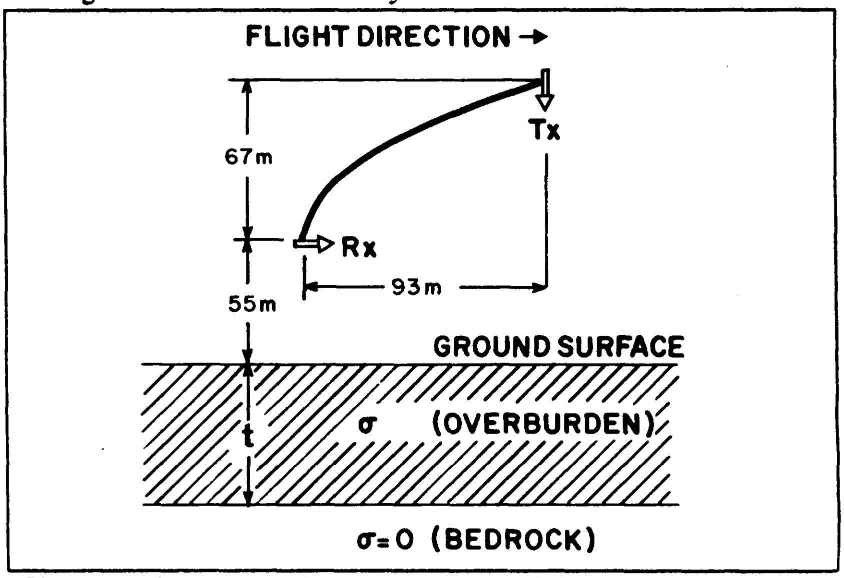


Figure 1. System configuration and simplified subsurface model to represent conducting overburden. (Project S55.)

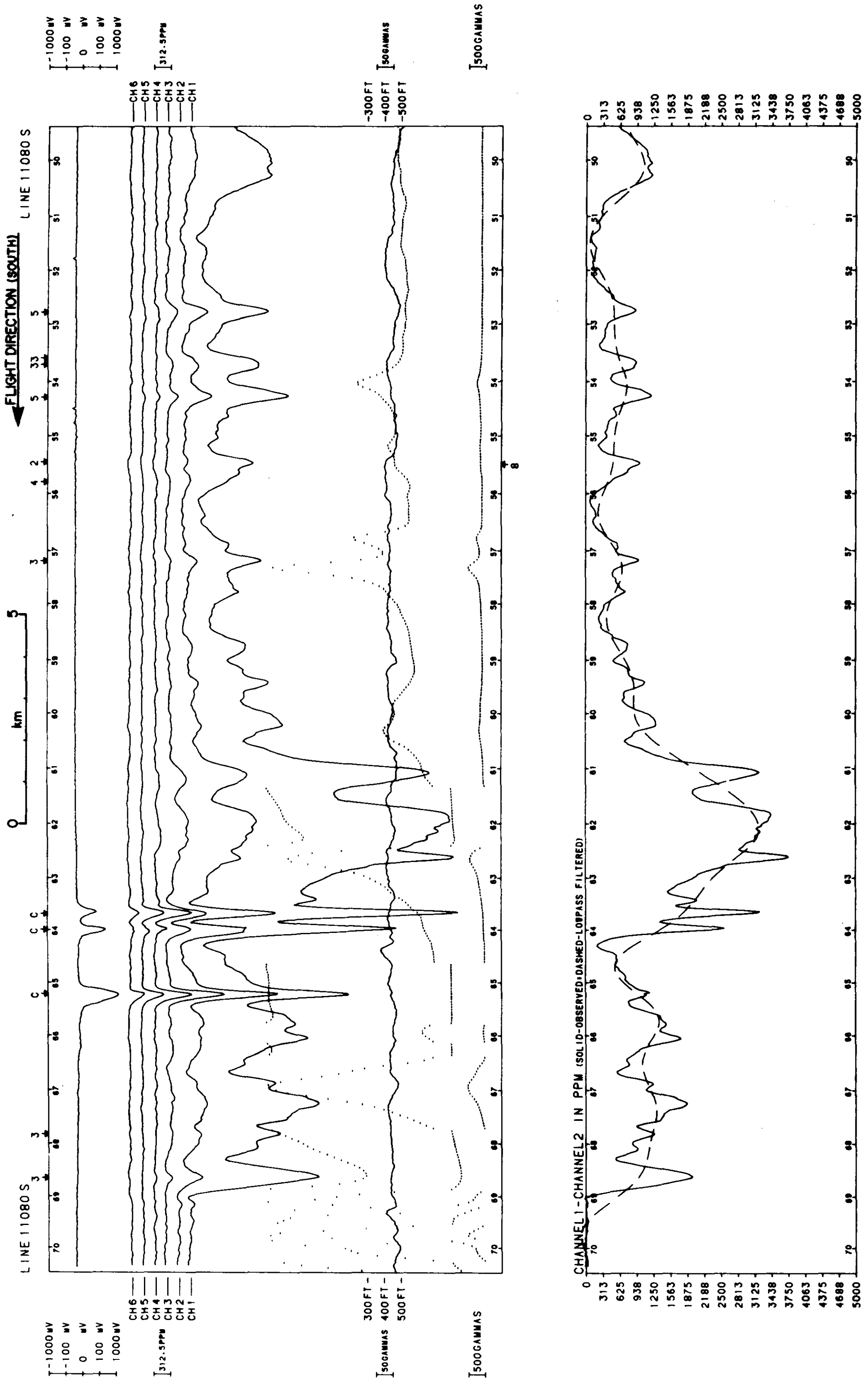


Figure 2. Computer generated profile of electromagnetic data for Line 11080S. (Project S55.)

demonstrates that the difference parameter is not seriously reduced compared to the Channel 1 amplitude, while the response of good conductors and cultural anomalies are effectively decreased.

Also from Figure 3, for low values of conductance of less than about 1 siemen, the difference parameter is proportional to the cube of conductance, while at higher values of conductance in the 1 to 2 siemen range, the parameter is proportional to the square of conductance. Hence, for all values of conductance encountered in the area, the difference parameter is sensitive to small changes in conductance.

FILTERED DIFFERENCE

Clearly, the spatial wavelength of cultural anomalies and bedrock conductor anomalies is much shorter than major overburden features. Hence, a way of further reducing the contribution of these responses is to apply a low-pass filter to the difference parameter. Figure 4 gives a plot of the frequency response of the low-pass filter that was applied to the difference parameter. The passband cutoff spatial frequency, FP of 0.01 per unit sample interval, implies that spatial wavelengths of less than 100 sample intervals, which in the case of the electromagnetic data is 2.5 fiducials, are reduced. In fact, beyond the stopband cutoff spatial frequency, FS of 0.02 per unit sample interval, features of wavelength less than 1.25 fiducials which represents distances in excess of 1 km are effectively suppressed. The dashed line shown in Figure 2 demonstrates the effectiveness of the filter suppressing the contributions due to short

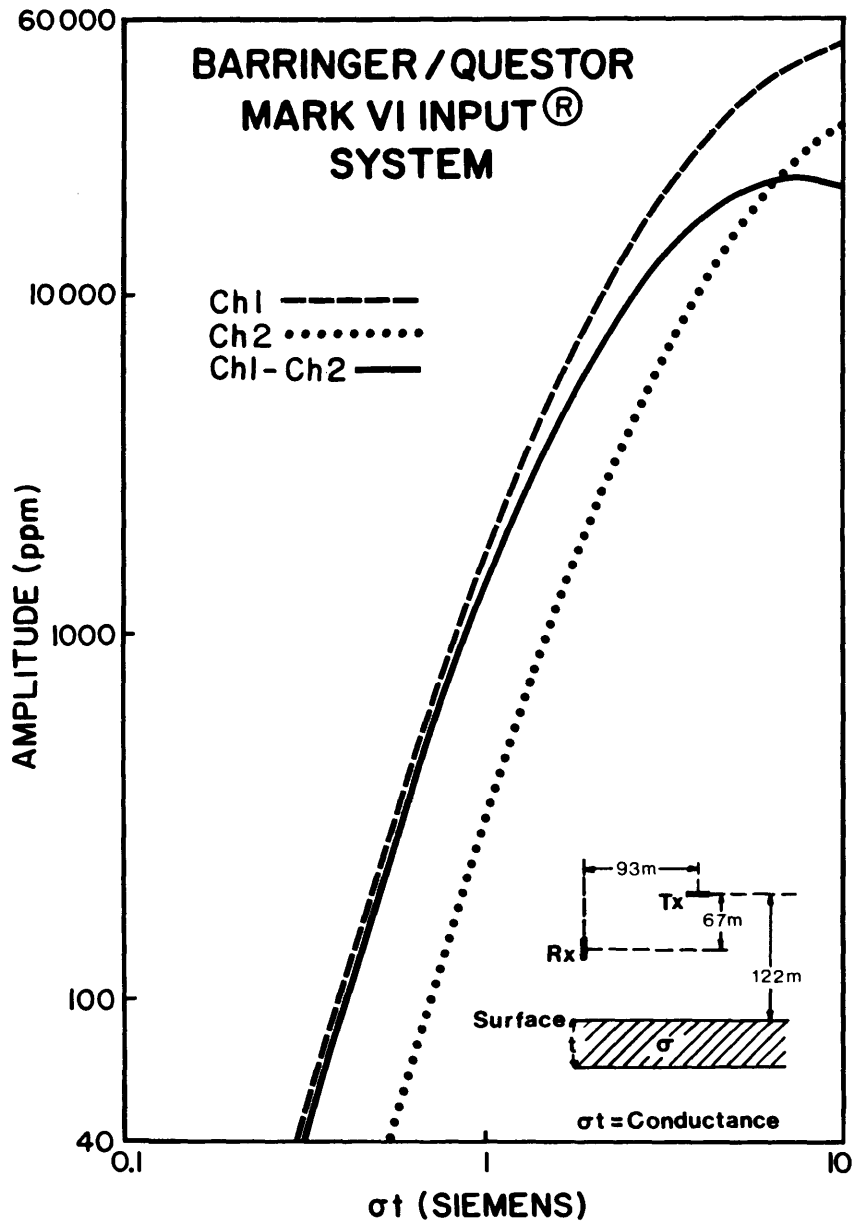


Figure 3. Comparison of the (Channel 1 - Channel 2) difference parameter with Channel 1 and Channel 2, shown separately, for a thin overburden layer. (Project S55.)

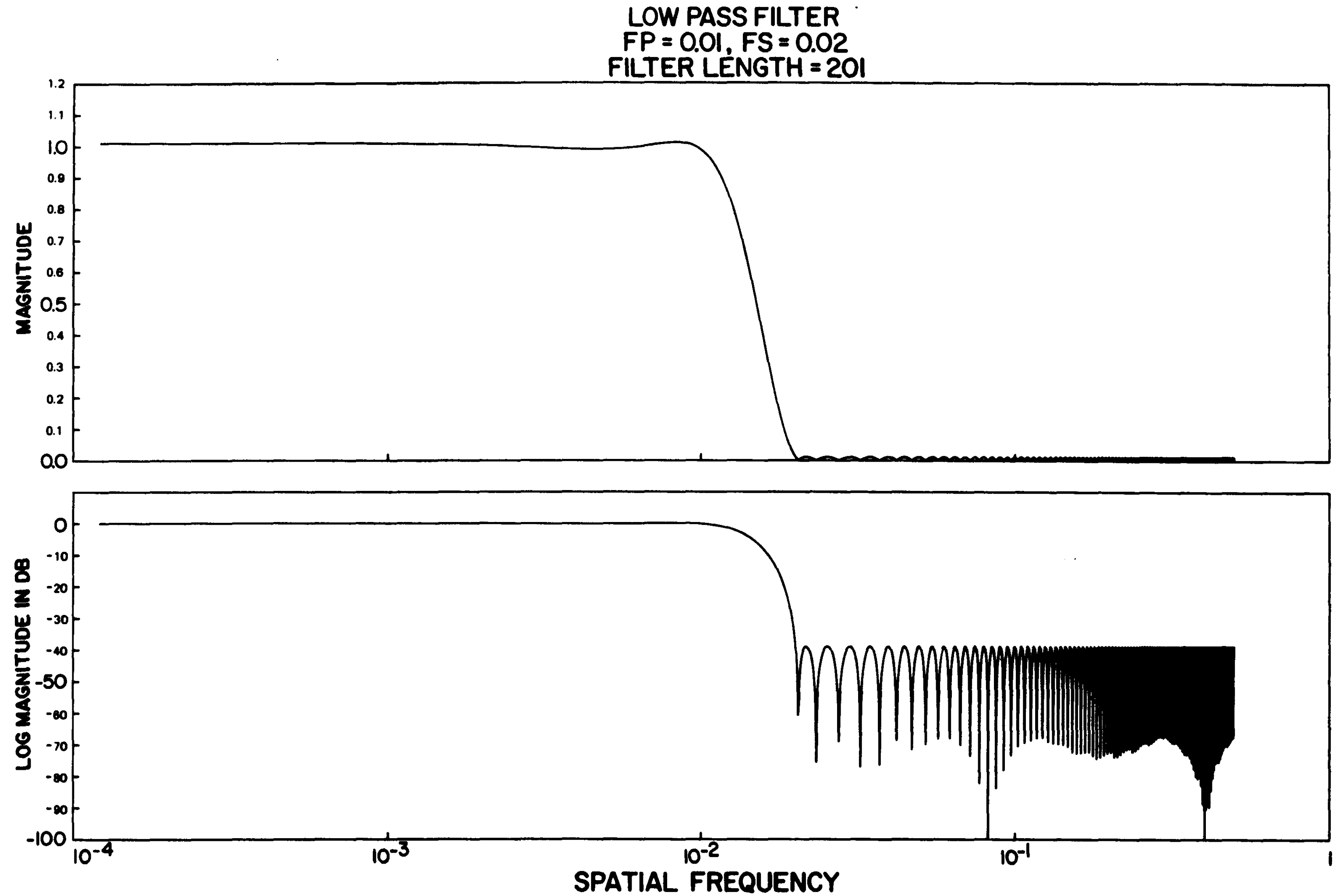


Figure 4. Frequency response of the optimally designed low-pass filter applied to the (Channel 1 - Channel 2) difference parameter. (Project S55.)

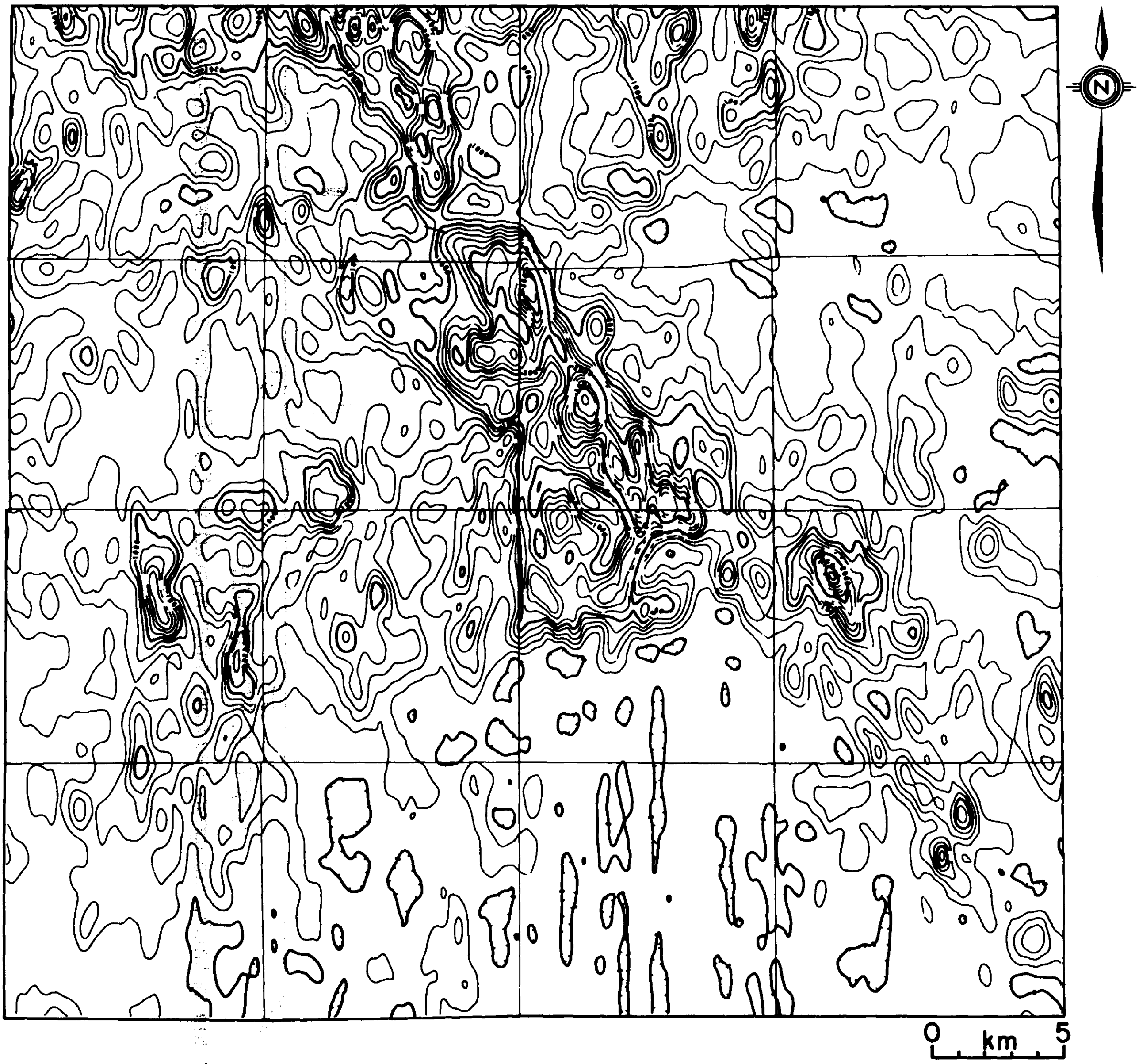


Figure 5. Contour map of the filtered difference parameter for the 16 western townships of the BRIM area. The contour interval is 200 ppm. (Project S55.)

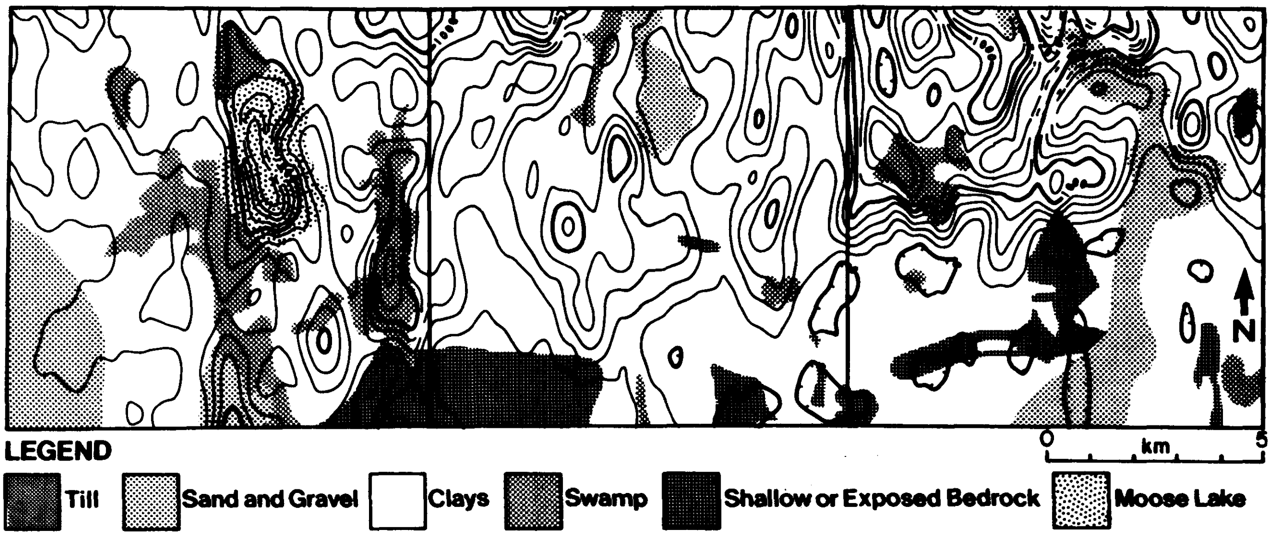


Figure 6. Correlation of the contoured difference parameter for Bond, Currie, and Bowman Townships (from west to east) with the surficial geology. (Project S55.)

wavelength features such as electromagnetic (EM) anomalies, bedrock conductors, and narrow overburden features.

REGIONAL OVERBURDEN FEATURES

An excellent qualitative representation of the aerial extent of conducting overburden features can be obtained by contouring the filtered difference parameter which, as described in the previous section, is an enhanced map of conductance. The contour map for the 16 western townships of the BRIM area where the overburden is the most conductive is represented in Figure 5. There is a major feature, trending northwest in the vicinity of the Black River, evident on the contour map, corresponding to the ice flow direction during the last period of glaciation and perhaps reflecting a drift-filled bedrock valley. Other trends on the contour map, particularly those perpendicular to the major northwest-trend may be associated with buried valleys that were enhanced during an earlier period of glaciation associated with a different ice direction. Hence, regional maps of the type presented in Figure 5 may be extremely useful in delineating such cross-cutting trends which may offer the most complete Quaternary section below the clay layer.

CORRELATION WITH SURFICIAL GEOLOGY

In order to extract the most useful information from the airborne electromagnetics, it is mandatory to compare features with the Quaternary maps of the area. For example, the geological and geophysical data for Bond, Currie, and Bowman Townships are presented in Figure 6 and are compared to the surficial geology from Lee (1979a, 1979b). The areas of till, sand, and gravel as well as the areas of bedrock exposure, where there may be a very thin veneer of clay, have lower difference parameter responses, due to their higher resistivity, than do the clay filled valleys, the swampy areas, and the areas comprising significant amounts of lake sediments which have lower resistivities. Moreover, since landforms consisting mainly of quite resistive sands, such as eskers, produce comparable responses to bedrock exposure areas, one must not try to relate responses to overburden thickness without considering the surficial geology.

Quantitative estimates of the overburden conductances can also be derived from the first few INPUT channels and even estimates of overburden thickness can be obtained over

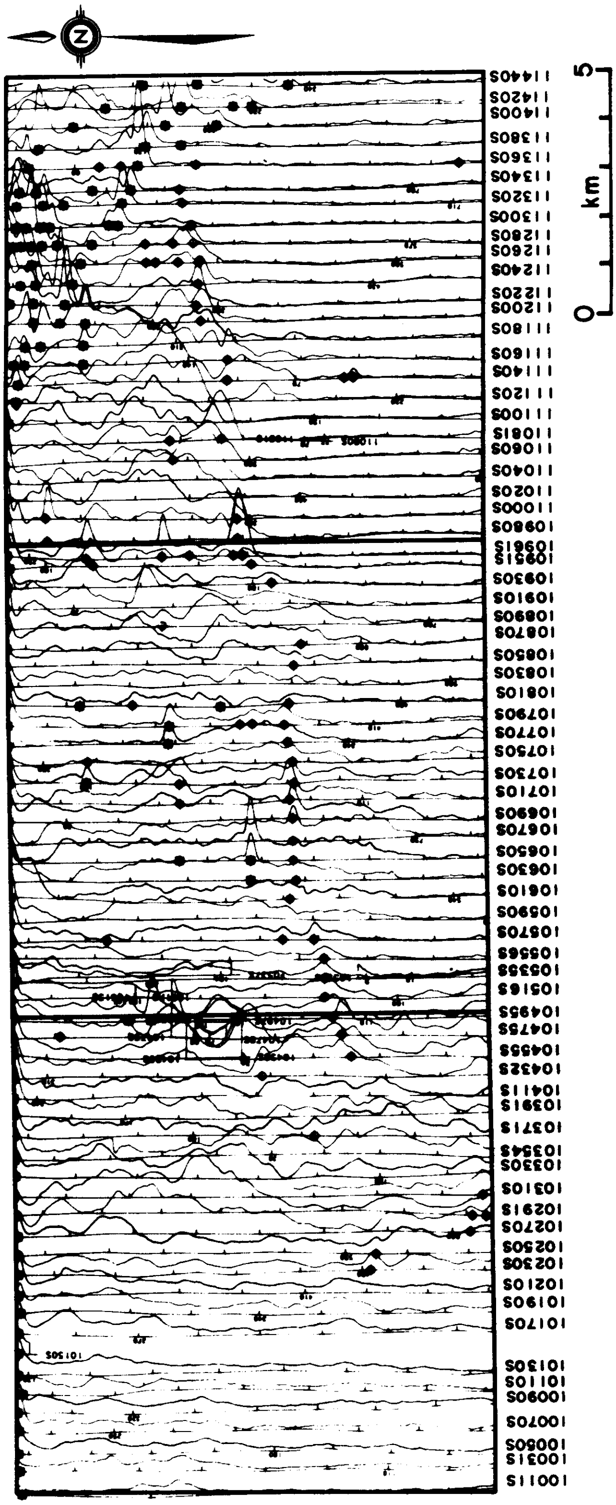


Figure 7. Unfiltered difference parameter, flight lines, and electromagnetic anomalies for the southbound lines over Bond, Currie, and Bowman Townships (from west to east). (Project S55.)

INDEX OF AUTHORS

TABLE 1. SAMPLES COLLECTED FOR ZIRCON U-Pb AGE-DATING, 1984. (Project 46.)

SAMPLE #	TOWNSHIP	LOCATION	DESCRIPTION
84SM2/TM	Tisdale	Northeastern corner of the 400 pit, approximately 20 m from the contact with basaltic flows, Hollinger Mine	Millerton porphyry; quartz-eye sericite schist
84SM4/TM	Tisdale	1700-foot level, 7th cross-cut, Hollinger Mine	Crown porphyry; medium- to coarse-grained, quartz-feldspar porphyry
84SM30/TM	Macklem	Drill core, Aquarius Mine	Equigranular to feldspar porphyritic, coarse-grained trondhjemite to granodiorite
84SM19/TM	Garrison	South central part of the Garrison Stock	Coarse-to medium-grained, equigranular monzonite
84SM8/TM	Tisdale	1200-foot level, 1222-foot drift Dome Mine	Coarse-to medium-grained, black Matachewan diabase
84SM7/TM	Beatty	500 m south of Salve Lake	Rhyolitic flow; aphanitic to fine-grained matrix containing quartz and/or feldspar phenocrysts; well developed flow banding

the Timmins camp, will provide an additional piece of evidence as to the intrusive nature of these porphyries. The sampling of the Millerton and Crown porphyries was timely because the 400 pit where the Millerton porphyry is best exposed, and the underground workings of the Hollinger Mine were closed down at the end of the summer of 1984.

3. *The Aquarius Mine* — a relatively fresh granodiorite-trondhjemite intrusion with highly carbonatized and hematitized zones which host substantial amounts of gold mineralization. Considering that the area to the south of the Destor-Porcupine Break is covered by very thick overburden, understanding of the timing of emplacement of this min-

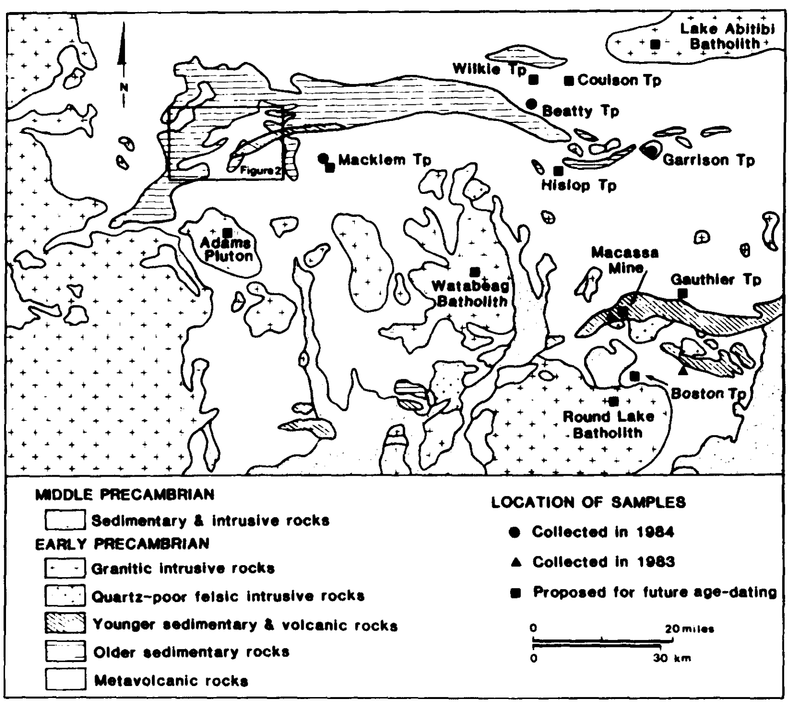
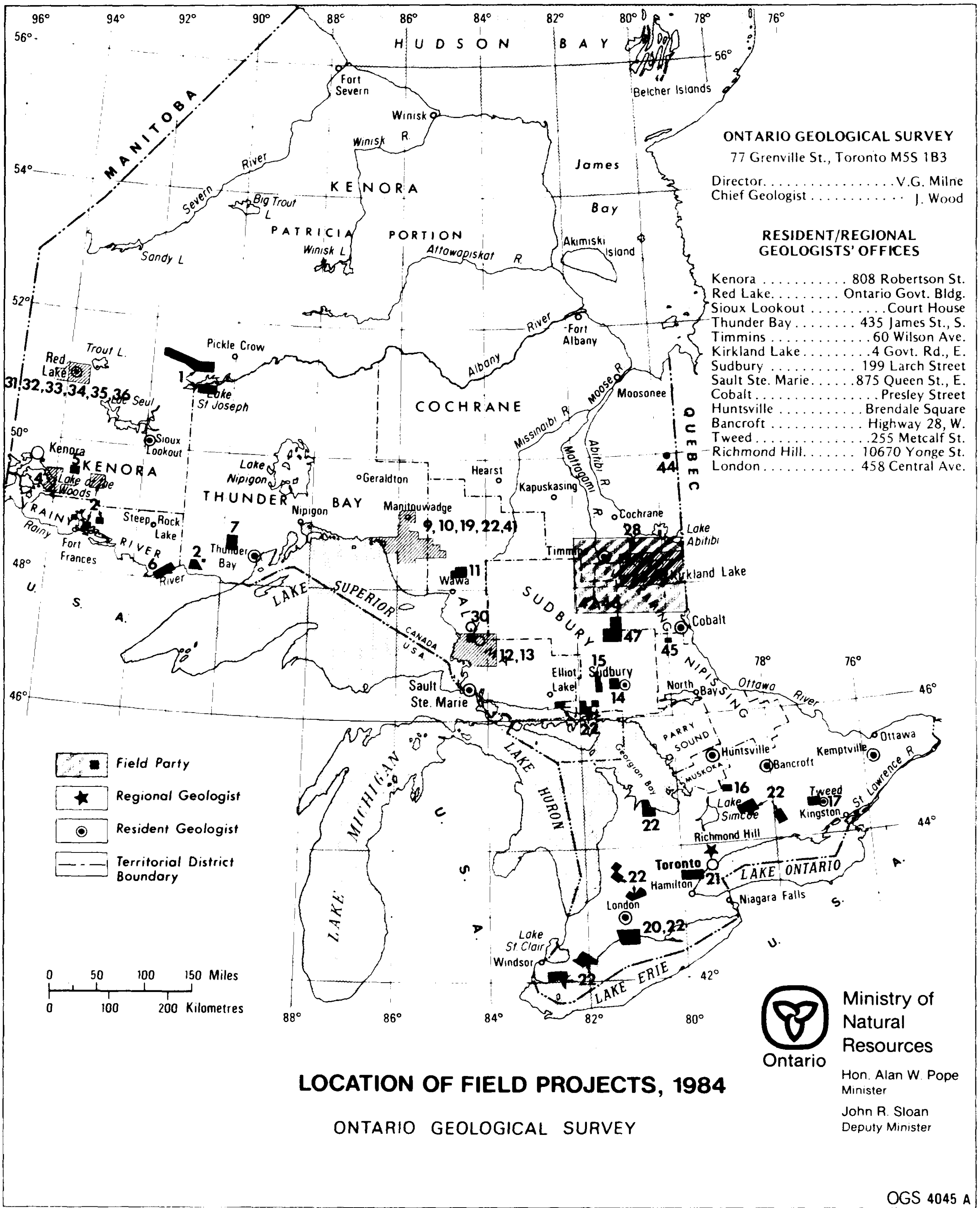


Figure 1. Simplified geology of the Timmins-Kirkland Lake area showing location of samples for zircon U-Pb age-dating. (Project 46.)



Location of Ontario Geological Survey Field Parties, 1984.

A complex meltwater drainage system apparently existed on top of, and along, the Niagara Escarpment at the margin of the Halton ice. The irregular surface of the reefy Amabel Formation was scoured along the meltwater channels, developing potholes up to 3 m in diameter and eroding 2 gorges, each about 1 km long, in the edge of the Escarpment west of Milton. These waters continued south along the western side of the Milton Outlier. Parts of these channels are the sites of swamps and bogs.

The pronounced irregularity of the bedrock surface (local relief up to 10 m), extensive bush cover, and bouldery till, made it necessary to map an area of outcrop complex between Milton and Limehouse. Striae directions on the bedrock surface, mostly observable in quarries because of overburden stripping, are due west between Milton and Limehouse, but west-northwest between Limehouse and Cheltenham.

ECONOMIC GEOLOGY

Several active quarries produce crushed stone from the Amabel Formation west of Milton and Limehouse. Whirlpool Sandstone quarries are active near Limehouse, and abandoned workings are common along its outcrop extent, which sometimes forms a secondary escarpment east of the main Niagara Escarpment. Queenston Shale was formerly quarried for ceramic products at Milton and Terra Cotta.

Only a few active pits exploit the glaciofluvial sand and gravel. Most of the gravels are coarse and require crushing, and the composition is commonly high in clastic rock types which limits their use. Extraction is presently centred around Limehouse.

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areas containing significant amounts of varved and massive clays, whose resistivity may be known through in situ measurements of the type reported by Barlow and Krentz (this volume).

IDENTIFYING BURIED RIVER VALLEYS

An effective parameter for identifying relatively short wavelength features associated with overburden features in the order of 500 m is the unfiltered difference plotted adjacent to the flight lines in plan map form along with the EM anomalies and cultural features. An example is shown in Figure 7. The features associated with cultural anomalies and bedrock conductors can be dismissed while the others can be correlated with the surficial geology. Due to the asymmetry of the INPUT system, the response shape is dependent upon flight direction. Hence, it is best to interpret the data from each flight line direction separately and investigate any inconsistencies when combining the interpretations of both flight line directions.

SUMMARY AND FUTURE WORK

The INPUT data has proven to be extremely useful in delineating the surficial geology of the Black River-Matheson area. In the western part of the area, a number of interesting features have been identified which may be associated with buried river valleys due to an earlier period of glaciation. Some of these areas will be investigated, where access permits, during a sonic drilling program in the fall of 1984.

It is anticipated that correlation of drill logs with airborne geophysics will assist in the production of more quantitative geophysical maps of the area outlining the electrical properties of the overburden.

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