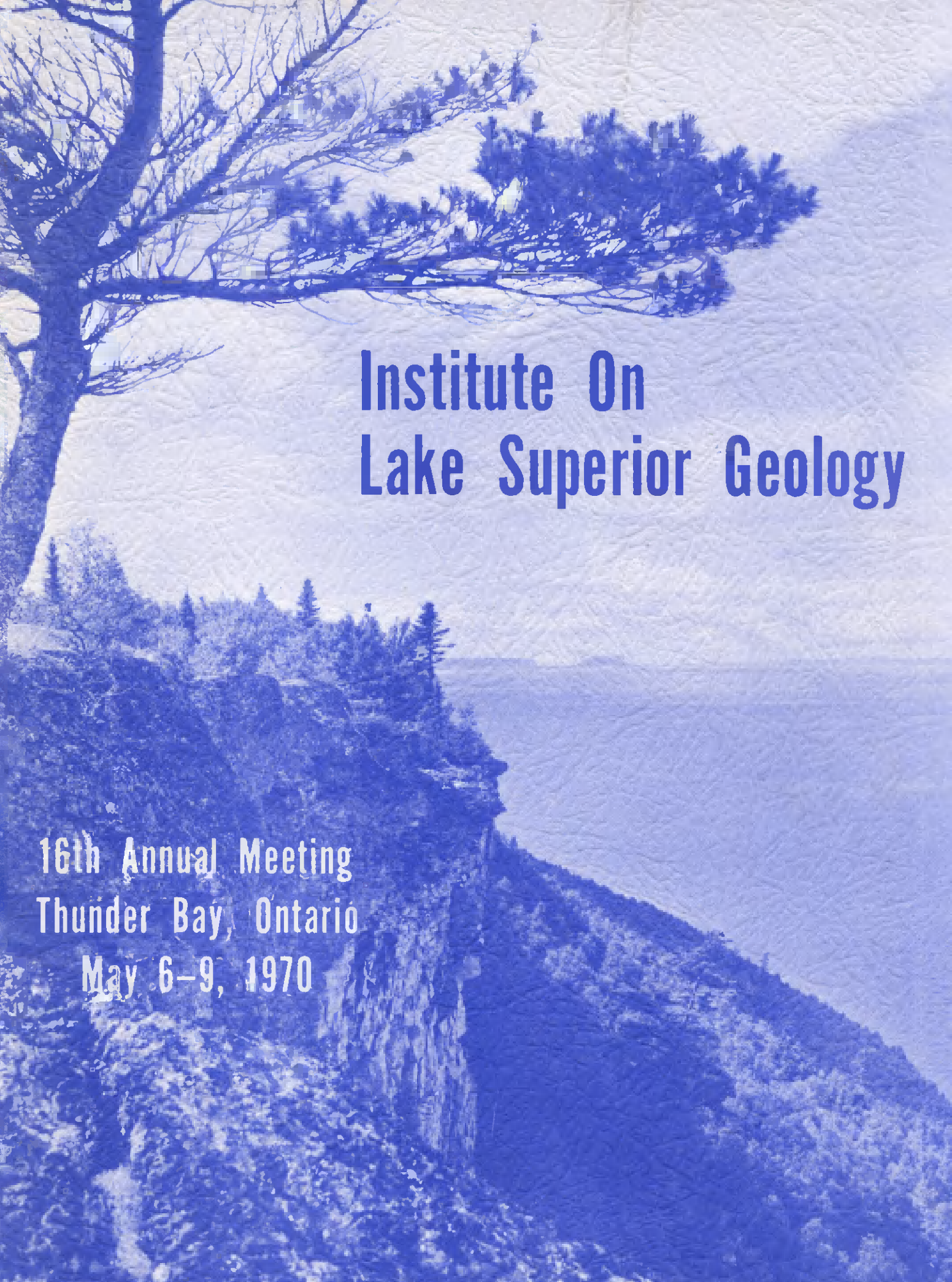


A blue-toned photograph of a rocky cliff overlooking a large body of water, with a pine tree in the foreground.

Institute On Lake Superior Geology

16th Annual Meeting
Thunder Bay, Ontario
May 6-9, 1970

TECHNICAL SESSIONS

ABSTRACTS

and

FIELD GUIDES

for

16th ANNUAL

INSTITUTE ON LAKE SUPERIOR GEOLOGY

held at

LAKEHEAD UNIVERSITY

Thunder Bay, Ont.

May 6 - 9, 1970

Edited by J.L. Talbot
J.M. Franklin
C. Kustra

TABLE OF CONTENTS

INSTITUTE DIRECTORS AND LOCAL COMMITTEE	1.
PROGRAM	2.
ABSTRACTS OF TECHNICAL SESSIONS	7.
FIELD TRIPS	
A- Proterozoic formations in the Thunder Bay Area.	49.
B- Sturgeon River Metavolcanic - Metasedimentary Formations in the Beardmore-Geraldton area.	69.
C- The Port Coldwell alkalic complex	85.

16th Annual

INSTITUTE ON LAKE SUPERIOR GEOLOGY

Lakehead University

Thunder Bay, Ontario

May 7-8, 1970

INSTITUTE BOARD OF DIRECTORS

- * J. W. Avery (Treasurer), Jones & Laughlin Steel Corp., Negaunee, Michigan.
- * R. C. Reed (Secretary), Michigan Geological Survey, Lansing, Michigan.
- A. K. Snelgrove, Michigan Technological University, Houghton, Michigan.
- W. J. Hinze, Michigan State University, East Lansing, Michigan.
- A. B. Dickas, Wisconsin State University, Superior, Wisconsin.
- G. L. LaBerge, Wisconsin State University, Oshkosh, Wisconsin.
- M. W. Bartley, Thunder Bay, Ontario.

* Permanent members.

LOCAL COMMITTEE

<i>Chairmen:</i>	M. W. Bartley	E. Mercy
<i>Programme Committee:</i>	J. Talbot	F. Harris E. Brinley
<i>General Members:</i>	A. Boerner	J. Mothersill
	V. B. Cook	A. Temple

FIELD TRIP COMMITTEE

C. Kustra
J. Franklin
H. Loubat

"P R O G R A M"

Tuesday, May 5th, 1970

6.00 p.m. *Field Trip 'B' (Geraldton-Beardmore) leaves the
Prince Arthur Hotel, Thunder Bay, Ontario.*

Wednesday, May 6th, 1970

7.00 p.m. *Field Trip 'B' returns to Prince Arthur Hotel*

7.00 p.m.
to
10.00 p.m. *Institute Registration - Prince Arthur Hotel*

7.00 p.m. *American Institute of Professional Geologists,
Dinner, Prince Arthur Hotel*

Thursday, May 7th, 1970

7.30 a.m.
to
9.00 a.m. *Registration, Main Cafeteria, LAKEHEAD UNIVERSITY*

S E S S I O N 1

'Morning'

Thursday, May 7th, 1970

			<u>Page No.</u>
8.15	R. Oja	<i>Keweenawan Copper Deposits in the Archean of Northwestern Ontario</i>	31
8.30	D. C. Mulder	<i>Ore Controls and Open Pit Geological Procedures in Steep Rock Iron Mines Limited</i>	30
9.00	W. F. Read	<i>Is the Limestone Mountain Structure an Astrobleme?</i>	36
9.20	S. Viswanathan	<i>A classification of granitic rocks with reference to Giants Range Batholith, Northern Minnesota</i>	40
9.35	G. N. Hanson & R. Malhotra	<i>K-Ar Ages of Mafic Dikes in North-eastern Minnesota</i>	19
9.50	C. W. Keighin	<i>Age and Petrology of the Fort Ridgely Granite, Southwestern Minnesota</i>	26
10.10	W. Bonnichsen	<i>The southern part of the Duluth Complex and associated Keweenawan rocks, Minnesota</i>	10
10.40	J. D. Mancuso & J. D. Dolence	<i>Structure of the Duluth Gabbro Complex in the Babbitt area, Minnesota</i>	27
11.10	J. C. Green	<i>Ultramafic bodies in the Vermilion District near Ely, Minnesota</i>	17
11.40	J. M. Berkson & C. S. Clay	<i>Side-Scan Sonar Survey of the Lake Superior floor near Freda, Michigan</i>	9
12.00 NOON	-	<u>L U N C H</u> - <u>Student Cafeteria</u>	

S E S S I O N 2

'Afternoon'

		<u>Page No.</u>
1.00	<i>Business Meeting</i>	
1.30	M. Y. Hsu & P. M. Clifford <i>Deformation of the Seine conglomerate in the Rainy River area, Ontario.</i>	20
2.00	H. M. Mooney et al <i>Refraction Seismic Investigations of Northern Midcontinent Gravity High</i>	28
2.30	R. N. Annells <i>Keweenaw Volcanic Geology of Michipicoten Island, Lake Superior</i>	7
3.00	J. Wood <i>Evidence for a Tropical Climate and Oxygenic Atmosphere in Upper Huronian Rocks of the Rawhide Lake - Flack Lake area, Ontario.</i>	45
3.30	G. M. Young <i>Widespread occurrence of Aluminous Minerals in Archean Quartzites</i>	47
4.00	C. Powell <i>Structural and metamorphic history of the Marquette Synclinorium</i>	35
4.30	W. Jenks <i>Root severance and tectonic transport of orebodies in Metavolcanic Host Rocks</i>	25

* * * * *

'Evening'

6.00 p.m. Cocktails - CAFETERIA - Lakehead University

7.15 p.m. Banquet - RESIDENCE DINING ROOM - Lakehead University

- ADDRESS: J. C. Rudolph, of
 GENERAL EXPLORATION CO. OF CANADA LTD.
- speaking on 'A philosophy of exploration'.

Friday, May 8th, 1970

SYMPOSIUM ON GREENSTONE BELTS

H. B. Wilson - General Chairman

		<u>'Morning'</u>	<u>Page No.</u>
9.00	H. B. Wilson	Introduction	
9.15	L. D. Ayres	Synthesis of early Precambrian Stratigraphy north of Lake Superior	8
9.45	Z. Peterman & S. Goldich	Early Precambrian Geology of the Rainy Lake District	34
10.15	P. Clifford	Mt. St. Joseph - An Archaean Volcano	14
10.45	W. C. Brisbin	The structure of the Northern Lake of the Woods Greenstone Belt, a Deform- ational Mosaic	12
11.15	R. H. Ridler	Archaean Volcanic Stratigraphy of the Kirkland-Larder Lakes area of North- eastern Ontario.	37
11.45	DISCUSSION		
12 NOON	LUNCH - Student Cafeteria		

Friday, May 8th, 1970

<u>'Afternoon'</u>			<u>Page No.</u>
1.30	G. N. Hanson & S. Goldich	<i>Early Precambrian Geology of the Saganaga-Northern Light Lakes area, Minnesota- Ontario.</i>	18
2.00	I. F. Ermanovics	<i>A Model for Tectonic Variation of 'Granitic Terrain' in Southeastern Manitoba</i>	16
2.30	R. W. Ojakangas	<i>Geology of a Greenstone Belt in Minnesota: Rainy Lake to Lake of the Woods</i>	32
3.00	D. H. Watkinson	<i>Geology of the Alkalic rock - Carbonatite complex at Prairie Lake, Ontario.</i>	44
3.30	P. M. Clifford	<i>Behaviour of an Archaean Granite Diapir</i>	13
4.00	R. W. Hutchinson	<i>Mineral Potential in Greenstone Belts of Northwestern Ontario</i>	22
4.30	H. B. Wilson	CONCLUDING REMARKS	
4.45	<u>End of Technical Sessions</u>		

* * * * *

- 4.45 DINNER
(Field Trip participants are advised to have dinner before leaving Thunder Bay)
- 6.00 Departure for Field Trip "B". (Geraldton-Beardmore)
Field Trip "C". (Port Coldwell)
Field Trip "D". (Atikokan)

Buses will depart from the University but will call at Hotels as necessary.

* * * * *

Saturday, May 9th, 1970

- 8.00 a.m. Departure for Field Trip "A". (Gunflint-Sibley)
Buses will depart from the Prince Arthur Hotel
- 7.30 p.m. (approx.) RETURN OF ALL FIELD TRIP BUSES.

KEWEENAWAN VOLCANIC GEOLOGY OF MICHIPICOTEN ISLAND,
LAKE SUPERIOR

R. N. ANNELLS

Postdoctorate Fellow

Geological Survey of Canada, Ottawa

A B S T R A C T

Recent re-mapping and petrographic examination by the author of the Keweenawan lava flows building Michipicoten Island shows that they form a highly differentiated 11,500-foot sequence of types ranging from coarse ophitic olivine-bearing basalts through olivine-free basalts and andesitic types to glassy porphyritic andesites and rhyolites. Some volcanoclastic horizons are intercalated in this south-dipping lava series and a few intercalations of conglomerate and sandstone outcrop at the west end of the island.

The different lava types are well intermixed and there is no obvious vertical gradation or cyclic distribution of lava types in the Michipicoten Island succession. The lavas tend to occur in groups of petrographically similar flows which can be traced as distinct stratigraphic units; an andesite group near the top of the succession can be followed across the entire island, a distance of 16 miles along strike. Near the median part of the succession the lavas show some lateral variation which may be the result of simultaneous extrusion of different flow types at the same general level from different vents.

An agglomerate bearing large angular and rounded blocks of island lava types outcrops on the northwest shore of the island, and indicates proximity to an eruptive vent. The lower half of the exposed lava sequence is intruded at numerous different horizons by sheet-like or lenticular bodies of pink acid quartz porphyry crowded with large phenocrysts of feldspar and quartz. These bodies are sometimes discordant to the lava flows and field evidence suggests that they are intrusions. Basic intrusions are extremely rare on Michipicoten Island, only about six very thin basic inclined sheets being found on the entire shoreline.

The varied basalt-andesite-rhyolite sequence and associated volcanoclastic rocks of Michipicoten Island are believed to have been erupted from a central volcano fed by a high level magma source. The presence of large volumes of acid material in the island sequence is a phenomenon very similar to that seen in the Icelandic central volcanoes, which consist of highly differentiated lava/volcanoclastic edifices interfingered with widespread flood basalts and often intruded by acid material.

SYNTHESIS OF EARLY PRECAMBRIAN STRATIGRAPHY
NORTH OF LAKE SUPERIOR

LORNE D. AYRES

Ontario Department of Mines
Toronto

A section from Lake Superior Park to Geraldton, Ontario crosses three major, east-trending, Early Precambrian, lithologic and structural elements of the Superior Province of the Canadian Shield. From south to north these are the northern part of the Abitibi island arc, the Quetico sedimentary basin, and the southern part of the Keewatin island arc.

Both the Abitibi and Keewatin arcs are formed from coalescing, subaqueous, basaltic shield volcanoes capped by subaerial to subaqueous, felsic to intermediate pyroclastic cones. Volcaniclastic greywacke sequences derived from felsic volcanism accumulated in intervalcano basins and partly overlap the felsic pyroclastic deposits. Small trondhjemite cratons within the island arcs were a local source of sedimentary detritus. Although the island arcs have easterly trends, individual basins and volcanoes have diverse trends.

Along the north edge of the Abitibi arc from Schreiber to Wawa, three isolated sedimentary formations were deposited in intervalcano basins, but they are all tongues of an extremely thick greywacke and siltstone formation deposited in the Quetico basin north of the arc. The formations become progressively younger from west to east.

The sedimentary rocks of the Quetico basin, which are equivalent to the Couchiching Formation of western Ontario, overlies and intertongues with the volcanic formations of the Abitibi arc and the source area was probably within the arc. Along the north edge of the basin, however, the sedimentary rocks underlie and intertongue with the volcanic formations of the Keewatin arc. In this area, Keewatin volcanism is thus younger than Abitibi volcanism.

SIDE-SCAN SONAR SURVEY OF THE
LAKE SUPERIOR FLOOR NEAR FREDA, MICHIGAN

J. M. BERKSON & C. S. CLAY

University of Wisconsin
Geophysical and Polar Research Center

A B S T R A C T

Approximately 300 miles of side-scan sonar profiles were made in Lake Superior near Freda, Michigan. The instrument scans to the side approximately 1/4 mile and gives the location of features on the lake floor which scatter sound. The shape of the scattering features can often be correlated with geological features. The ship's tracks were close enough together so that nearly continuous sonar coverage was obtained. Underwater photographs and divers were used to identify some of the scattering features. Three distinct bottom types were observed in the survey area: rocky, sandy, and bedrock. The bedrock appears to correlate with the Freda sandstone, which outcrops on the land. This study was supported in part by The National Center for Atmospheric Research and The Office of Naval Research.

THE SOUTHERN PART OF THE DULUTH COMPLEX AND
ASSOCIATED KEWEENAWAN ROCKS, MINNESOTA

BILL BONNICHSEN

Cornell University,
Ithaca, N.Y. 14850

A B S T R A C T

The southern part of the Duluth Complex was reported to consist mainly of troctolitic rocks and older anorthositic rocks at the 15th Annual Institute on Lake Superior Geology and elsewhere (Bonnichsen, 1969). Geologic mapping in several 7½-minute quadrangles in the Babbitt-Hoyt Lakes area (Bonnichsen, 1970) shows that troctolitic rocks lie north and west of the principal occurrences of anorthositic rocks, thus forming the footwall side of the complex in the same manner as at Duluth (Taylor, 1964). Between Duluth and the Babbitt-Hoyt Lakes area, troctolitic rocks predominate across the width of the complex; exposures of anorthositic rocks are restricted to isolated occurrences and inclusions within the troctolitic rocks, rather than large areas with contiguous outcrops.

In 1969, the writer suggested that troctolitic magmas had intruded along a contemporaneously widening fracture zone between the previously-formed anorthositic rocks to the east and the Early and Middle Precambrian basement to the west. Field work during the summer of 1969 and examination of drill core in recent months tends to substantiate this view. Recently obtained knowledge on the variety and diversity of rock types within the southern part of the complex indicates the development of the troctolitic rocks was a complex event involving multiple injections of magma, the incorporation of a great amount of previously-formed Keweenawan igneous rocks as inclusions and the development of relatively small quantities of Fe- and Ti-rich magma, some of which was ultramafic, from magmas which initially were troctolitic.

Much of the 1969 field season was devoted to looking for and examining outcrops along, and east of, the eastern or hanging wall margin of the complex. This margin, for the first 30 miles north of Duluth, is mainly a contact between troctolitic and locally anorthositic rocks to the west and gabbroic and dioritic intrusives to the east. Exposures of mafic volcanics are uncommon east of the southern part of the complex, except within one or two miles of Lake Superior.

In the Mt. Weber-Greenwood Lake area, about 40 miles N.N.E. of Duluth, a number of granophyre exposures occur but the area underlain by granophyre is much less than shown on the 1932 Minnesota state geologic map. Gabbros, ferrogabbros, and magnetite troctolites are exposed north of the granophyre area; these rocks are responsible for the intense magnetic anomalies in that area. Exposures of rhyolite, other felsites and magnetic basalts occur south of the granophyre area. In the central part of this volcanic area is a one-fourth mile long outcrop area of strongly-laminated, locally cross-bedded, weakly metamorphosed, feldspathic rock that is interpreted to be equivalent to the Virginia Formation; this occurrence is about 25 miles east of the footwall of the complex where other Virginia Formation is exposed.

Bodies of hornfels are common throughout the southern part of the complex; many of these, especially in the Babbitt-Hoyt Lakes area, are inclusions of the Virginia Formation which forms the footwall of the complex in that area. The majority of hornfels bodies in the southern part of the complex, however, are considered to be metamorphosed basalt, probably of Keweenaw age. This type of hornfels occurs throughout the complex, including along the western margin. It is suggested that along parts of the western margin of the complex between Duluth and Hoyt Lakes, the footwall consists of volcanics which overlie the Virginia Formation and the equivalent Thompson Slate, much like the situation at Duluth.

A feature of interest in the southern part of the complex are a number of bodies of titaniferous peridotite and similar ultramafic rocks. These dike- or sill-like bodies are known from drilling to locally have thicknesses of hundreds of feet. These rocks are characterized by lithologic heterogeneity, medium to coarse grain sizes, local rhythmic layering and abundant titanite, olivine, and ilmenite; locally, magnetite, graphite, plagioclase, and pyrrhotite are abundant. These rocks may have crystallized from liquids approximating their present composition because they are the latest intrusive rocks known in that area and because fine-grained dikes with identical mineralogical compositions cut adjacent rock bodies in the vicinity of the large peridotite bodies.

References:

- Bonnichsen, Bill, 1969, Geology of the southern part of the Duluth Complex, Minnesota; Proc. of 30th Annual Mining Symposium, Univ. of Minn.; p. 89-93.
- Bonnichsen, Bill, 1970, Geologic maps of the Duluth Complex in the Babbitt-Hoyt Lakes area, Minnesota; geologic maps and accompanying explanation for the Allen, Babbitt, Babbitt NE, Babbitt SE and Babbitt SW 7½-minute quadrangles, 1/24,000; on open file with the Minnesota Geological Survey, University of Minn., Minneapolis, Minn.
- Taylor, R. B., 1964, Geology of the Duluth Gabbro Complex near Duluth, Minnesota; Minn. Geol. Survey Bull. 44, 63 p.

THE STRUCTURE OF THE NORTHERN LAKE OF THE WOODS GREENSTONE BELT,
A DEFORMATIONAL MOSAIC.

W. C. BRISBIN

University of Manitoba

A B S T R A C T

The structure of the northern portion of the Lake of the Woods greenstone belt may be described as a complex mosaic, consisting of the effects of several deformation events, each of which has been developed spatially to differing degrees. Individual domains, within the mosaic, may show strain effects of one, or more, of three widespread and dominant tectonic events, the chronology and tectonic styles of which are remarkably persistent.

The earliest deformational period is manifest by folds in layering which are seldom unaffected by later events. Where structural overprinting is poorly developed the evidence suggests that these folds were developed by a flexural mechanism, under conditions of low mean ductility, where layer contacts were active. These folds are interpreted as having developed post lithification and prior to any major metamorphic event.

Large areas of the greenstone belt show evidence of a second deformational event which has led to the development of a penetrative and tectonically active foliation. Differential movements, either leading to, or on, the foliation have resulted in passive folds which, in many areas, have been superimposed on earlier sets. Evidence on all scales, from deformed clasts to deformed early plutons, indicates that strain during this event was accomplished by a combination of simple shear and differential pure shear. The directions of extensive strain and simple shear movements during this event had strong vertical components; the strain effects of this event are linked to the reorganization of upper crustal masses which accompanied the emplacement of the numerous granitic diapirs which have intruded the greenstone.

The third period of deformation is portrayed best in many of the areas where the second period penetrative foliation occurs. The earlier foliation served as an active surface for the development of flexural folds on all scales; from microscopic crenulations, to mesoscopic kink bands, to major folds with structural relief of several thousand feet. Movement directions during this event were variable within, and between, domains, suggesting a wide variety of late stress conditions both temporally and spatially.

BEHAVIOUR OF AN ARCHAEOAN GRANITE DIAPIR

PAUL M. CLIFFORD

Department of Geology
McMaster University

A B S T R A C T

Much evidence now is available linking part, possibly all, of the deformation in Archaean greenstone belts with the emplacement of diapiric granites. This is now well documented for the Keewatin-type belts of the Canadian Shield, and their analogues in Southern Africa, Western Australia and elsewhere. These granites are large ovoid, lobate masses in plan view, commonly heterogeneous internally. Between clusters of such granites lie linear and stellate arrays of volcanic-sedimentary rocks - greenstones, set in a granite sea.

The Bamaji Granite about 300 kms. N.N.E. of Thunder Bay is one such granite mass. It and the Carling Granite lie N.W. and N.E. respectively of the Lake St. Joseph volcanic-sedimentary basin. Pillows in the lavas within 500 metres of the Bamaji Granite margin have suffered considerable flattening in a plane parallel to the margin. The amount of flattening increases towards the granite, reaching values of about 80%, with an average of 60% in this distance. In the same zone, "granitic" dykes which emanate from the granite into the lavas are buckled. The axial surfaces of the buckles are statistically parallel to the granite margin. The shortening implied by the dykes is 40% or less. Both these flattening features suggest that emplacement of the granite led to effective compression of the lower levels of the supracrustal pile on axes everywhere normal to the granite margin, and that there was probably stretching on subvertical axes in order to accommodate the distortion. The discrepancy between compressions in pillows and dykes suggests that the dykes were intruded some time after compression commenced.

At certain localities right at the granite margin, "chocolate-tablet" boundinage occurs in already flattened lavas. This implies late extension in all directions within the plane parallel to the granite margin. This in turn implies an axially symmetric stress field, whose unique symmetry axis lay normal to the granite margin. The best explanation for this late stage extensional strain is that the granite was then being inflated by the introduction of low-viscosity granitic material (? magma).

MT. ST. JOSEPH - AN ARCHAEOAN VOLCANO

PAUL M. CLIFFORD

Department of Geology
McMaster University

A B S T R A C T

An Archaeoan composite strato-volcano is preserved about 300 kms. N.N.E. of Thunder Bay. Despite severe deformation and modest metamorphism, a fairly clear picture of the history of this volcano, Mt. St. Joseph, can be gained.

The lower portion of the volcano pile is now some 2700 metres thick, but allowance for tectonic flattening raises this to 3700 metres at least, and the true thickness was probably much more, if large xenoliths within flanking granites can be assigned to this sequence. This effusive sequence, dominantly mafic, consists of unstructured flows intercalated with pillowed lavas, autobreccias and pillow breccias. About two-thirds up the sequence, there is an erosional unconformity developed on a diorite intrusive into the lavas. A conglomerate lies on the unconformity, and this is succeeded by the upper levels of the effusive sequence.

Above the effusive sequence lie about 3250 metres of volcanic fragmental rocks of mainly silicic composition - the explosive sequence. The lower units of the sequence consist of large accidental blocks in a finer grained matrix. The higher units are generally finer-grained.

The effusive rocks are commonly vesiculated. The degree of vesiculation in pillows generally increases with height in the pile. This implies progressive shallowing of the water into which the lavas were emitted. The upward decrease in size of accidental fragments in the explosive sequence suggests an increase in the intensity of explosive force as the volcano matured.

Chemically, lavas range from 45% to 75% SiO_2 . The change from effusive to explosive activity occurred at about 58% SiO_2 . The estimated explosive index of the volcano is less than ten. The silicic materials now preserved form a relatively minor portion of the total volume of volcanic rocks. In an Osborne-type plot, the lavas 'evolve' on a line intermediate between the lines for Skaergaard and the Cascades.

The volcanic history, taken in conjunction with the tectonic development of the area, implies very restricted areas of deposition,

capable of accepting considerable thicknesses of volcanic rock and derived sediments. This, in turn, implies considerable crustal mobility at the time. Note that no deformed belts occur without a volcanic pile. The local mobility and the vulcanicity are inextricably linked for this area, as they seem to be for analogous areas elsewhere.

A MODEL FOR TECTONIC VARIATION OF 'GRANITIC TERRAIN'
IN SOUTHEASTERN MANITOBA

I. F. ERMANOVICS

Geological Survey of Canada, Ottawa

A B S T R A C T

The Precambrian rocks of the Superior (Structural) Province of southeastern Manitoba, between latitudes 51 and 54 degrees fall into three groups: metavolcanic-sedimentary rocks (domain I); an adjacent, hybrid mobile zone (domain II) and a siliceous (sialic) nucleus (domain III).

Domain III, situated between 51° 15' and 53° 30' N, comprises augen-gneiss and weakly layered to stratiform layered gneiss (50 per cent of the domain) whose compositions range from quartz monzonite to granodiorite; mafic hornblende gneiss and amphibolite are abundant locally. Siliceous mafic-poor quartz monzonite to granodiorite intrude these gneisses and the magnetite content of the massive rocks is correlatable to regional magnetic 'highs'. Metavolcanic-sedimentary rocks (3 per cent of domain III) and mafic granodioritic gneiss occupy relict keels of folds; 'down-plunge' views of such structures show that these remnants are underlain by siliceous gneiss and massive rocks peculiar to rocks of domain III.

Rocks of domain II, flanking belts of metavolcanic-sedimentary rocks, consist of high-grade aluminous and mafic gneiss intruded by diapiric mafic granodiorite to quartz gabbro; large bodies of quartz monzonite are absent from this domain. The coarse-grained igneous rocks may be the intrusive equivalents (cogenetic magmas) of the lavas of domain I and both domains constitute the total volcanic-sedimentary tectogene.

A seismic 'break', located along the lithologic boundary between domains II and III, indicates displacement of the Conrad discontinuity downward beneath domains I and II with respect to domain III. Thus if the seismic break is a fault (albeit annealed by later intrusions) and if the volcanic-sedimentary tectogene is underlain by rocks of domain III, then the sialic nucleus (domain III) is exposed by virtue of erosion.

It is concluded that the volcanic-sedimentary rocks were deposited upon a sialic (relatively siliceous) basement which is now represented by 'granitic gneiss'.

ULTRAMAFIC BODIES IN THE VERMILION DISTRICT
NEAR ELY, MINNESOTA

JOHN C. GREEN

University of Minnesota, Duluth

A B S T R A C T

A few dozen pods of harzburgitic peridotite have been intruded into the greenstones of the belt immediately north of Ely (Newton Lake Formation). They range up to two miles in length by up to 1,000 feet in width. They have undergone varying degrees of serpentinization, evidently after emplacement; tectonic fractures uniformly crosscut magmatic minerals and textures (olivine and poikilitic pyroxene) and predate serpentinization. They carry negligible Ni, Cu, Au, and Pt - group values and about 5,000 ppm Cr. No significant amounts of asbestos have been seen.

An area in the Ely Greenstone east of Fall Lake contains unserpentinized ultramafic rocks, transitional to gabbros, that are characterized by hornblende and biotite instead of olivine.

EARLY PRECAMBRIAN GEOLOGY OF THE SAGANAGA-NORTHERN
LIGHT LAKES AREA, MINNESOTA-ONTARIO

G. N. HANSON

State University of New York at Stony Brook

Stony Brook, N. Y. 11790

S. S. GOLDICH

Northern Illinois University

DeKalb, Illinois 60115

A B S T R A C T

The principal Early Precambrian rock units in the Saganaga-Northern Light Lakes area of Ontario and Minnesota, from oldest to youngest, include the Keewatin volcanic and related rocks, the Northern Light Gneiss, the Saganaga Tonalite, formerly called the Saganaga Granite, and the Knife Lake Group. These units were intruded by numerous small plutons and dikes.

The Northern Light Gneiss, the Saganaga Tonalite, and syenodioritic to granodioritic phases of a small pluton at Icarus Lake, from oldest to youngest on the basis of field relationships, have been dated by the Rb-Sr, whole-rock technique. The isochron ages range from 2700 to 2750 m.y. and are indistinguishable but suggest that all these rocks formed within a time span of less than 100 m.y. and probably less than 50 m.y.

Modal and chemical analyses show that the greater part of the Northern Light Gneiss is trondhjemitic in composition. As suggested originally by Frank Grout the gneiss may have resulted from the lit-par-lit injection of the Keewatin greenstones during a period of folding. The gneiss, however, may have been formed by folding and metamorphism of a Keewatin volcanic pile composed of basaltic, trondhjemitic, and rhyolitic volcanic rocks, and possibly some sediments.

The Saganaga Tonalite is a late or postkinematic intrusion emplaced in the greenstones and the Northern Light Gneiss, and inclusions of both rock types are found in the tonalite. The Icarus Lake pluton intrudes both the Northern Light Gneiss and the Saganaga Tonalite. It consists of an older western phase of syenodiorite and a younger eastern phase of granodiorite. Both rocks are alkalic, containing aegerine-augite and hastingsite.

Rb-Sr and K-Ar mineral ages from the principal rock units range from 2500 to 2700 m.y. and are difficult to interpret. In part these ages may be related to faulting and alteration. Movements on the major fault zones ceased before the deposition of the Animikie sediments. Metamorphism is low-grade, greenschist facies of the Abukuma type.

K-AR AGES OF MAFIC DIKES IN NORTHEASTERN MINNESOTA

G. N. HANSON and R. MALHOTRA

Department of Earth and Space Sciences
State University of New York
Stony Brook, New York

A B S T R A C T

Sixteen mafic dikes in the Vermilion District, Minnesota and in the Saganaga-Northern Light Lakes area, Minnesota-Ontario border, give K-Ar whole-rock and mineral ages of 2600 m.y., 1900-2000 m.y., 1500-1600 m.y., 1400 m.y., and 100-1100 m.y. One sample of a Logan Sill near Suomi, Ontario gives a whole-rock K-Ar age of 1380 m.y. The dikes range in composition from hornblende andesite with modal quartz and microcline to tholeiitic basalt. There does not appear to be a clear-cut difference in composition as a function of age nor a difference in strike. Most dikes have a north-northwest strike in the Vermilion district and a northerly strike in the Saganaga-Northern Light Lakes area.

Dikes with ages greater than 1500 m.y. have a characteristic alteration, possibly due to burial metamorphism, as shown by highly sericitized plagioclase and the development of actinolite, chlorite, epidote, sphene, prehnite, and calcite. The younger dikes do not show this same style of alteration nor are they as highly altered. The dikes which give 1500-1600 m.y. whole rock K-Ar ages are extensively altered, and these ages may indicate the time of recrystallization rather than the time of intrusion.

DEFORMATION OF THE SEINE CONGLOMERATE
IN THE RAINY RIVER AREA, ONTARIO

MAO-YANG HSU and PAUL M. CLIFFORD

Department of Geology
McMaster University

A B S T R A C T

The Seine conglomerate exposed between Mine Centre and Flanders, Ontario, is of Archaean age (> 2500 m.y.). The conglomerate has been subjected to low-grade regional metamorphism, so that pebbles now lie in a fine-grained foliated matrix of mica schist. The foliation is intensely developed over the whole area studied, but mineral lineation is indifferently developed.

Pebbles vary in lithology, shape, size and orientation. Most are good approximations to oblate triaxial ellipsoids, with the XY planes parallel to foliations and the X axis commonly subparallel to mineral lineation or to intersections of bedding with foliation. Elongations of pebbles on a major fold hinge are parallel to the fold axis. We think that buckling preceded passive slip or flow.

Principal planes of finite strain cannot be identified with any confidence in the field. A new method has been developed which allows the calculation of finite strain ellipsoids from average axial ratios measured in any two rectiplanar surfaces in an outcrop oriented at a fairly large angle one to another. Plots based on these calculations for thirty-four stations show that the average pebble shape is an oblate triaxial ellipsoid, with axial ratios which vary independently of location when followed parallel to the foliation trace. Pebbles of different lithology occurring on fold limbs lie along the same deformation path. This means that original pebble orientations were about the same for all lithologies studied, and that ductilities varied from lithology to lithology. Pebbles of the same lithology lying on the same shortening curve, imply that pebbles of roughly identical shape had different original orientations. Mildly deformed granite pebbles seem not to have suffered rotational strain.

A few examples of ripple marks and cross-bedding in metarenites intercalated with the conglomerate imply that the palaeo transport direction was generally towards the present day south. A plot of volcanic pebble orientations against axial ratios of individual pebbles, measured

in the foliation plane (parallel or sub-parallel to bedding) has a skewed unimodal distribution. A comparable plot for planes normal to foliation has a symmetrical unimodal distribution. These imply that the original volcanic pebbles were deposited with their original XY planes parallel or sub-parallel to the bedding plane with their longest axes generally easterly.

MINERAL POTENTIAL IN GREENSTONE BELTS
OF NORTHWESTERN ONTARIO

R. W. HUTCHINSON

University of Western Ontario

A B S T R A C T

The distribution of producing metal mines has, until recently, suggested that the Archaean greenstone belts of northwestern Ontario were favourable only for gold deposits and iron formations, in contrast to similar belts of northeastern Ontario - northwestern Quebec that are obviously favourable for base metal sulphides as well as gold and iron formations. The metal distribution is no longer so distinctive. Important base metal deposits were discovered at Manitouwadge in 1953 and recently near Uchi and Sturgeon Lakes in northwestern Ontario. Important iron production has commenced from Algoman-type iron formations in eastern Ontario.

Detailed geologic work in the northwestern Ontario greenstone belts shows extensive development of rhythmically-banded, shelf-facies "Coutchiching-type" rocks, of immature, first-cycle "Timiskaming-type" rocks and of thick, well differentiated "Keewatin-type" volcanic sequences. All these have lithologic counterparts in the Abitibi region, where the latter are long-recognized hosts for base-metal sulphides, and where the stratigraphic succession of the three "types" appears similar. Age dating methods fail to reveal any significant age differences between these rocks in northwestern Ontario and their counterparts in eastern Ontario-Quebec. All these features suggest that the greenstone belts of northwestern Ontario are similar in origin and age to those farther southeast, and therefore that all have more-or-less equivalent mineral potential for base metal sulphide, iron formation, and gold deposits. These three types of deposit appear metallogenically characteristic of Archaean sequences. They may be lithofacies-related equivalents of one another; the base metal sulphides forming under reducing conditions near exhalative centres, the iron formations forming under oxidizing conditions remote from the centres, and the gold of similar exhalative derivation but perhaps initially "fixed" in other sedimentary lithofacies such as pyritic or carbonate iron formations, or montmorillonitic, volcanic-derived Timiskaming sediments.

Locally, as at Manitouwadge, the northwesterly greenstone belts have been more highly metamorphosed than those of Ontario-Quebec,

and this complicates exploration for base metal deposits. It is essential to recognize markedly metamorphosed exhalative centres. These centres, originally defined by accumulations of felsic flows, pyroclastics and cherts may be represented by quartz-sericite schists or gneisses, quartzites, quartzitic "conglomerates" or "breccias". Their bulk composition is important, for it survives metamorphism, but primary textures may be much altered or obliterated. Minor-element geochemical studies of oxide, sulphide and carbonate-facies iron formations may be useful in guiding exploration from remote lateral lithofacies toward exhalative centres.

ROOT SEVERANCE AND TECTONIC TRANSPORT OF OREBODIES
IN METAVOLCANIC HOST ROCKS

WILLIAM F. JENKS

University of Cincinnati

A B S T R A C T

Association of lenticular, concordant, semi-concordant, and cross-cutting massive sulfide bodies with mafic and felsic volcanic sequences is well known. Some are clearly of submarine exhalative or replacement origin. Others may well be related to subaerial volcanism, but near sea level in a zone of negative crustal movement, since preservation of near surface phenomena in a eugeosynclinal environment requires relatively rapid covering and burial. Metavolcanic sequences originating in active and subsiding tectonic belts have been subjected to all postvolcanic events affecting the enclosing metasedimentary rocks; they may have undergone deformation by overthrust faulting, nappe folding, and refolding. Separation of the volcanic pile (and associated ores) from its roots during such deformation would be expected. These structures, in metavolcanic terranes, can go unrecognized because of originally complex volcanic-stratigraphic relations, transposition by sliding, and deep folding and metamorphism.

Tectonic severance appears to be the reason for the absence of obvious plutonic source rocks in many metavolcanic sequences and their ores. Separation of ores from roots may be more than 50 km if we take Alpine deformation as a model. Certain types of volcanic masses such as rhyolite domes would yield to tectonic transport in a manner controlled by local contrasts in ductility, shape, and size. The deformational style is quite unlike that produced in regularly layered rocks. Orebodies, with their normal envelopes of hydrothermal alteration, may be transported in an environment especially susceptible to structural irregularity because they are in ductile shells adjacent to irregular volcanic masses. Resultant structural details would be expected to be still more complicated by selective flowage of some sulfide minerals and by migration in response to new chemical gradients.

AGE AND PETROLOGY OF THE FORT RIDGELY GRANITE, SOUTHWESTERN MINNESOTA

C. W. KEIGHIN

Northern Illinois University, DeKalb, Illinois

A B S T R A C T

A number of small outcrops of granite were mapped by Lund in 1949 in the Minnesota River Valley west and southwest of Fort Ridgely. Lund (1956) described the Fort Ridgely Granite as a pinkish-gray porphyritic granite with aligned phenocrysts, some of which are two inches or more in length. Lund suggested that the granite may represent a less contaminated and more massive phase of the Morton Gneiss.

Preliminary whole-rock Rb-Sr data give an isochron age of 2650 m.y. If this value is accepted, the Fort Ridgely granite is similar in age to granite in the valley south of Sacred Heart and is much younger than the Morton Gneiss, 3300-3550 m.y., as reported by Goldich in 1968.

Two rock types are present in outcrops of the Fort Ridgely Granite. A dark-gray rock containing plagioclase, quartz, K-feldspar, hornblende, and biotite appears to be older than a leucocratic phase composed of K-feldspar, quartz, plagioclase, and minor biotite. Textural features suggest granulation and recrystallization with the development of intricately sutured contacts between quartz and feldspar. It appears possible that the Fort Ridgely Granite may be an older rock that was metamorphosed 2650 m.y. ago. Additional isotopic analyses, field, and laboratory studies are being made to eliminate one of the two alternatives.

STRUCTURE OF THE DULUTH GABBRO COMPLEX
IN THE BABBITT AREA, MINNESOTA

J. D. Mancuso and J. D. Dolence

Humble Oil & Refining Company

A B S T R A C T

The Babbitt area is located about 60 miles north of the City of Duluth just northeast of where the trend of the trace of the lower contact of the Duluth gabbro complex changes from north to northeast. The complex in this area intrudes Archean greenstone, Algoman granite, and Animikie iron formation and slate-argillite. The basal contact of the complex is irregular; the dip ranges from almost vertical to flat, but generally dips to the southeast. Major influences on the structure of the contact are 1) stratigraphic: the gabbro selectively rode on top of the iron formation, 2) pre-gabbro folding: an anticline is reflected at the base of the complex, and 3) faulting: both pre and post-gabbro faulting affect the floor of the complex. Various geologic features at and beneath the complex are indicated by aeromagnetism and gravity. The termination of the iron formation beneath the complex is suggested by an inflection in the aeromagnetic data, and a probable contact between greenstone and granite is indicated by gravity.

We suggest that the complex was intruded as irregular sheets and came up from the southeast. It cut weaker units such as the Virginia slate, utilized the Virginia slate--Biwabik iron formation contact, a pre-existing zone of weakness, as a platform to ride upon, and stopped, plucked, and assimilated pre-gabbro rock on its way up. The bottom of the intrusion probably did not influence the structure of the older rocks, but instead its structure was influenced by pre-existing conditions.

REFRACTION SEISMIC INVESTIGATIONS OF THE
NORTHERN MIDCONTINENT GRAVITY HIGH

HAROLD M. MOONEY, CAMPBELL CRADDOCK¹, PAUL R. FARNHAM²,
STEPHEN H. JOHNSON³, AND GARY VOLZ⁴

Department of Geology and Geophysics
University of Minnesota
Minneapolis, Minnesota

A B S T R A C T

Eighty-seven seismic refraction profiles have been obtained to define the geologic structure in the upper crust associated with the Midcontinent Gravity High in Minnesota and Wisconsin. The seismic measurements were taken across a fixed spread of seven geophones from distances up to 13 km. A structural section was prepared for each profile by interpretation of the travel-time graph, and the individual sections were compiled into regional cross sections.

Measured seismic velocities in bedrock fall in the 2.5 - 7.1 km./sec. range. Observed velocities can be assigned to seven groups corresponding to Paleozoic, upper, middle, and lower Upper Keweenawan strata, Middle Keweenawan volcanics, pre-Keweenawan felsic intrusives, and pre-Keweenawan mafic intrusives. These groups display good continuity through the area and allow tentative correlation of rock bodies between geologic provinces.

The St. Croix Horst and its flanking basins underlie the Midcontinent Gravity High and its parallel gravity lows north of Minneapolis. Minimum throw along the western and eastern boundary fault zones reaches about 3.0 and 2.0 km. Sedimentary rocks in the Eastern Basin reach a thickness of at least 2.6 km. A complex horst-like structure also underlies the Midcontinent Gravity High in southern Minnesota; an uplifted basaltic body is bordered by sedimentary basins about 3.0 km. thick.

Middle Keweenawan basalts are present locally in the Eastern and Western Basins underlying the Upper Keweenawan strata. Rocks probably equivalent to the Oronto Group are rare in the Western Basin, common in small basins on the St. Croix Horst, and abundant in the Eastern Basin. Rocks probably equivalent to the Bayfield Group are extensive in the Western and Eastern Basins, but they have not been found on the St. Croix Horst. The Bayfield Group seems to be several km. thick across Douglas County north of the Douglas Fault, and it does not appear to increase in thickness under the Bayfield Peninsula.

1. Department of Geology and Geophysics, University of Wisconsin,
Madison Wisconsin, 53706.
2. Department of Geology, College of St. Thomas, St. Paul, Minnesota.
3. Department of Oceanography, Oregon State University, Corvallis,
Oregon, 97331.
4. Chevron Oil Company. Houston. Texas. 77027.

ORE CONTROLS AND OPEN PIT GEOLOGICAL PROCEDURES
AT STEEP ROCK IRON MINES LIMITED

DAVID C. MULDER

Steep Rock Iron Mines Limited,
Atikokan, Ontario

A B S T R A C T

The ore controls of the Middle Arm orebodies of the Steep Rock Iron Range have been well established as the result of an almost continuous programme of mapping, sampling, and development drilling from 1945 to the present time, during which period Steep Rock Iron Mines Limited has shipped a total of thirty-five million tons of ore.

The remarkably uniform stratigraphic sequence of the Steep-rock Group, which lies within a sedimentary-volcanic sequence of Archean age, has proven to be the most useful ore control, particularly with regard to projections on the smaller scale. A major fault system strikes from 020 to 065 with steep dips mainly to the east; a minor fault system strikes a fairly consistent 115 with steep dips to the north and south. Both fault systems are of post-orezone age with the majority of the vertical and horizontal offsets ranging from 15 feet to 60 feet. Cross-cutting and conformable altered basic dykes of post-orezone age often occupy planes of weakness, such as faults and stratigraphic contacts, and are erratically distributed causing considerable dilution of high grade ore to crude ore in the mining process. Silicification of the Goethite Member is quite erratic on the larger scale, and produces a type of crude ore which is difficult to beneficiate.

The above ore controls play a very important role in pit planning, both on the short and long term. Due to the complexity of the total geological picture, it is continually necessary to gather new data and reinterpret previous vertical projections. A major underground development drilling programme, which commenced in 1967 and is presently nearing completion, is establishing the position of the major geological contacts at the proposed ultimate pit elevation for pit planning purposes. Highly successful new techniques in drilling and identifying rubbly goethitic formations were developed during the early stages of this programme. The drilling results provide an invaluable control when projecting the geology on the vertical plane below the present pit bottom. Experience has provided invaluable guidelines in the form of approximate limits of projection with relation to allowable limits of error. Besides estimating reserves over the long term, the Geology Department plays a vital role in controlling the recovery of ore during the daily mining operations.

KEWEENANWAN COPPER DEPOSITS IN THE ARCHEAN OF NORTHWESTERN ONTARIO

by R. OJA

Thunder Bay, Ontario

A B S T R A C T

A number of copper showings related to breccia zones in highly metamorphosed sedimentary rocks and in granitic gneisses have been discovered north of Lake Superior but south of the volcanic-sedimentary Leitch-Geraldton-Little Long Lac gold belt in Northwestern Ontario. Geological mapping and diamond drilling has been carried out at some of the more promising prospects. The mineralization, which occurs in breccia zones up to 150 feet wide, consists primarily of pyrite and chalcopyrite with small quantities of bornite. The breccia zones are seen to accompany both large and small fault zones. The largest fault zones are thought to cut both the late Keweenawan-Logan diabase sill as well as the Keweenawan sedimentary and volcanic formations of the Sibley and Osler series.

GEOLOGY OF A GREENSTONE BELT IN MINNESOTA:
RAINY LAKE TO LAKE OF THE WOODS

Richard W. Ojakangas

University of Minnesota, Duluth
and
Minnesota Geological Survey

A B S T R A C T

A poorly exposed greenstone belt located between Rainy Lake and Lake of the Woods is currently being explored actively by drilling. Outcrops are, in general, found only within fifteen miles of the Rainy River; the clays of Glacial Lake Agassiz cover the rest of the area. A generalized geologic map has been drawn on the bases of the limited outcrops, aeromagnetic maps, and a gravity map furnished by R. Ikola. The structural trends and lithologic assemblages are similar to those in adjacent Canada (Fletcher and Irvine, 1955; Ontario Department of Mines Map 2115, 1967). Pillowed greenstones, felsic to intermediate metavolcanics, metatuffs, and metasediments are the main rocks of the belt.

Most bedding and foliation trends northeastward and dips steeply, and apparently reflects the limbs of major folds. Lineations in the metavolcanics, metatuffs, and metasediments generally plunge steeply to the southwest or northeast. Lineations in gneisses and granites have variable orientations.

Outcrops exist on three zones of pillowed greenstone. One zone south of Birchdale is apparently four miles wide and appears to lie within a northeast-trending syncline. Another zone just east of Clementson is less than a mile wide and appears to be on the southeastern flank of another northeast-trending syncline. The third zone trends east-west in the vicinity of Indus and Manitou.

Several small and large granitic plutons are present in the belt; all except a big body on Lake of the Woods contain abundant K-feldspar. The metamorphic grade of the metatuffs and metasediments is generally high; biotite and blue-green amphibole are common whereas chlorite is relatively scarce. Biotite-quartz-plagioclase schists, hornblende-quartz-plagioclase schists, and biotite-hornblende-quartz-plagioclase schists are common. Hornblende-quartz-plagioclase gneisses are prevalent in the western and southern parts of the area near the larger plutons.

The youngest rocks in the area are northwesterly trending dioritic dikes up to 400 ft. wide. Some are intermittently exposed over a total distance of 65 miles in Minnesota and Ontario. These contain plagioclase, hornblende, quartz, and opaques.

Minor gossans were observed in the field. Cores from holes drilled in the belt on state-owned land contain pyrite, pyrrhotite and minor chalcopyrite. These minerals are disseminated in the metavolcanics, metatuffs and metasediments, and are massive in thin zones of black shale. Iron formation is associated with metasediments in the southeastern part of the area.

References:

Fletcher, G. L., & Irvin, T. N., 1955, Geology of the Emo Area:
63rd Annual Report, Ontario Department of Mines, Part 5, 36 p.

Ontario Department of Mines, 1967, Kenora-Fort Frances Sheet, Geological
Compilation Series, Map 2115.

EARLY PRECAMBRIAN GEOLOGY OF THE RAINY LAKE DISTRICT

Z. E. PETERMAN

U. S. Geological Survey, Denver, Colorado 80225

S. S. GOLDICH

Northern Illinois University, DeKalb, Illinois 60115

A B S T R A C T

Geologic relations of major rock units in the Rainy Lake region have been variously interpreted since the classic studies of A. C. Lawson around the turn of the century. Although radiometric dating has not resolved the controversy over the relative ages of the Keewatin and Couthiching Series, many ages determined by different methods have provided some insight into the complex history of this region. Results of total rock Rb-Sr dating of major units in the area are summarized below:

<u>Unit</u>	<u>Isochron Age (m.y.)</u>	<u>Initial Sr^{87}/Sr^{86}</u>
Algoman Granites:		
Small stocks, Rainy Lake	2540 ± 90	0.7015 ± 0.0009
Vermilion Granite	2680 ± 95	0.7005 ± 0.0012
Keewatin Series	2595 ± 45	0.7005 ± 0.0009
Couthiching Series	2625 ± 85	0.7011 ± 0.0023

Uncertainty represents the 95% confidence level

Isochron ages for the Couthiching and Keewatin Series probably register a metamorphic event since zircons from both units as well as from the Laurentian Granite gives ages of about 2750 m.y. as reported by S. R. Hart and G. L. Davis in 1969. The age of 2680 m.y. may represent the time of emplacement of the Vermilion Granite. Mineral ages of small stocks of Algoman Granite show discordances between biotite and muscovite. Three muscovites average 2650 m.y. whereas biotite ages are as low as 2150 m.y. Loss of radiogenic strontium preferentially from the biotites may have lowered the total rock isochron. Older ages for the muscovites may approach the true time of emplacement for these granites.

STRUCTURAL AND METAMORPHIC HISTORY
OF THE MARQUETTE SYNCLINORIUM

DR. C. MCA. POWELL

University of Cincinnati

A B S T R A C T

The Menominee Group of the early Proterozoic Marquette Synclinorium is composed of three formations: the Ajibik Quartzite grades conformably upwards into the Siamo Slate which by stratigraphic transition and interdigitation passes into the overlying Negaunee Iron Formation. Structural analysis of the Siamo Slate reveals two periods of deformation. The first deformation, F_1 , was the more intense, and produced the main east-west folds, and was accompanied by development of a quasi-vertical slaty cleavage. Tabular sandstone dykes and thin pelitic foliae intruded parallel to the cleavage during deformation indicate that the cleavage formed when the sediments were only partially lithified. F_2 deformation continued after cleavage formation, and rotation of the more competent psammitic beds accompanied by plastic deformation in the interbedded pelitic layers produced refraction of cleavage. Little or no heat accompanied the F_1 deformation.

Subsequent to F_2 , the Marquette Synclinorium was affected by thermal metamorphism of regional extent. Isograds centered on a sillimanite-grade node near Republic cut obliquely across the F_1 structures. Relict diagenetic textures and structures including overgrowths on rounded quartz grains are preserved in all metamorphic facies as high as the staurolite facies near the western end of the Marquette Synclinorium. In the lower metamorphic grades, the banding produced by intrusive pelitic cleavage foliae is accentuated owing to reconstitution of the intrafolial phyllosilicates and migration of silica into the interfolial lenses. At higher grades crystallization of more randomly oriented phyllosilicates has reduced the microscopic banding, and many of the large, overgrown, detrital quartz grains have polygonized into smaller equidimensional grains. The regional metamorphism involved thermal recrystallization only, and did not produce preferred dimensional orientation of quartz.

A weak deformation, F_3 , after the climax of the thermal metamorphism produced a steeply plunging, crenulation lineation, L_2 , and a few open angular folds. Pennine chlorite was developed later in many of the rocks during widespread retrogressive metamorphism.

IS THE LIMESTONE MOUNTAIN STRUCTURE AN ASTROBLEME?

W. F. READ

Lawrence University

A B S T R A C T

Limestone Mountain is located about 10 miles WNW of Baraga, Michigan. The term "Limestone Mountain structure" is here used to include, not just the "mountain" itself, but also Sherman Hill, another Ordovician outlier about 2 miles to the northeast, and an area of disturbed Jacobsville sandstone a mile and a half south of Sherman Hill.

Exposures are limited due to abundance of glacial drift. If the structure has a center, its location is not revealed by known exposures.

Ellis Roberts (1940) and Thwaites (1943) attributed the deformation here to a major fault striking NE. Bucher put Limestone Mountain on the Tectonic Map of the United States (1944) as a possible "cryptovolcanic structure".

If the structure is considered as an astrobleme, then the Ordovician outliers presumably belong to an encircling graben or downwarp. Limestone Mountain is, in general, a syncline, but with much cross-faulting and other complexities. In Sherman Hill, the limestone (actually dolomite), though perhaps slightly synclinal, is nearly flat-lying. Joints are so numerous in both places as to give the rock a "shattered" appearance.

The disturbed Jacobsville exhibits both folding and faulting. Thin sections show grains of quartz and feldspar with microstructures similar to those found in quartz and feldspar from generally accepted astroblemes. However it cannot be said with certainty that the Jacobsville here has been "shocked". No shatter cones or breccia dikes have yet been found.

Available gravity and magnetic readings suggest structural complexity in the area but do not particularly favor either the astrobleme or the NE-trending-fault hypothesis.

ARCHAEOAN VOLCANIC STRATIGRAPHY OF THE KIRKLAND-LARDER LAKES
AREA OF NORTHEASTERN ONTARIO

R. H. RIDLER

University of Western Ontario

A B S T R A C T

The Archaeoan volcano-sedimentary complex of the Kirkland-Larder Lakes area has served as a tectonic-stratigraphic model in the Superior Province for over thirty years. Traditionally, an older, predominantly volcanic sequence, the Keewatin, is separated by a pronounced angular unconformity equivalent to the Laurentian orogenic epoch from a younger predominantly sedimentary sequence, the Timiskaming. The Timiskaming complex also includes a suite of hyperalkaline igneous rocks unique in the Superior Province (Cooke and Moorhouse, 1969; Roscoe, 1965). The accessibility, mineral wealth and geological complexity have encouraged so much geological study that the area ranks as one of the best mapped in the Superior Province (Thomson, 1948).

Recent volcano-stratigraphic studies (Ridler, 1969 - 1970), suggest a revision of the classical stratigraphy into a succession of three mafic to salic volcanic cycles (Fig. 1). The Timiskaming volcanic complex (Fig. 1) represents the salic volcanic culmination of the second cycle. Thus, the Timiskaming complex is not only preceded but also followed by volcanics traditionally classified as "Keewatin". Further, a major volcanic centre co-axial with the Lebel Syenite is recognized and correlated closely with the salic phase of the second cycle. Typical Archaeoan volcano-genic sediments associated with this centre include several facies of exhalative iron formation.

The volcanic rocks within a few miles of Kirkland Lake tend to be anomalously alkaline and sub-siliceous compared to Archaeoan calc-alkaline suites. Older, sub-alkalic tholeiites, andesites and dacites are succeeded gradually by under-saturated hyper-alkaline volcanics. Thus the uniquely alkaline volcanics of Timiskaming complex are preceded and presaged by a trend to potash enrichment. This overall increase in potash with time makes relative potash content a useful local index for correlation.

In place of the traditional concept of a pre-Timiskaming orogeny followed by peneplanation, the author suggests a history of polyphase deformation consistent with the concept of a continuously evolving volcanic mobile belt. "Granitic" cobbles in Timiskaming conglomerates record erosion of pre-Timiskaming hypabyssal plutons (Hewitt, 1963), during an early, geographically restricted, non-orogenic period of deformation. At least two periods of ductile deformation within the mobile belt followed Timiskaming sedimentation.

REFERENCES:

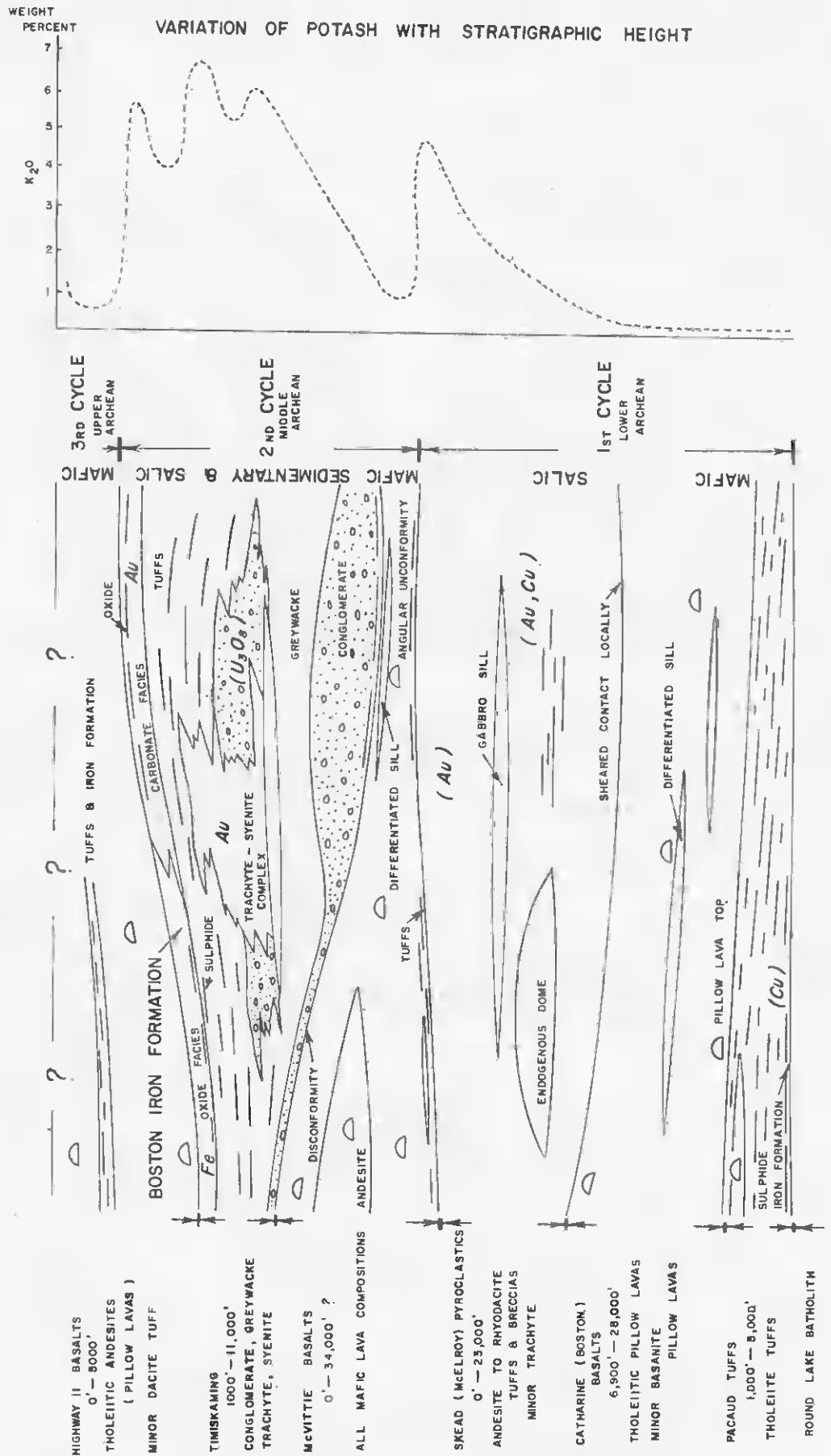
- Cooke, D. L., and Moorhouse, W. W., 1969, Timiskaming Volcanism in the Kirkland Lake Area, Ontario, Canada: Can. J. Earth Science, v. 6, no. 1, pp. 117-132.
- Hewitt, D. F., 1963, The Timiskaming Series of the Kirkland Lake Area: Canadian Mineralogist, v. 7, pt. 3, pp. 497-522.
- Ridler, R. H., 1969, The Relationship of Mineralization to Volcanic Stratigraphy in the Kirkland Lake Area, Northeastern Ontario, Canada; Unpublished Ph.D. Thesis, U. of Wisconsin, Madison, p. 141.
- Ridler, R. H., 1970, Relationship of Mineralization to Volcanic Stratigraphy in the Kirkland-Larder Lakes Area, Ontario: Proc. Geol. Assoc. Can. v. 21, pp. (not known at this time).
- Roscoe, S. M., 1965, Geochemical and Isotopic Studies, Noranda and Matagami Areas; Symposium on Strata-Bound Sulphides, Bull. Can. Inst. Min. Met. v. 58, no. 641, pp. 965-971.
- Thomson, J. E., 1948, Geology of Teck Township and Kenogami Lake Area: Ont. Dept. of Mines, Ann. Rept., v. 57, pt. 5, pp. 1-53.

LIST OF ILLUSTRATIONS:

- Fig. 1 - Idealized Stratigraphic Synthesis of the Kirkland Lake Area with folding removed.

IDEALIZED STRATIGRAPHIC SYNTHESIS OF THE KIRKLAND LAKE AREA WITH FOLDING REMOVED

R.H. RIDLER; Figure 1



A CLASSIFICATION OF GRANITIC ROCKS WITH REFERENCE TO
GIANTS RANGE BATHOLITH, NORTHERN MINNESOTA

S. VISWANATHAN

Minnesota Geological Survey, University of Minnesota
Minneapolis, Minnesota 55455

A B S T R A C T

Figure 1 shows a classification of granitic and related rocks favoured by many field geologists. The inadequacy of this scheme and some of its flaws became apparent while investigating granitic rocks from the western part of the Giants Range batholith (Algoman) in Northern Minnesota. For example, rocks which plotted in the adamellite field were found to lack the characteristics of an adamellite: their plagioclases were albite rather than oligoclase, and their muscovite content was as high as 10 percent instead of being insignificant. A revised classification proposed in this paper, shown in Figure 2, differs substantially from the other one, and mainly as follows:

(1) The adamellite field is compressed, and the upper limit of its quartz content fixed at 30 percent as against 50 percent. This change is made because adamellites that plot below the 30 percent quartz level (Group 1 adamellites) and those that plot above the 30 percent quartz level (Group 2 adamellites) show the following important petrographic differences:

- (a) muscovite is rare in Group 1 adamellites but may be present in amounts as high as 10 percent in Group 2 adamellites,
- (b) plagioclase in Group 1 adamellites generally is more calcic than that in Group 2 adamellites, and
- (c) non-opaque calcic trace minerals (sphene, epidote, apatite) in Group 1 adamellites total more than 1 percent, whereas Group 2 adamellites generally have a substantially lower content of these trace minerals.

(2) The granite field is extended not only laterally to include the Group 2 adamellites, but also vertically upto the 60 percent quartz level.

(3) The upper limit of 30 percent quartz fixed for the adamellite field is extended towards the Plagioclase-Quartz join and the Alkali feldspar-quartz join; thereby, the granodiorite, tonalite and granite fields of the classification shown in Figure 1 have been sub-divided into the granodiorite (<30 percent quartz)-quartz granodiorite (>30 percent quartz), tonalite (<30 percent quartz)-quartz tonalite (>30 percent quartz) and the syenogranite (<30 percent quartz)-granite (>30 percent quartz) fields.

Although one cannot assert that feldspar types reveal the tectonic grouping of granites, a correlation between the two seems to exist. In the nomenclature of granites, therefore, it is desirable to indicate the feldspar type as well as colour, texture, alteration, and accessory minerals. One could thus have modified root names like "microcline-calcic oligoclase-granite", "microcline-albite-granite", "orthoclase-microcline-calcic oligoclase-granite", etc. In general terms, these three modified root names are correlatable with synkinematic, late-kinematic, and post-kinematic granites, respectively.

An application of the revised classification combined with field observations has enabled me to recognize twelve distinctive major rock units in the western part of the Giants Range batholith where only two principal units were distinguished previously. Its applicability to adjacent areas of the Lake Superior region, and elsewhere, needs to be tested.

Figure 1

Classification of granitic and related rocks favoured by many field geologists; it is based on the modes of quartz, K-feldspar and plagioclase recalculated to 100 percent.

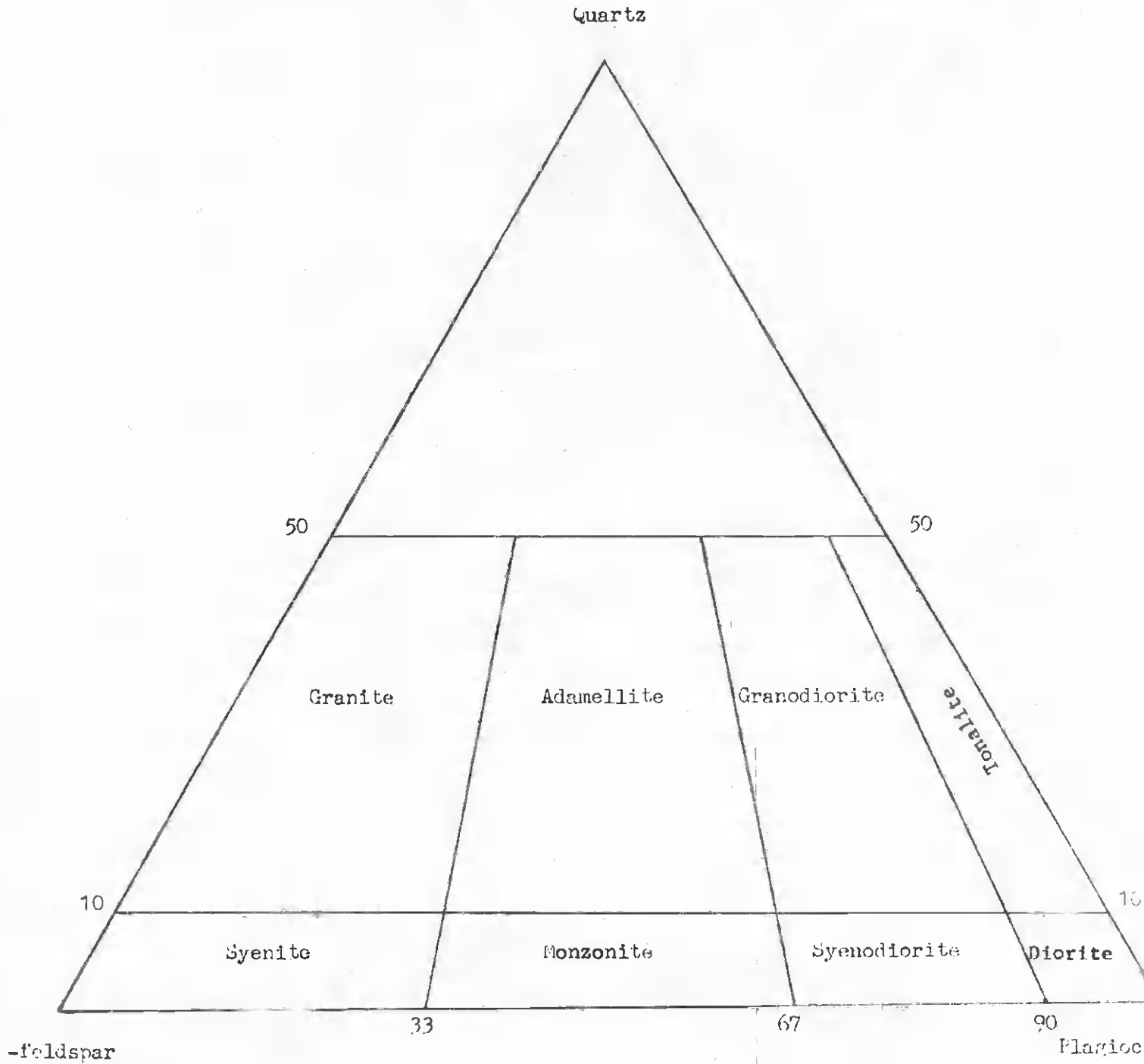
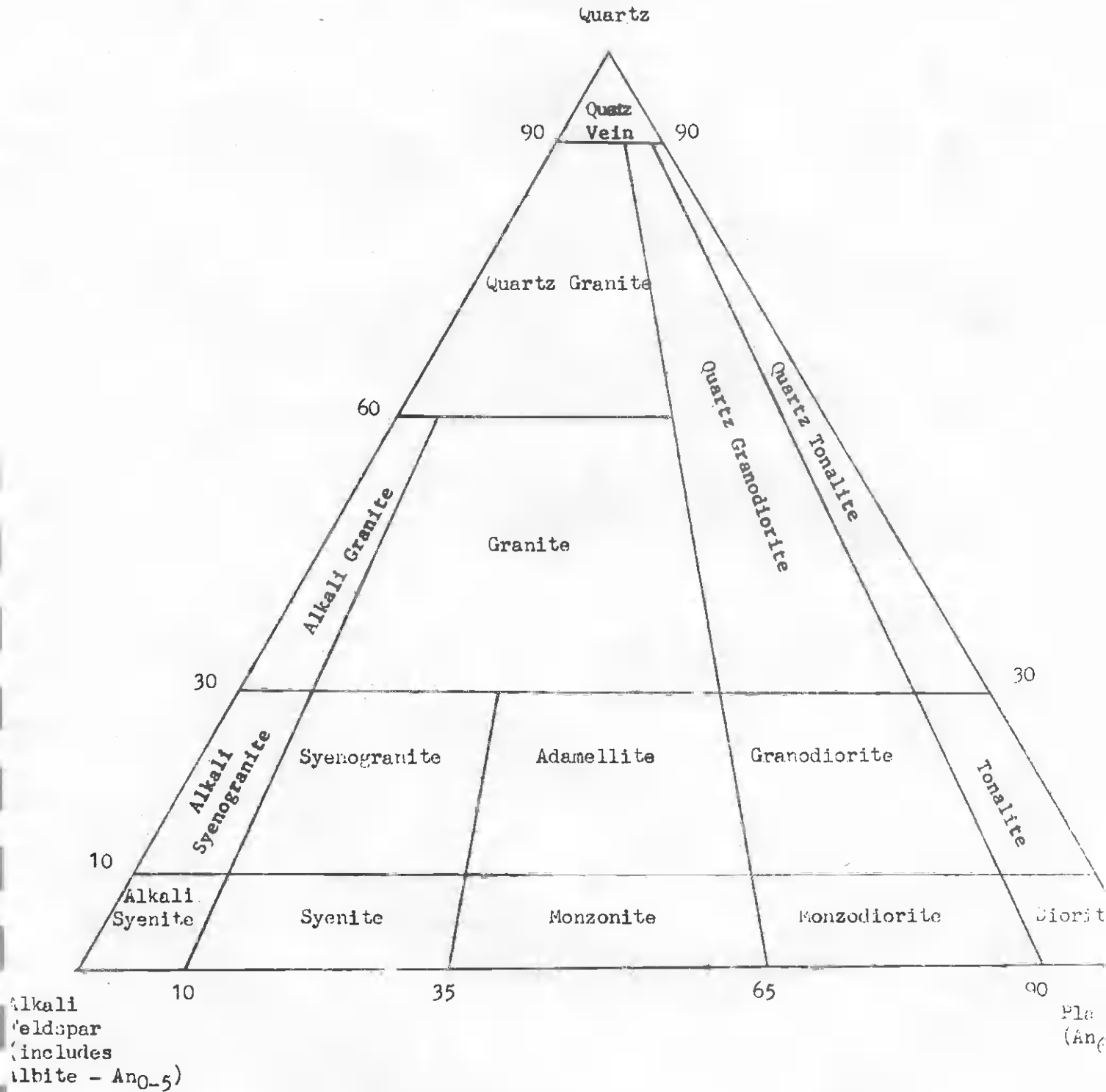


Figure 2

The revised classification; it is based on the modes of alkali feldspar, plagioclase and quartz recalculated to 100 percent.



GEOLOGY OF THE ALKALIC ROCK - CARBONATITE
COMPLEX AT PRAIRIE LAKE, ONTARIO

DAVID H. WATKINSON

Department of Geology
University of Toronto

ABSTRACT

The Prairie Lake complex of ijolitic rocks and carbonatite (age: 1112 million years) is intrusive into granitic gneisses 25 miles northwest of Marathon, Ontario. The complex has positive relief, is somewhat circular in plan, and is composed of concentric arrangements of carbonatites and rocks of the pyroxenite - melteigite - ijolite - urtite series. The latter series has two culminations: nepheline-rich rocks characterized by melanite, wollastonite and alkali feldspar with interstitial calcite and nepheline -feldspar intergrowths; and pyroxene-rich rocks characterized by magnetite and biotite. Pyroxenitic rocks are often separated from carbonatite by micaceous zones. The carbonatites are strongly banded with near-vertical dips; banding is a consequence of biotite and olivine + magnetite concentrations. Most carbonatites are calcite-rich, but some are dolomitic and breccias with groundmass dolomite intrude the calcitic rocks. Pyrochlore is common in the carbonatites and in calcite-rich interstices and lenses in pyroxenites. In some zones pyrochlore contains as much as 30 weight % U_3O_8 . Some fenitized country-rock occurs at the contact with carbonatite. The complex is interpreted to have formed by intrusions of magmas generated by strong differentiation of a carbonated, nephelinitic parent.

EVIDENCE FOR A TROPICAL CLIMATE AND OXYGENIC ATMOSPHERE
IN UPPER HURONIAN ROCKS OF THE RAWHIDE LAKE - FLACK LAKE
AREA, ONTARIO

JOHN WOOD
Department of Geology
University of Western Ontario

ABSTRACT

The upper Huronian of the Rawhide Lake-Flack Lake Area Ontario is comprised of four formations - the Gowganda, Lorrain, Gordon Lake and Bar River, in ascending stratigraphic order.

The Gowganda Formation consists of orthoconglomerates (with clasts up to 2 metres in diameter), paraconglomerates, graded greywackes, finely banded siltstones, finely banded arkoses (with dropped stones), and massive arkoses.

The Lorrain Formation can be divided into three parts. Rocks in the lower part, although variable in grain size and colour, are all arkosic. Feldspar (both sodic and potassic) is fresh near the base, but towards the top becomes progressively more weathered until only pseudomorphs are visible. Diaspore, kaolinite, and pyrophyllite are present at the top of the lower unit and at the base of the middle unit. Concentrations of heavy minerals including hematite and U/Th minerals are associated with these aluminous minerals. The middle Lorrain is a sequence of interbedded kaolinitic quartzites and quartz jasper pebble conglomerates, while the upper Lorrain is essentially an orthoquartzite sequence. Feldspar is not present in the middle or upper parts of the Lorrain Formation.

In contrast rocks of the Gordon Lake Formation are quite feldspathic and much finer grained. Vari-coloured quartzo-feldspathic siltstones and shales with intraformational breccias are the dominant rock types. Chert is present near the bottom and top of the formation while gypsum and anhydrite are concentrated in the lower parts. Authigenic hematite and hematite oolites occur in the middle and upper parts of the formation. Ripple marks and shrinkage cracks are present throughout.

The Bar River Formation consists essentially of cross-bedded ortho-quartzites (often cemented by hematite), with some interbedded siltstones. The latter who contain shrinkage cracks are ripple marked, and include many small scale sedimentary intrusions.

Most geologists who have studied sediments of the Gowganda Formation have concluded that these rocks were deposited during a frigid climatic regime. Accepting their conclusions and using feldspars as indicators of climatic conditions, there would appear to have been a rapid amelioration of climate while sediments of the lower Lorrain Formation were being deposited. Diaspore and kaolinite are considered to be the products of 'in situ' feldspar alteration under tropical climatic conditions. The presence of kaolinite and pyrophyllite in drill-core samples from -3,500 feet rule out a late surface weathering origin for these minerals. This change from frigid to tropical conditions is represented in a stratigraphic thickness of 160 metres. These tropical conditions persisted while sediments

of the middle and upper Lorrain Formation were being laid down.

The clastic hematite beds in the Lorrain Formation, the hematite oolites in the Gordon Lake Formation and the hematite cement in the Bar River orthoquartzites, together with the presence of sulphates in the Gordon Lake Formation, are indicative of an oxidising atmosphere in upper Huronian times. This conclusion is important in relation to uranium exploration.

The chert, anhydrite, gypsum, and hematite as well as demonstrating conditions of chemical sedimentation provide more evidence for proposed correlations of upper Huronian rocks with those of the Animikie Series = Marquette Range Supergroup of Michigan. Postulation of a tropical climatic regime during deposition of part of the upper Huronian sequence removes one of the previous barriers to this correlation, for previously only frigid climatic regimes have been documented in the Huronian, while the ferruginous sediments of Michigan were considered to have been deposited under tropical or sub-tropical conditions (James et al.).

REFERENCES

- Frarey, M. J., 1966. Discussion: Huronian stratigraphy of the McGregor Bay area, Ontario: Relevance to the paleogeography of the Lake Superior region, by Grant M. Young. Can. J. Earth Sci. 3, 997.
- James, H. L., Clark, L. D., Lamey, C. A., and Pettijohn, F. J. 1961. Geology of central Dickinson County, Michigan, U.S. Geol. Surv. Profess. Papers, 310.

WIDESPREAD OCCURRENCE OF ALUMINOUS MINERALS IN APHEBIAN QUARTZITES

GRANT M. YOUNG

Department of Geology
University of Western Ontario

ABSTRACT

After the conclusion of the world-wide Kenoran thermo-tectonic events (ca. 2.5 b.y. ago) there was development of the first extensively preserved stable shelf assemblages of the geological record. Rocks of this type were first studied in Canada in the region north of Lake Huron by Murray (1849) and Logan and Sterry Hunt (1855). The Huronian succession includes several polymictic conglomerates which have been interpreted as glacial deposits. The youngest of these conglomerates (Gowganda Formation) is thick and extensive and has recently been considered correlative with other early Proterozoic (Aphebian) tillites in a large area extending from S.E. Wyoming to the Keewatin District of the N.W.T. (Young, in press).

The upper stratified unit of the Gowganda Formation is overlain by a thick (5-6,000 ft.) quartzite formation (Lorrain) that is also very extensive. Many different subdivisions of this unit have been proposed, but on a regional scale, a threefold subdivision seems most reasonable. The lowest subdivision is a varicoloured (red, white and green) succession of feldspathic grits and sandstones. This is followed by a unit characterised by the presence of quartz and jasper pebble conglomerates and the uppermost unit is an extremely pure orthoquartzite. In many areas the middle unit and the lower part of the upper unit contain aluminous minerals such as kaolinite, diaspore, pyrophyllite, kyanite and andalusite (Church, 1967; Chandler et al., 1969). These minerals are thought to represent an in situ weathering (bauxitization) process which occurred shortly after deposition and gave rise to kaolinite which was later changed by further diagenesis and metamorphism to the other minerals listed above. The reasons for invoking this mode of origin rather than origin by deposition of "primary" kaolinite at the time of sedimentation or by late post depositional weathering are as follows: -

1. Fresh feldspars are abundant in other Huronian outcrops.
2. The kaolinite commonly occurs as "clots" of the same order of size as the associated quartz grains, suggesting that each clot represents an altered feldspar grain.
3. It is difficult to envisage the conditions under which fine kaolinitic crystals could be sedimented together with coarse quartz grains (see Ojakangas, 1965, for discussion of the same problem in Jatulian quartzites of Finland).
4. In some sections metamorphic minerals may be seen developing from kaolinite.

Aluminous minerals similar to those of the Lorrain Formation occur in quartzites in the lower part of the Animikie "Series" = Marquette Range Supergroup (Church and Young, in press) of the south shore of Lake Superior (Keyes Lake quartzite, Sturgeon quartzite, Ajibik quartzite and Breakwater quartzite). Kaolinite is also present in the Baraboo and Barron quartzites of Wisconsin and pyrophyllite and diaspore were reported from the Sioux quartzite of Minnesota and South Dakota (Berg, 1937). Kyanite is present in the Medicine Peak Quartzite of S.E. Wyoming, the Petaca Schist of New Mexico and kaolinite, andalusite and diaspore have been found in the Hurwitz C quartzites of the Keewatin District of N.W.T. Bimodal size distribution in many of these quartzites may indicate that much of the clastic material was wind transported prior to sedimentation in an aqueous medium (Folk, 1968).

Similar aluminous quartzites of similar age from other continents include those of Finland (Jatulian quartzites), Brazil (Jacobina Series), India (Iron Ore Series) and South Africa (Witwatersrand System). Some of these extremely widespread quartzites may be deposits formed as a result of post-glacial transgression. If the formation of kaolinite in the quartzites took place under climatic conditions similar to those under which present day bauxites and laterites are formed, there must have been a significant amelioration of climate following deposition of the Gowganda Formation and its possible correlatives.

REFERENCES

- Berg, E. L. 1937. An occurrence of diaspore in quartzite. *Amer. Mineralogist*. v. 22, pp. 997-999.
- Church, W. R. 1967. The occurrence of kyanite, andalusite and kaolinite in Lower Proterozoic (Huronian) rocks of Ontario (abst.) *Tech. Prog. Geol. Assoc. Can. Meet. Kingston, Ontario*, pp. 14-15.
- Church, W. R. and Young, G. M. (in press). Discussion of the Progress report of the Federal-Provincial Committee on Huronian stratigraphy. *Can. J. Earth Sc.* v. 7.
- Folk, R. L. 1968. Bimodal supermature sandstones: product of the desert floor. *XXIII International Geological Congress Section 8; Genesis and Classification of Sedimentary Rocks*. pp. 9-32.
- Logan, W. E. and Sterry Hunt, T. 1855. *Esquisse geologique du Canada*. H. Bossange et fils, Paris. 100 pp.
- Murray, Alexander. 1849. On the north coast of Lake Huron. *Geol. Surv. Canada, Rept. Prog.* pp. 93-124.
- Ojakangas, R. W. 1965. Petrography and sedimentation of the Precambrian Jatulian quartzites of Finland. *Bull. Comm. Geol. Finlande*. No. 214, 74 pp.
- Young, G. M. (in press). An extensive Early Proterozoic glaciation in North America? *Palaeogeog. Palaeoclimat. Palaeoecol.*

PROTEROZOIC ROCKS IN THE THUNDER BAY AREA

May 9, 1970

Prepared by

J. M. Franklin, Lakehead University, Thunder Bay

C. R. Kustra, Ontario Department of Mines, Thunder Bay



10 μ

- 1 (a): Microfossils in Gunflint chert from shore of Lake Superior near Schreiber, Ontario; spheroids are Huroniospora, filaments are Gunflintia.



- 1 (b): Side view of a weathered block of Sibley stromatolites; note polygonal columns of Conophyton.

Guide to the Proterozoic Rocks of the Northwestern Lake Superior Area, Ontario

INTRODUCTION:

The Proterozoic rocks of Northwestern Ontario, which form part of the "Animikie" and "Keweenawan" units, represent one of the most complete geological records of middle and late Proterozoic sedimentation and igneous activity in eastern North America. These rocks are virtually unmetamorphosed and only slightly deformed.

Mineral deposits in these Proterozoic rocks include silver in Keweenawan dykes and the Rove Formation, iron in the Gunflint Formation, nickel in mafic intrusive rocks, copper in various volcanic and sedimentary strata, and lead-zinc-barite associated with the Sibley Group. During the last century, the famous Silver Islet mine produced over three million dollars in silver. Currently, a minor amount of silver is recovered from the Creswel mine near Stanley (Fig. 1).

GENERAL GEOLOGY

The Proterozoic rocks lie unconformably on the peneplained Archean surface. Archean meta volcanic and meta sedimentary rocks form a "belt" extending from west of Shebandowan to Thunder Bay city. Another similar belt crops out in the Schreiber-Big Duck Lake area (Pye, 1964). To the north, the Geraldton-Beardmore belt may be traced westward by aeromagnetic interpretation under Lake Nipigon, and may possibly join with the Lac Des Mille Lacs-Atikokan belts. The remainder of Archean outcrop is composed of intrusive and metamorphic granitic rocks, and small ultramafic bodies.

The Proterozoic rocks are subdivided as shown in Table 1.

- TABLE 1 -

Proterozoic Stratigraphy of Northwestern Ontario

Neohelikian

Osler Group: basalt, minor rhyolite and sedimentary rocks

Intrusive rocks: gabbro plugs
undersaturated plugs
layered bodies
northeast trending dykes
Logan diabase sills

Paleohelikian

Sibley Group: red beds, stromatolite zone

Aphebian

Animikie Group

Rove Formation: shale

Gunflint Formation: iron formation

APHEBIAN

The Gunflint Formation (Figs. 1*, 3, 4, 5) has been studied in detail by Goodwin (1956) and Moorhouse (1960), the Rove Formation by Morey (1967). Much of the descriptive detail is taken from these authors.

Gunflint Formation (adapted from Goodwin, 1956)

Deposition of the Gunflint Formation was in part cyclical. A basal conglomerate member is overlain by two members each composed of chert, tuffaceous shale, and carbonate-taconite submembers. These members are in turn overlain by a discontinuous limestone member, (Fig. 2 and Table 2). The Gunflint Formation was deposited 1635±24 million years ago (Faure and Kovach, 1969).

-TABLE 2-

Stratigraphy of the Gunflint Formation (modified from Goodwin 1956)

Limestone-dolomite member

Upper Member

Taconite-chert carbonate submember; taconite (west) facies
chert carbonate (east) facies

Tuffaceous shale submember

Algal chert submember

Lower Member

Taconite-chert carbonate submember; west taconite facies
chert carbonate facies
east taconite facies

Tuffaceous shale submember

Algal chert submember

Kakabeka conglomerate member

(a) Basal Kakabeka Conglomerate Member

This member ranges to five feet in thickness and is composed of polymictic conglomerate. Clasts of Archean volcanic rocks and granite are cemented in a matrix of chlorite and quartz. The unit is discontinuous but persistent.

(b) Lower Member

The lower algal chert submember (Fig. 2) consists of reef-like mounds of finely banded black, red, and white oolite chert. These mounds are intergrown or cemented in dolomite. This submember forms the western margin of Gunflint outcrop (Fig. 1), but is continuous only to the west of Kakabeka Falls. It contains abundant microflora remains (Baarghorn and Tyler, 1965) (Plate 1a).

The lower tuffaceous shale submember ranges to 20 feet thick and overlies the lower algal chert in the area west of Kakabeka Falls is composed of fissile black shale containing much volcanic ash.

* see back cover

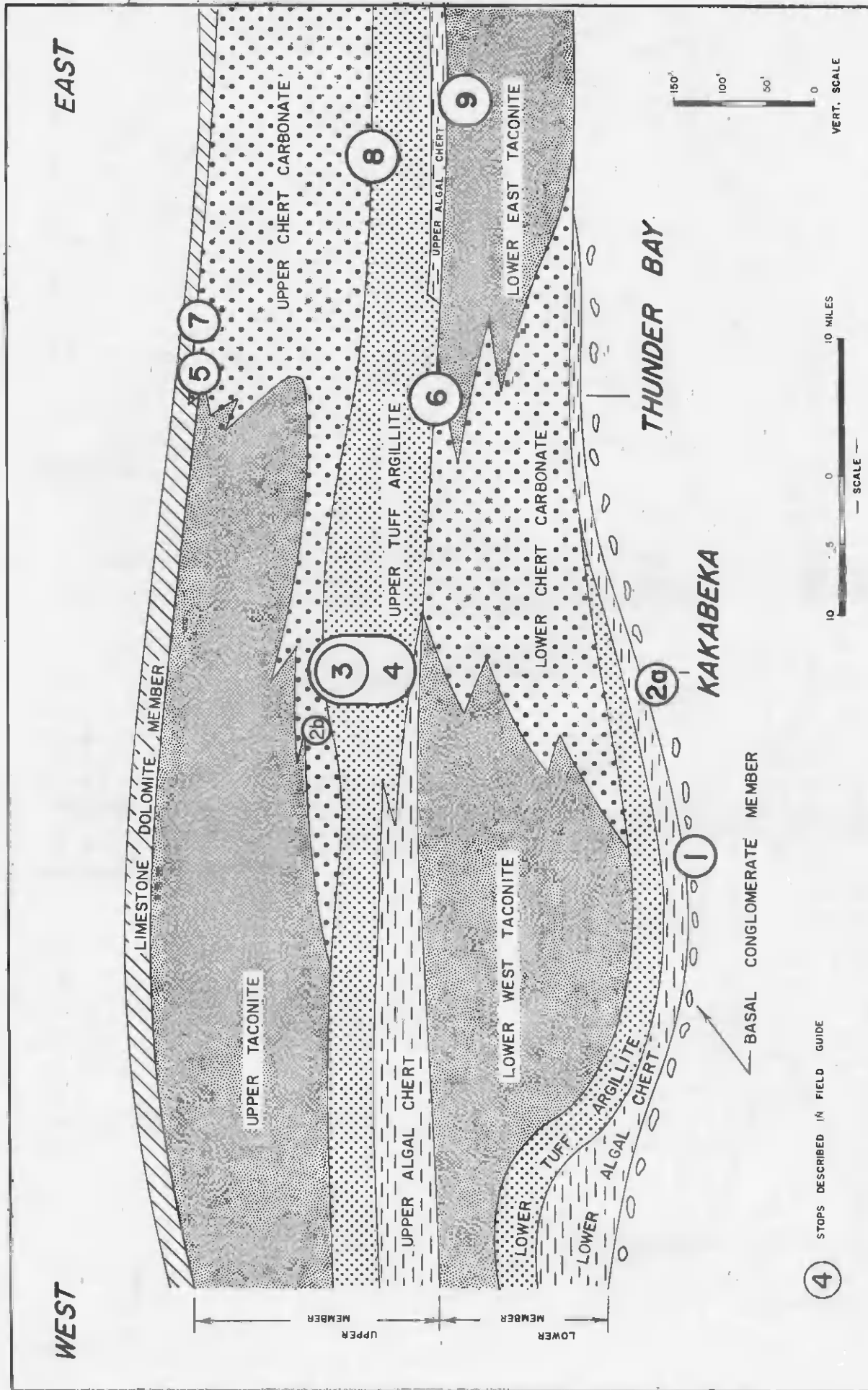


Fig. 2 Longitudinal section of the Gunflint formation (after Goodwin, 1956).

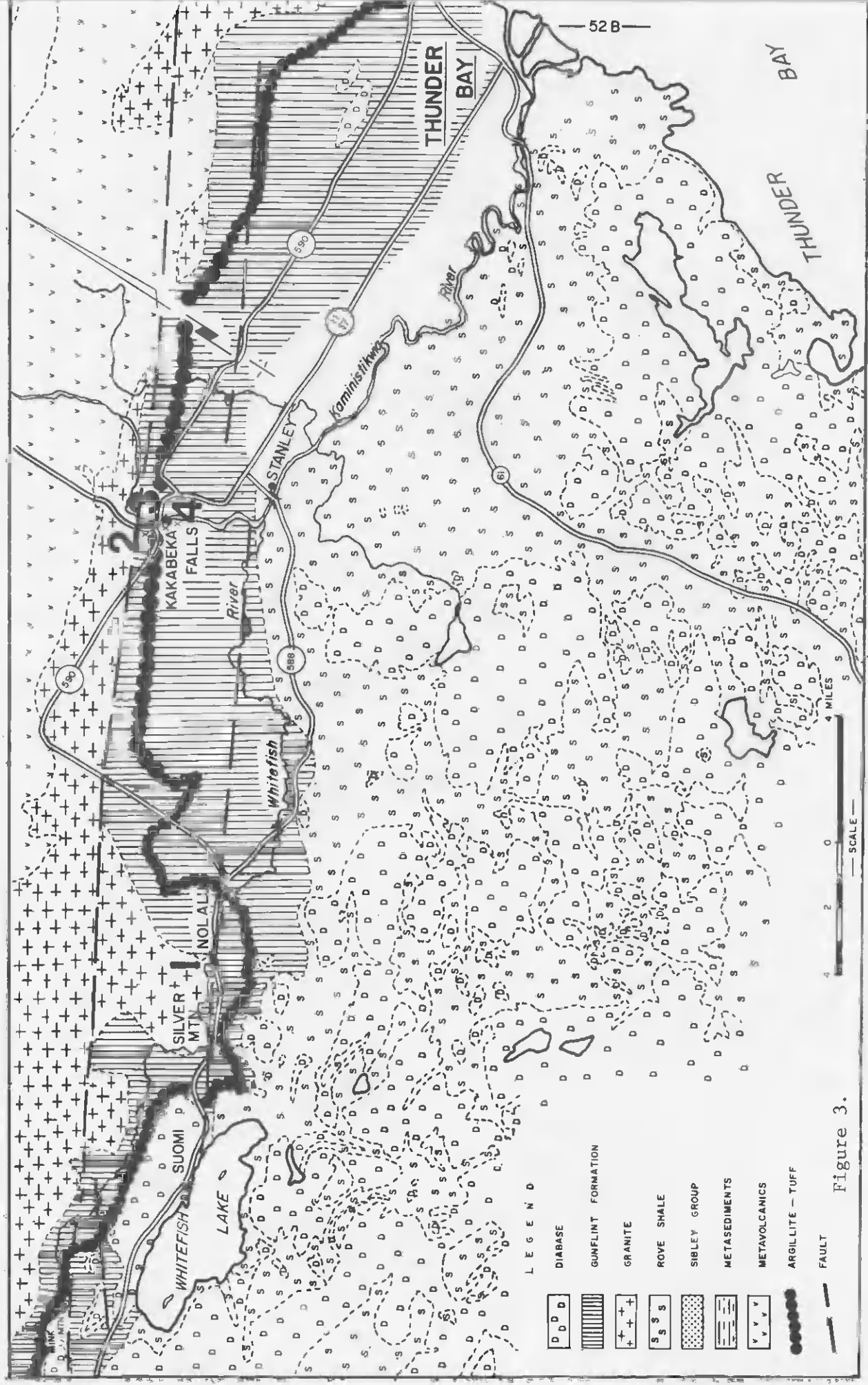


Figure 3.

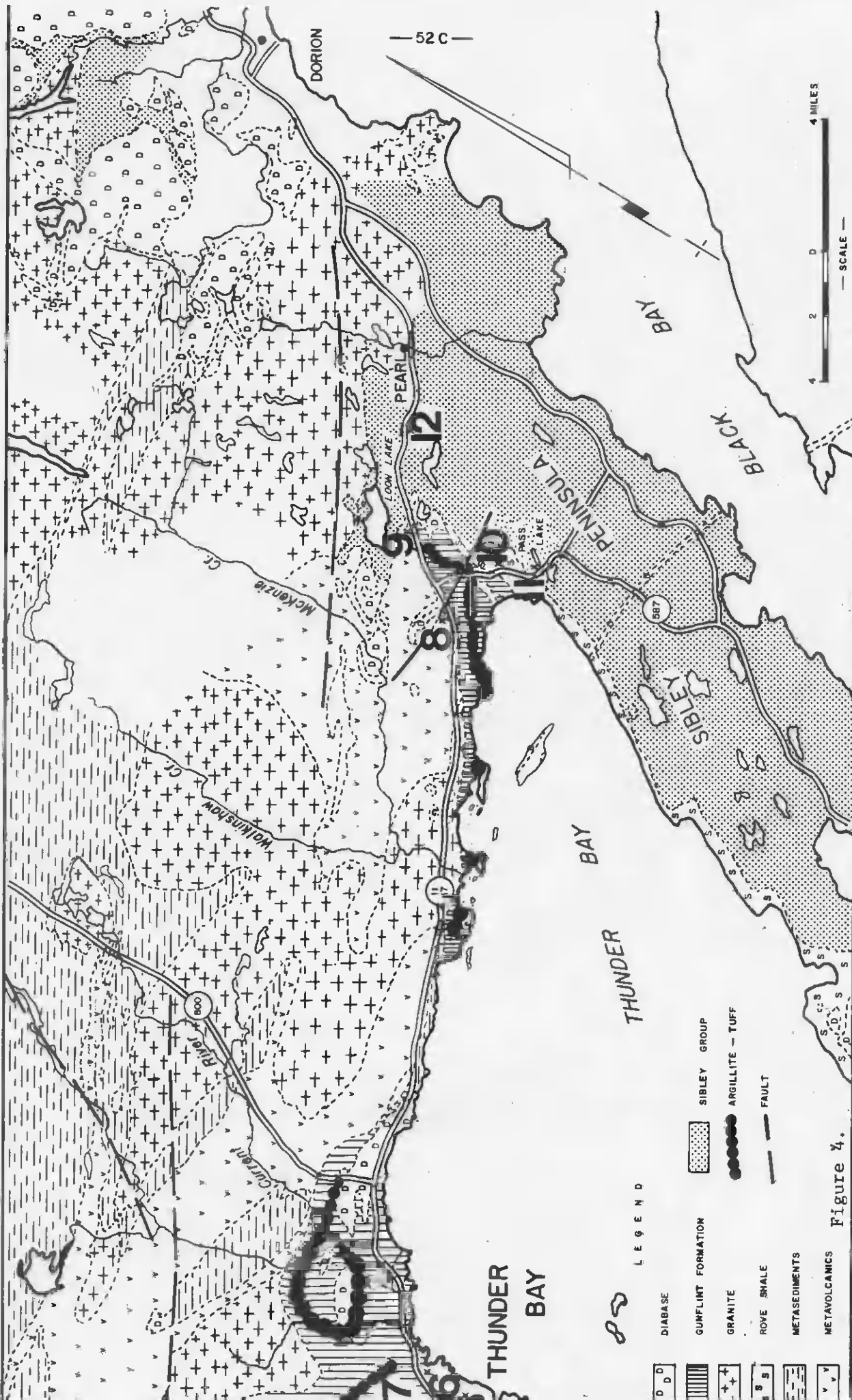


Figure 4.

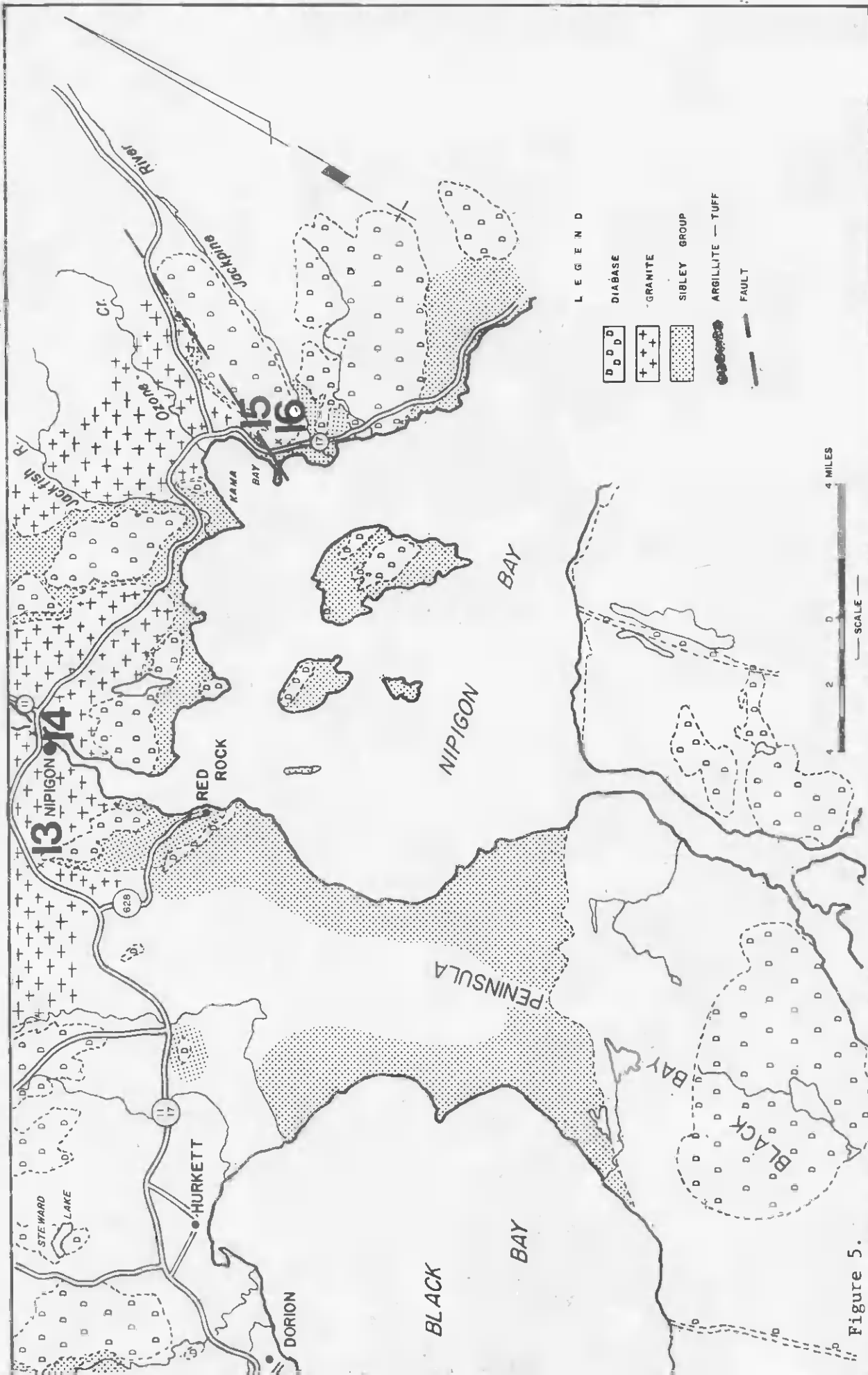


Figure 5.

The uppermost submember of the lower member is subdivided into three facies (Fig. 2). The lower west taconite facies, which is 150 feet thick, extends northeastward from Gunflint Lake to Kakabeka Falls, is composed of wavy-banded granular chert, carbonate, and oxides. The lower half contains disseminated greenalite granules in pale grey chert; siderite forms local beds. The upper half contains increasing amounts of hematite and magnetite. This facies grades upward into jaspilitic upper algal chert and grades laterally into the lower banded chert-carbonate facies.

The lower banded chert-carbonate facies extends from Kakabeka Falls to Thunder Bay city, and consists of 4 to 6 inch siderite beds, with interbedded 2 to 6 inch grey cherty beds. Carbonaceous material and pyrite are common in shale interbeds. This facies grades into granular taconite towards the northeast.

The lower east granular taconite facies extends from Thunder Bay city to Loon Lake. The basal 2 to 6 feet are formed of interbedded granular chert and ankerite. The upper 10 to 20 feet consist of interbedded red to green mottled chert and dolomitic limestone. This facies grades upward into the tuffaceous shale submember of the upper member.

(c) Upper Member

The upper algal chert submember extends west from Nolalu to Gunflint Lake and consists of basal granular chert overlain by algal chert and, in the Mink Mountain area, amygdular basalt flows. The flow and algal chert are overlain in turn by granular chert and bedded jasper. Jasper beds grade into tuffaceous shale of the overlying submember.

The upper tuffaceous shale is the only continuous submember in the Gunflint Formation and forms a key stratigraphic marker (Figs. 3, 4). It ranges to 100 feet thick and thins laterally in either direction from Kakabeka Falls. It consists of black tuffaceous shale and siltstone with interbedded siderite and pyrite and extensive beds of volcanic ash. The ash contains ellipsoidal structures which resemble mudballs and are composed of concentric layers of small angular tuff fragments, arranged about a larger central fragment.

The upper tuffaceous shale submember grades into the upper taconite and banded chert-carbonate submember. The upper taconite facies extends from Gunflint Lake to the City of Thunder Bay (Fig. 2), and is composed of wavy bands of granular greenalite-bearing chert. The greenalite-bearing granules are round to oval, evenly distributed throughout a layer, and appear to have formed "in situ". The unit exhibits a rusty weathering, contains abundant hematite and magnetite in granules towards the top, and grades laterally (Fig. 2) into the upper banded chert-carbonate facies which extends from west of Thunder Bay city to Loon Lake. The latter facies consists of interbedded grey chert and brown carbonate. The carbonate consists of siderite with lesser dolomite and ankerite. Brecciation and folding, apparently contemporaneous with deposition, are common.

(d) Upper Limestone Member

The upper limestone member marks the top of the Gunflint Formation. Minor chert beds, illite and volcanic shards are present, and tuffaceous shale is most prevalent in the eastern area of Gunflint outcrop.

Stratigraphic Interpretation

Goodwin (1956) concluded that Gunflint deposition occurred in a shallow basin which had limited circulation with an open sea. After initial algal activity in the neritic zone, volcanic activity (tuff-argillite) was accompanied by sinking of the basin. Silicate-bearing material (taconite) was deposited in the deepest portions while in the neritic, or intertidal zone (between Kakabeka Falls and Thunder Bay city) banded chert-carbonate formed. Further to the northeast, the lower east taconite facies formed in agitated, oxygenated, waters. As the basin filled, conditions of algal growth returned, initiating the "Upper Gunflint" cycle.

Volcanic activity, marked by local basalt flows and crustal unrest, terminated the upper algal chert deposition and resulted in widespread distribution of pyroclastics of the upper tuffaceous shale. Downwarping resulted in deposition of granular iron silicate rocks in the deeper, southwest portion of the basin, while on the shallow northeast shore, chert carbonate was deposited. As the basin filled, sporadic but violent volcanic activity was accompanied by entry of sea water, resulting in formation of the upper limestone member. Basinal sinking set the stage for deposition of the Rove shale.

Goodwin (1956), in drawing an analogy with the Santorin volcano of the Aegean Sea, suggests that volcanism was the chief source of iron and silica. Alternatively, Hough (1958) suggests deposition in a fresh water basin, with material derived through weathering of adjacent landmass, and deposition controlled by limnic cycles. Clearly, re-evaluation of both ideas is necessary in light of recent data on both Santorin (Butozova, 1966) and bottom sedimentation studies in Lake Superior, (Mothersill, 1969).

Rove Formation

The Rove Formation conformably overlies the Gunflint Formation and consists of up to 3200 feet of argillite and sandstone (Morey, 1967). Morey subdivides the Rove into three lithologic units, which are, in ascending order: (1) lower argillite, (2) transition sequence, and (3) thin-bedded greywacke. The lower argillite is the dominantly exposed unit in Ontario and consists of grey to black highly fissile, thin-bedded, pyritic shale, with minor limestone and sandstone beds. Calcite and dolomite concretions are common near the base of this unit.

The transition sequence consists of interbedded argillite and sandstone. The topmost thin-bedded greywacke, consisting of grey to pink greywacke and sandstone, is the thickest unit of the Rove, and is exposed predominantly in northern Minnesota.

Morey notes that sediment transport was from the north and that material was derived from Archean granite, gneiss and greenstone.

PALEOHELIKIAN

Sibley Group

The Sibley Group is a red bed sequence, deposited 1298 ± 33 million years ago (Rb-Sr whole rock isochron, Franklin, 1970) extending from the Sibley Peninsula north to Armstrong, Ontario, and east to Rossport.

The seven units which compose the Sibley Group are:

- (a) basal conglomerate
- (b) sandstone
- (c) sandy red mudstone
- (d) chert-stromatolite
- (e) limey red mudstone
- (f) purple mudstone
- (g) limestone

Polymictic basal conglomerate lentils are most common on the western margin of Sibley outcrop. Locally derived Gunflint taconite boulders are found where the Sibley overlies the Gunflint, but granitic boulders prevail where the Sibley overlies Archean rock. Lentils range to 15 feet in thickness, and occur in pre-Sibley valleys.

Cream, green, and pink sandstone forms the lowest semicontinuous unit of the Sibley Group, and attains a thickness in the basin margins of over 200 feet. Beds are poorly graded; ripple marks and cross beds are present throughout, but are common only in the eastern margin of sedimentation near Rossport. Beds are composed of 50 to 70 per cent quartz, up to 8 per cent chert, 5 per cent feldspar, and 5 per cent mica, cemented with calcite and minor barite. Syneresis cracks are common near Edward Island. At the top of the unit, interbedded sandstone and mudstone mark the beginning of the sandy red mudstone unit.

The sandy red mudstone unit is composed of less than 50 per cent quartz and feldspar clasts, in a red hematite-carbonate-clay-feldspar matrix, and ranges to 300 feet thick near Rossport. Bedding is moderately well developed. Brecciation and soft-sediment folding are common in this unit; chaotic conglomerate lentils are exposed in the western margin of outcrop near Dorion.

In the area south and east of Nipigon, the sandy red mudstone is separated from the limey red mudstone by a thin, but laterally continuous, chert unit. To the north and west of Nipigon a stromatolite unit may occupy the same position. The stromatolites exposed

¹ using 1.47×10^{-11} yr.⁻¹ Rb⁸⁷ decay constant; using 1.39×10^{-11} yr.⁻¹ constant, age is 1376 ± 33 m.y. The latter may be compared with the date of Faure and Kovach (1969).

at Disraeli Lake and near Stewart Lake belong to the group *Conophyton* (Hoffman, 1969), formed of vuggy columnar "cone in cone" structures (Plate 1b). The chert facies ranges to 10 feet in thickness at Rossport, and is composed of finely laminated grey to black chert and brown dolomite. Anthraxolite accumulations are common along the base of this unit.

The overlying limey red mudstone contains less than 20 per cent coarse microcline with less than 2 per cent hematite. The clay expands in ethylene glycol, and is a mixed layer chlorite-montmorillonite, similar to corrensite (Peterson, 1961). The feldspar is very fine-grained (less than 10 μ diameter) and is probably authigenic.

The overlying purple mudstone unit is finely laminated, moderately but irregularly fissile, and is composed of approximately 40 per cent each of corrensite and microcline, with less than 4 per cent hematite, less than 15 per cent quartz, and minor calcite. Less than 10 per cent coarse clastic material is present in most of this unit.

The uppermost limestone unit is grey to buff, poorly bedded, and crops out only north and west of Nipigon.

The Sibley Group is distributed over both the edge of an older mobile belt (the Penokean orogenic deformation of Aphebian rocks) and the stable Archean craton. Deposition occurred in a basin restricted on the south and west by uplifted Aphebian rocks. A shallow, periodically dry, basin transgressed northward over the craton. Material was derived from both the Aphebian highlands and adjacent Archean granitic rocks in a semi-arid, warm environment, (Franklin, 1970).

NEOHELIKIAN

Osler Group

Volcanic and sedimentary rocks of the Osler Group disconformably overlie the Sibley Group and are exposed on an arcuate belt of islands parallel to the shore of Lake Superior, and on Black Bay Peninsula (Ont. Dept. Mines Map 2137). The lavas are similar to those of the Portage Lake Lava Supergroup (DuBois, 1962) and are composed of thin, laterally extensive sheets of vesicular, tholeiitic flood basalt with minor interflow greywacke beds, & rhyolite (quartz porphyry) bodies.

Intrusive Rocks

The four types of intrusive rocks present in this area are as follows:

(a) Logan sills: laterally extensive thin diabase sheets, cutting Archean, Aphebian, and Paleohelikian rocks

(b) northeast-trending gabbro dykes, parallel to the shore of Lake Superior, extending from Pigeon Point to Edward Island

(c) layered mafic bodies, as at Great Lakes Nickel Company property in Pardee Township

(d) dykes and associated stocks cutting all Helikian and Aphebian rocks.

The Coldwell syenite complex near Marathon is an undersaturated laccolith, similar in age to the other Helikian intrusive rocks (Fairbairn et al, 1959).

STRUCTURE

Structural deformation is limited to block faulting and regional tilting, imposed during and after Keweenawan intrusive and volcanic periods. Two parallel major fracture or fault zones bound the block of Aphebian and Paleohelikian rocks exposed in the northwestern Lake Superior region. The most northerly of these is a steeply dipping fracture zone, five miles in width extending from west of Whitefish Lake to east of Pass Lake. Dragfolding of sediments along faults suggests slight uplift of the southern side. The northern boundary is marked by a fracture zone which is occupied by the northeast-trending dyke set. The block between these faults has been slightly tilted, resulting in a 3 to 5 degree dip of the sediments to the south-east.

ACKNOWLEDGEMENT

The authors wish to acknowledge the assistance of S. Spivak, who compiled and drafted the figures.

SELECTED REFERENCES

- | | |
|--|--|
| Baarghorn, D.S. & Tyler, S.A., 1965; | Micro-organisms from the Gunflint chert: Science, v. 147, p.563-577. |
| Butuzova, G.Y., 1966; | Iron ore sediments of the fumarole field of Santorin volcano, their composition and origin: (Zhelezorudngye osadki fumarol'ngo polya vulkana Santorin, ikh sostav i genezis): Doklady Akad. Nauk., S.S.S.R., v.168, no.6, p.1400-1402. |
| DuBois, P.M., 1962; | Paleomagnetism and correlation of Keweenawan rocks: Geol. Survey, Canada, Bull. 71. |
| Fairbairn, H.W., Bullwinkel, H.J., Pinson, W.H., & Hurley, P.M., 1959; | Age investigation of syenites from Coldwell, Ontario: Proc. Geol. Assoc. Can., v.11, p.141-144. |

SELECTED REFERENCES

- Faure, G. & Kovach
J., 1969; The age of the Gunflint Iron Formation
of the Animikie Series in Ontario,
Canada. Ohio State University Laboratory
for Isotope Geology and Geochemistry
Contribution no. 8.
- Franklin, J. M., 1970; Metallogeny of the Proterozoic rocks of
Thunder Bay District, Ontario, Ph.D.,
thesis, Unpublished., University of
Western Ontario, London, Ontario.
- Goodwin, A.M., 1956; Facies relations in the Gunflint Iron
Formation: Econ. Geol., v.51, no.6,
p.505-595.
- Hoffman, H.J., 1969; Stromatolites from the Proterozoic
Animikie, and Sibley Groups, Ontario:
Geol. Survey, Canada, paper 68-69,
p.1-77.
- Hough, J.L., 1958; Fresh-water environment of deposition
of Precambrian banded iron formations:
Jour. Sed. Pet., v.28, no. 4, p.414-430.
- Moorehouse, W. W., 1960; Gunflint Iron Range in the vicinity of
Port Arthur: Ont. Dept. Mines, v.LXIX,
pt.7, p.1-40.
- Morey, G.B., 1967; Stratigraphy and sedimentology of the
Middle Precambrian Rove formation in
northeastern Minnesota. Jour. Sed. Pet.,
v.37, p.1159-1162.
- Mothersill, J. S., 1969; A grain size analysis of longshore-
bars and troughs, Lake Superior, Ont.,
Jour. Sed. Pet., v.39 no.4, p.1317-1324.
- Peterson, N.M.A., 1961; Expandable chloritic clay minerals from
upper Mississippian carbonate rocks of
the Cumberland plateau, in Tenn.: Am.
Mineralogist, v.46, p.1745-1764.
- Pye, E. G., 1964; Mineral deposits of the Big Duck Lake
area; Ont. Dept. Mines, Geol. Rept.
no. 27.

DESCRIPTION OF STOPS

Mileage count begins west of Nolalu, a small community on Highway 590, approximately 35 miles southwest of Lakehead University, and may be reached via Highways 17-11, 588 and 590.

Mileage

- 0.0 1.8 miles west of Nolalu. The exposure is located in the bed of the Whitefish River, on the north side, approximately 200 feet downstream from the bridge.

STOP 1 LOWER GUNFLINT MEMBER, LOWER ALGAL CHERT SUBMEMBER OVERLYING BASAL CONGLOMERATE AND ARCHEAN BASEMENT (FIG. 2)

Lower algal chert in the shape of concretionary, cauliflower-like growths, forms an irregular, hummocky surface. It is underlain by a thin veneer of basal (Kakabeka) conglomerate, resting unconformably upon metamorphosed, little weathered Archean granodiorite.

The chert forms thinly banded, white, red and black algal structures resembling piles of inverted thimbles; red, white and brown chert-hematite oolitic granules are dispersed within the structures. Fossil microflora occur in the darker, almost black, variety of chert.

Note several exposures of algal chert mounds in the area between the road and the river bank.

- 1.9 Co-op store, Nolalu.
- 2.4 Junction, Highways 588 and 590. Turn north on Highway 590.
- 17.9 Junction, Highways 590 and 17-11. Outcrop is the road cut 300 feet north of junction, west side of Highway 17-11.

STOP 2a BASAL KAKABEKA CONGLOMERATE, LOWER ALGAL CHERT SUBMEMBER (FIG. 2).

Basal conglomerate, grading upward into reddish, lower algal chert and granular chert, consists of pebbles of white quartz, chert and jasper set in a matrix of sandy quartz grains and minor carbonate (calcite). Near the north end of the outcrop, the Gunflint Formation is in fault contact with Archean granitic gneiss.

STOP 2b Road cut, west side of Highway 590, 250 feet south of junction and 500 feet south of stop 2a.

UPPER CHERT-CARBONATE FACIES (FIG. 2).

Orange-brown weathered, banded chert-carbonate is interbedded with tuffaceous shale.

- 18.3 Entrance to Kakabeka Falls Park. Proceed over old bridge to parking lot by Greenmantle restaurant, thence by foot to falls rim.

STOP 3 UPPER TUFFACEOUS SHALE SUBMEMBER (FIG. 2)

Kakabeka Falls drop 128 feet into a gorge formed in fissile, thinly bedded upper tuffaceous shale submember (Goodwin, 1956).

A more resistant, massive two-foot bed of thinly banded chert-carbonate caps the escarpment.

- 18.7 Access road to Ontario Hydro station. Turn right just before the Kakabeka Falls motel. Proceed to the parking lot by the station, thence by foot to the west side of the plant, via a cat-walk over the penstock pipes. Follow the riverbank for approximately 600 feet to the spillway cut. Beware of poison ivy.

Be advised that permission to trespass the Hydro property must be obtained from the plant supervisor. The spillway serves as a safety valve to bleed-off excess water in the event of generator failure at the power station.

STOP 4 UPPER TUFFACEOUS SHALE SUBMEMBER (FIG. 2)

The best section of upper tuffaceous shale submember is exposed at this locality. Pyrite-bearing chert of the upper algal chert submember occurs at the base of the section; it is overlain by shale containing pyrite nodules and calcareous concretions, interbedded shale and tuff and a cap of thinly bedded upper chert-carbonate.

One of the best exposures of "mud ball tuff" in the shale occurs near the bottom of the section; the tuff is formed of closely packed ellipsoidal structures, elongated along the bedding. Individual ellipsoids contain small, angular fragments of uniform size, grouped concentrically around a larger shard fragment. The remainder of the material comprising the beds consists of fragments of lava in a groundmass of a green, clay material. (Goodwin, 1956)

Note downwarping of beds on the west side of the exposure and the fault filled with quartz-carbonate and anthraxolite.

Return to Highway 17-11 and proceed east.

- 19.2 Junction Highways 17-11 and 590 north. Proceed on Highway 590 north.
- 29.0 Thunder Bay city limit. Good view of the mesa topography of the Nor'westers.
- 30.1 Junction, Highways 590 and 130. Highway 590 ends.
- 37.0 Lakehead University.
- 38.0 Intersection, High St. and Oliver Road (Highway 130)
Turn left at the traffic lights and proceed up High Street.
- 38.6 Entrance to Hillcrest Park.

STOP 5 UPPER LIMESTONE MEMBER (FIG. 2)

Hillcrest Park. The park stands about 160 feet above the level of Lake Superior and offers a panoramic view of Thunder Bay harbour, the Sleeping Giant, the Welcome Islands, Pie Island and the Nor'westers.

Dolomitic limestone and chert layers are exposed at the base of the flag pole and bell.

Follow stairs to base of hill where the fragmental limestone of Goodwin's upper limestone member is exposed. The rock consists of many angular to rounded chert fragments in a matrix of coarsely crystalline, iron-bearing carbonate, and thin chert interbeds. Traces of volcanic shards and fragments occur in the limestone (Goodwin, 1956).

Proceed north on High Street.

- 40.1 Intersection with Balsam St. Turn left on Balsam Street.
- 40.7 Huron St., 300 feet south of Highway 17-11. Turn right on Huron St., then immediate left.

- 42.1 Bridge over Current River, cross bridge, turn right into Boulevard Lake Park and proceed 0.3 miles; park on right side of road. Traverse begins on creek bed.

STOP 6 LOWER CHERT-CARBONATE FACIES (FIG. 2)

The lower chert-carbonate facies is overlain by the upper tuffaceous shale submember. An upstream traverse encounters ferruginous carbonate, interrupted by thin layers and lenses of granular and algal chert, and dark, fissile shale. At the beginning of the traverse, note the rounded chert lenses showing concretionary structures, attributed to action of algae. Please refrain from sampling some of the better preserved structures.

Features to observe include stylolite surfaces lined with anthraxolite, pyrite veinlets, imbrication of thin chert layers and the striking, weathered appearance of the rock.

Under the bridge, a bed of gray, massive limestone, enclosing pancake-like lenses of serpentine material, and interrupted by a thin band of pyrite-bearing chert, is overlain by upper tuffaceous shale. Note the hummocky upper surface of the limestone at the shale-limestone interface.

Several hundred feet north of the bridge, at the lookout, a diabase sheet caps the shale. East of the bridge, in the picnic area, several well developed river terraces are preserved.

From bridge, proceed east along Arundel Street.

- 43.1 Intersection, Arundel St. and Hodder Ave. Turn left on Hodder Ave. at Hodder Avenue Hotel.
- 44.1 Highway 17-11. Turn right.
- 44.7 Scenic lookout. View of Thunder Bay harbour. Park car and walk 500 feet east to roadcut on north side of road. Exercise extreme caution.

STOP 7 UPPER LIMESTONE MEMBER OVERLAIN BY DIABASE

Sill of Logan diabase overlies argillite and fragmental limestone of the upper limestone member. The contact is gently undulating and visible effects of contact metamorphism are little evident. In thin section, however, a microporphyroblastic texture is developed in the argillite. Pyrite is altered to pyrrhotite.

Note the lenticular chert patches within the limestone, some veined with pyrrhotite, exhibiting agate textures.

- 46.1 Highway 800. Turn right.
- 47.5 Highway 17-11 (Nipigon Highway). Turn left.
- 66.1 Blende Creek. The outcrop is situated 200 feet northwest of the highway and is accessible by a dirt road located approximately 0.7 miles southwest of the intersection of Highway 17-11 with Highway 587.

STOP 8 UPPER CHERT-CARBONATE FACIES (FIG. 2)

Regularly bedded upper chert-carbonate is interbedded with thin, fissile tuffaceous shale and underlain by cross-bedded to massive greywacke.

The severe drag folding of the chert-carbonate beds on the northwest side of the outcrop is a manifestation of a regional fault system.

Note that chert layers are brecciated and cemented by carbonate. A vertical fracture at the east end of the outcrop is filled with fragments of chert carbonate cemented by calcite.

- 66.8 Highway 587.
- 68.8 First roadcut beyond West Loon road, on northwest side of highway.

STOP 9 EAST TACONITE FACIES, LOWER MEMBER (FIG. 2)

The exposure shows wavy-banded, hematitic greenalite taconite, locally folded and brecciated. A thin band of algal structures at the top of the section is correlated with the upper algal chert facies southwest of Thunder Bay.

- 0.0 Intersection of Highways 17-11 and 587. Proceed southeast on Highway 587.
- 2.3 Quarry on west side of Highway 587. Park on top of hill and walk back.

STOP 10 ROVE FORMATION

Rove shale is black, carbonaceous, and forms part of the lower argillite unit (Morey, 1967); it contains several large, irregular "mushroom" shaped concretions. The concretions are composed of calcite with pyrite-marcasite bands and anthraxolite, and appear to have formed diagenetically. Remnant shale bedding planes are evident in some concretions. Shale beds are warped around the top and bottom of some concretions. Concretions are found throughout the lower argillite, and more commonly, have a distinct oblate spheroid shape.

Proceed southeast on Highway 587.

- 4.1 A large area of outcrop extends along the north side of the C.N.R. railway tracks and Highway 587 where they parallel Pass Lake.

STOP 11a SIBLEY GROUP - ROVE FORMATION

At the western end of this outcrop, a sandstone quarry provides an excellent exposure of Sibley sandstone. In the railway cut at the western edge of the quarry, Rove shale is altered to a reddish colour. This alteration affected the Rove for several feet below its contact with the Sibley Group. Basal conglomerate is absent at this point but is exposed to the east behind the small railroad house along the siding opposite the Pass Lake station.

Clasts in the basal polymictic conglomerate are composed of 93 per cent Gunflint iron formation, 6 per cent quartz and 1 per cent granite. Boulders are of variable size and angularity, and are cemented in a sandy matrix. The contact with overlying sandstone is sharp; only a few pebbles are found in the base of the overlying unit. The sandstone is moderately to poorly indurated, thick bedded at the bottom of the section, and composed of quartz, with minor chert and feldspar, in a calcite matrix.

- STOP 11b At the west end of Pass Lake, a quarry, which may be reached by a short road leading from Highway 587 just east of the entrance to Sibley Provincial Park, has an excellent exposure of the contact between Rove shale and Sibley sandstone. The contact is occupied by a thin porphyritic diabase sheet. Sandstone beds have a few poorly developed cross laminations and ripple marks. Very little basal conglomerate is present in this outcrop.

Return to Highway 587 and follow it back to Highway 11-17.

0.0 From the intersection of Highways 587 and 11-17, proceed east toward Dorion and Nipigon.

3.3 East Loon Road

5.2 Outcrop on southeast of road.

STOP 12 SIBLEY GROUP, BRECCIATED RED MUDSTONE

This outcrop of highly brecciated conglomeratic red mudstone probably forms either the lower part of the limey red mudstone or upper part of the sandy red mudstone. Balls of red mudstone and fragments of angular chert, sandstone and mudstone are cemented in red mudstone of similar composition, suggesting an intraclastic conglomerate. Possibly periodic, rapid flooding off adjacent Archean highlands caused chaotic re-distribution of partially consolidated muds. Such conglomerates are common along the western margin of Sibley outcrop and are generally lenticular in shape. On the eastern margin of Sibley outcrop brecciation is less chaotic.

Continue east on Highway 17-11.

14.3 Note outcrops of brecciated red mudstone.

38.4 Historical marker, west side of Highway 17-11 near Beaver Valley tent and trailer park.

STOP 13a RED ROCK CUESTA

This stop provides a panoramic view of the Red Rock cuesta. Diabase forms a cap on the "red rock" of Sibley mudstone. The colour is due to less than 2 per cent hematite which coats clay, feldspar and carbonate grains.

Proceed to the next major road-cut.

38.6 Road-cut.

STOP 13b DIABASE SILL CUTTING ARCHEAN ROCKS AND SIBLEY GROUP

At the north end of the road-cut, a diabase dyke leaves Archean rocks, cuts across the Sibley section and becomes a Logan sill. On the top of the road-cut a small selvage of Sibley mudstone may be seen. The chilled margin at the base of this sill in the road cut gave a K-Ar age of 1000 ± 140 million years (Franklin, 1970). Fractures in this sill are

filled with pectolite and calcite. An almost complete Sibley section is evident along this hill. Above the limey red mudstone, a white weathering unit which forms a steep cliff beneath the diabase, is composed of purple mudstone overlain by limestone. Unfortunately, access to these units is difficult.

Proceed east along Highway 11-17 to the town of Nipigon.

43.1 Nipigon lookout and historical marker.

STOP 14 CUESTAS

This lookout provides a panoramic view of the Nipigon-Red Rock area. Diabase capped cuestras form high flat topped hills in the area. Islands in the distance are composed of Osler basalt.

0.0 From lookout, continue east on Highway 17-11 to the 17-11 intersection; continue on Highway 17.

6.9 Small outcrops of interbedded white sandstone and red sandy mudstone are exposed in road cuts near Fire Hill.

14.0 A thick sheet of columnar-jointed diabase caps the Sibley Group at Kama Bay.

14.5 First lookout, Kama Hill.

STOP 15 SANDY RED MUDSTONE, SIBLEY GROUP

A broad anticline of sandy red mudstone is exposed in the prominent road cut to the north of this lookout. Soft-sediment deformation probably produced this structure. Three thin diabase sheets follow bedding planes; the sills pinch out, and locally cut across bedding at a high angle.

Proceed southeast along the highway towards the second lookout. Kama Hill may be cut by a northeast-trending fault system. Movement has resulted in uplifting of the west side. Thus the sandy red mudstone north of the first lookout, although low in the stratigraphic section, is slightly higher in elevation than those beds described in the next stop. This fault cuts the hill between the "anticline" and the first lookout.

15.3 Second (southern) lookout.

STOP 16 In the roadcut to the north of the second lookout, the following features may be observed:

- (1) Two thin Keweenawan diabase sills, partially replaced by carbonate, cut across the poorly developed bedding plane at a low angle.
- (2) Finely laminated chert of the chert-stromatolite unit cuts out below the lower sill. Up to six inches of anthraxolitic carbonate has accumulated at the base of the chert. An oily smell may be detected when this anthraxolite is freshly broken.
- (3) Limey red mudstone above this unit is marked by many cream-coloured spots, (average diameter $\frac{1}{2}$ inch). Similar spots are evident throughout this unit, and commonly have a small amount of graphite or hydrocarbon at the center. In thin section, the only apparent mineralogical change in the spots is the lack of hematite coating on clay and carbonate grains.
- (4) Irregular, flame-shaped, bleached zones follow fractures and bedding plane cleavage in the red limey mudstone. Leaching of hematite, and destruction of clay minerals and feldspar has occurred along the fractures.
- (5) Above the road cut and overlying talus slope, the purple mudstone crops out. It is more highly fissile, and contains approximately 4 per cent hematite, which coats very fine grained corrensite and microcline, and forms blades of specularite in tiny vugs. Bleaching along fractures is common in this rock.

End of Trip

For anyone interested in a more complete view of the Sibley Group, two additional areas should be visited.

(1) From Rossport, a boat trip to Quarry Channel and Wilson Islands, which lie one to two miles off shore, will allow the visitor to see an almost complete section of Sibley rocks. On Quarry Island, Rove shale is overlain by a thick section of Sibley sandstone. Here, crossbeds and ripple marks are abundant.

On Channel Island, the upper part of the sandstone unit, sandy red mudstone units are all exposed. The latter is disconformably overlain by Osler volcanic rocks.

(2) The stromatolites near Disraeli Lake may be reached by following the Armstrong road north from Hurkett for 21.6 miles, to the Disraeli Lake road, which connects the Armstrong road with the Spruce River road

(Hwy. 800). Follow the Disraeli Lake road west for 22.2 miles past Shillabeer and Seagull creeks to the Disraeli campground road. Proceed for $\frac{3}{4}$ of a mile beyond this, to the first bush road leading north. Follow this road for two miles. Blocks of stromatolite are strewn along side the road for some distance. Stromatolite blocks are common throughout the Disraeli area, and may be found in outcrop and float along most of the bush roads.

THE BEARDMORE-GERALDTON BELT

May 6 and 9, 1970

Prepared by

W. O. Mackasey, Ontario Department of Mines, Toronto

Published by permission of the Chief Geologist,
Ontario Department of Mines

Guide to Sturgeon River Metavolcanic-Metasedimentary Formations in the Beardmore-Geraldton area

INTRODUCTION

This field trip is a one-day excursion to illustrate the stratigraphy and structure of an Early Precambrian metavolcanic-metasedimentary sequence in the Beardmore-Geraldton area (Fig. 1), 120 miles northeast of Thunder Bay. Late Precambrian sedimentary rocks and diabase sheets will also be examined. The area is part of an east-trending metavolcanic-metasedimentary belt that is at least 60 miles long and is bounded by younger granitic batholiths except on the west where it is covered by Lake Nipigon and by Late Precambrian diabase sheets.

The Mineral potential of the region has been studied since the turn of the century; the first memoir of the Geological Survey of Canada described the geology and mineral deposits of the "Nipigon Basin" (Wilson, 1910). Iron was the magnet which attracted most of the early prospectors, but the discovery of gold in 1925 near the present town of Beardmore established the area as a major gold camp. Many gold mines were in operation in the late 1930's, but several of the smaller ones closed down with the entry of the United States into the Second World War. Major producers were the Leitch, Little Long Lac, Hard Rock Consolidated Mosher and MacLeod-Cockshut Mines. Macleod-Mosher Gold Mines Limited is the only mine still operating in the area. Interest in iron, pyrite and base metal sulphide deposits is continuing.

The pulp and paper industry has played a major role in the economy of the area in recent years, while tourism and commercial fishing are also important industries.

Many of the Stops for the field trip were suggested by Dr. E. G. Pye. Discussions with Dr. L. D. Ayres, and his review of the paper are greatly appreciated. Mr. S. Spivak, Lakehead University, drafted the figures.

GENERAL GEOLOGY

Regional Setting

The metavolcanic-metasedimentary sequence is part of the Early Precambrian Superior Province of the Canadian Shield and occurs along the boundary between two major east-trending, lithologic and structural units of the Superior Province. These are the northern Keewatin belt composed predominantly of metavolcanic and granitic rocks (Goodwin, 1966) and a metasedimentary-granitic complex, termed

the Quetico belt by Stockwell (1964). The relationship between these two belts has been considered in recent papers by Goodwin (1968), Kalliokoski (1968) and Ayres (1969, 1970). Goodwin and Kalliokoski postulate that the Keewatin belt is older than the Quetico belt while Ayres suggested that Quetico rocks are overlain by those of the Keewatin belt.

Early Precambrian Metavolcanic and Metasedimentary Rocks

1. Lithologies:

A - Metasediments

Metasedimentary rocks form two distinct lithologic groups: a thick sequence of relatively uniform greywacke, siltstone, and argillite that is predominantly within the Quetico belt; and a thinner sequence more variable and coarser-grained of conglomerate, greywacke, argillite and iron formation that is interlayered with metavolcanic formations of the Keewatin belt. The finer-grained metasediments within the Quetico belt and the southern part of the Keewatin belt have been tentatively correlated with the Couchiching formation by many authors (Horwood and Pye, 1955; Macdonald, 1942; Pye, 1952). The coarser grained metasediments within the Keewatin belt form part of the Windigokan series of Tanton (1921).

B - Metavolcanics

The metavolcanic rocks in the southern part of the area are predominantly mafic to intermediate, massive, pillowed and amygdaloidal flows. In the northwestern part of the belt, however, intermediate to felsic volcanic breccias and flows are abundant.

2. Stratigraphic Relationships:

Reconstruction of the stratigraphy is difficult because of paucity of good exposure along contacts, deformation by folding and faulting, and interfingering of the various units.

In the southern part of the area the finer-grained relatively uniform metasediments (Couchiching) are overlain in most cases by the coarser-grained lithologically heterogeneous metasediments (Windigokan). Both of these units thin northward and interfinger the metavolcanic sequence.

The finer-grained metasedimentary unit contains a thin but laterally extensive mafic metavolcanic unit that defines the boundary between the Quetico and Keewatin belts. Metasediments above and below this metavolcanic unit are lithologically similar (Peach, 1951; Mackasey, 1970). Metasediments above the metavolcanic unit are part of Pye's (1952) group B defined in the eastern part of the

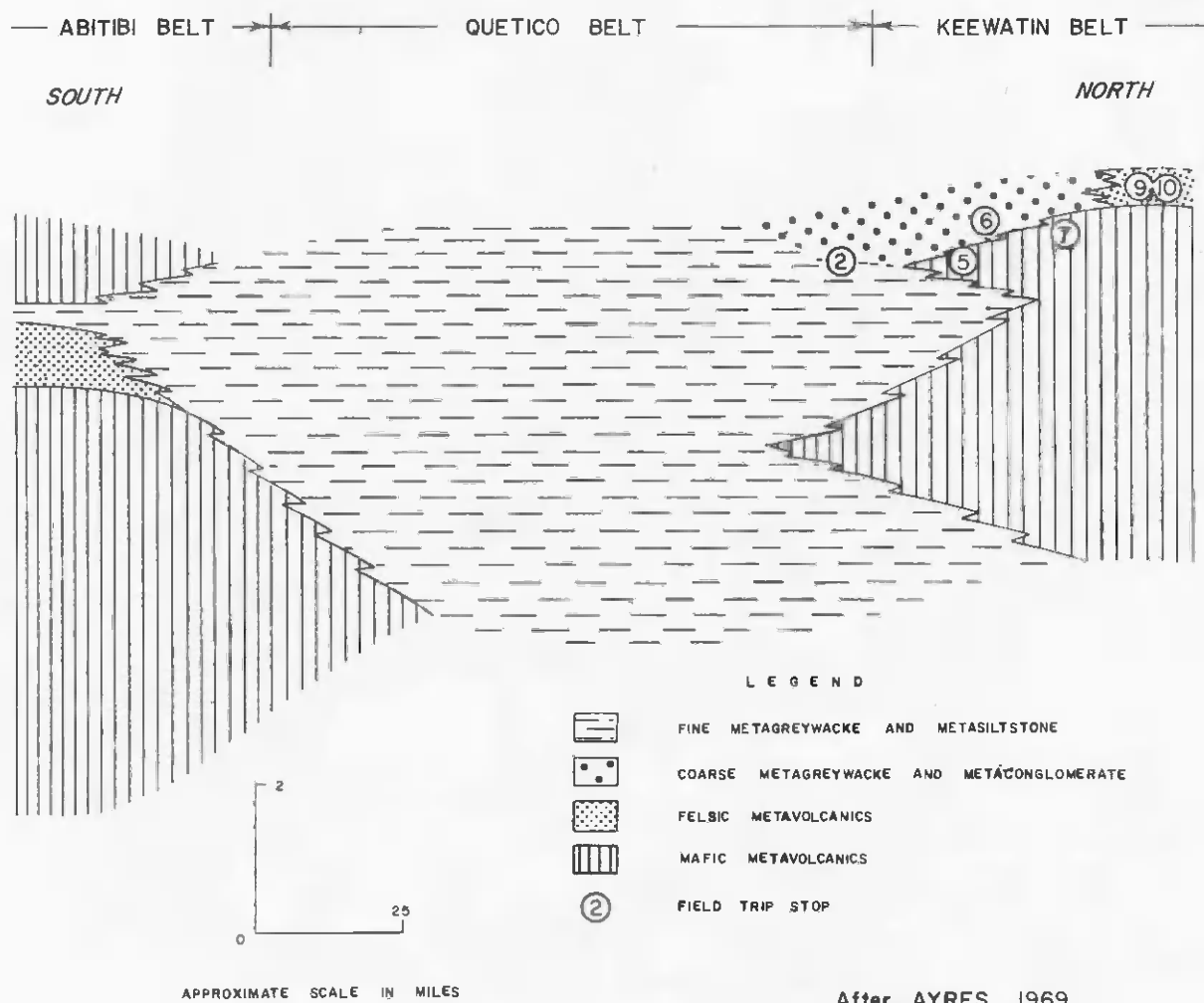


Figure 2. Diagrammatic cross-section showing relationship between Abitibi, Quetico, and Keewatin belts. Section through Abitibi belt approximately corresponds to Jackfish-Middleton area (Walker, 1967); section through Keewatin belt approximately corresponds to Little Long Lac area (Pye, 1952).

belt.

Near Geraldton the finer-grained metasediments (Pye's group B) are disconformably overlain by conglomerate (Pye, 1952) which is the lowermost unit of the upper metasedimentary sequence (Windigokan or group A). The same general lithological changes have been observed in the Beardmore area (Mackasey, 1969) but disconformable relationships have not been recognized.

A mafic to intermediate volcanic unit overlies the upper (Windigokan) metasediments in the Beardmore area.

3. Origin:

The metasediments in the Beardmore-Geraldton belt thin and become coarser grained to the north. The metavolcanic rocks on the other hand, are thickest in the northern part of the belt and thin southward (Bruce, 1937; Macdonald 1942, 1943).

Ayres (1969) suggested that the metavolcanic rocks of the Beardmore-Geraldton area were part of an east-trending metavolcanic arc that is now represented by the Keewatin belt. This arc developed in an older sedimentary basin within which metasediments of the Quetico belt were deposited. Volcanism commenced with subaqueous extrusion of mafic to intermediate flows that built up submarine shield volcanoes. The flows interfinger southward with the metasediments of the basin. Later felsic pyroclastic volcanism built subaqueous to subaerial cones on top of the older mafic shield volcanoes. The change in sedimentation from relatively uniform fine-grained sand and silt to more heterogeneous, coarser grained gravel, sand, and silt corresponds to the initiation of major felsic volcanism and the emergence of the volcanoes above sea level. (Ayres, 1969).

The coarser-grained metasediments of the upper metasedimentary formations contain abundant clasts of felsic to intermediate volcanic rocks.

Figure 2 is a diagrammatic cross-section (after Ayres, 1969), showing the interfingering relationships existing between rocks of the Keewatin and Quetico belts.

Igneous Activity and Regional Metamorphism

The metavolcanic-metasedimentary sequence has been intruded by large felsic batholiths ranging in composition from granitic gneiss to quartz diorite. These batholiths form the north and south boundaries of the Beardmore-Geraldton belt. Relatively small lenticular bodies of mafic intrusives occur in the central part of the belt.

Most of the metavolcanic-metasedimentary sequence has been metamorphosed to greenschist facies but metamorphic grade increases southward within the Quetico belt (Macdonald, 1942; Peach, 1951).

Structure

The early Precambrian metavolcanic-metasedimentary sequence has been isoclinally folded along east-trending axes. Detailed work by Horwood and Pye (1955) and Pye (1952), based on surface and subsurface mapping and geophysical data, outlined the style of folding in the Geraldton area.

Several prominent east-trending faults have been recognized. The Paint Lake fault is a major structural discontinuity in the Beardmore area and marks a change in both lithology and structural style. South of the fault, interbedded metasediments and mafic metavolcanic flows are folded along east-trending axes, but to the north, intermediate to felsic pyroclastic rocks predominate and fold axes trend north and northwest.

Late Precambrian Rocks

Relatively flat-lying sedimentary and volcanic rocks unconformably overlie Early Precambrian rocks in many places along the north shore of Lake Superior. Rare exposures of conglomerate, sandstone, shale, and dolomite of the Sibley Group are present in the western part of the Beardmore-Geraldton area near Lake Nipigon.

Keweenaw diabase forms north-trending dikes throughout the Beardmore-Geraldton area and flat-lying sheets near Lake Nipigon. A diabase sheet, 400 to 650 feet thick forms a cuesta just east of Beardmore. The sheet dips gently westward and at the Leitch Gold Mine, four miles west of Beardmore is 1871 feet below surface (Benedict and Titcomb, 1948; Ferguson, 1967). Porphyritic diabase dikes, locally known as "Greenspar porphyry" are thought to be older than the sheets and equigranular dikes.

Late faulting has disrupted the Keweenaw diabase sheets and dikes and probably represents reactivation of older faults.

Pleistocene

Thick deposits of sand and gravel are present throughout the belt and in some areas outcrop is scarce. Spillway channels, and deltaic sand and valley train deposits have been outlined by Zoltai (1965). Wave-cut terraces and sand dunes are found near Lake Nipigon.

ECONOMIC GEOLOGY

Concentrations of gold, silver, iron, copper, nickel, molybdenum,

pyrite, zinc, lead, tungsten, sand and gravel are present within the Beardmore-Geraldton belt.

Gold and Silver

The Northern Empire Mine (near Beardmore), which began operation in March 1934, was the first producer in the region. By 1940, 11 mines were in operation. Today, however, MacLeod-Mosher Mines Limited, near Geraldton, is the sole producer.

The gold deposits, which contain minor silver, were classified by Horwood (1948) into four types: 1. Simple fractures filled by quartz veins, 2. Shear or breccia zones containing both quartz and sulphides, 3. Fracture zones containing quartz stringers, and 4. Fracture zones containing massive pyrite.

Most of the gold deposits occur in metasediments of the upper (group A or Windigokan) formation but gold mineralization is also found in the lower metasedimentary formation, in metavolcanic rocks, in early felsic and mafic intrusive rocks, and along the contacts between different lithologic units.

Iron

Iron deposits in the belt are interbedded with clastic metasedimentary rocks and are composed of interlayered hematite and/or magnetite with greywacke and argillite and, in places, jasper, chert and iron silicates.

Sulphides

Chalcopyrite, pyrite, sphalerite, pyrrhotite, and galena occur in fracture-filling quartz veins and in shear zones. Many of the known occurrences are in the metavolcanic rocks north of the Paint Lake Fault. Molybdenite occurs near the west end of the belt in quartz veins and is also disseminated with chalcopyrite in altered quartz diorite. Copper and nickel sulphides are associated with a gabbroic intrusion in Elmhirst Township.

A brecciated pyritic iron formation at least 2½ miles long within metavolcanic rocks in Summers Township has been explored for its sulphur content.

Other Commodities

Minor scheelite was recovered from the gold ores of the Little Long Lac Mine during the Second World War (Pye, 1952).

Sand and gravel deposits have been used in highway and railroad construction.

SELECTED REFERENCES

- Anonymous, 1965; Longlac, Ontario; Ontario Department Mines, Geol. Survey. Canada. Aeromagnetic series, Map 7102 G.
- Ayres, L. D. 1969; Early Precambrian stratigraphy of part of Lake Superior Provincial Park, Ontario, Canada, and its implications for the origin of the Superior Province; Unpublished Ph.D. thesis, Princeton University, 399 pages.
- - - - - 1970; Synthesis of Early Precambrian stratigraphy north of Lake Superior (abstract); see this volume.
- Benedict, P. C. & Titcombe, J. A. 1948; The Northern Empire Mine; in Structural Geology of Canadian Ore Deposits; C.I.M.M., p. 389-399.
- Bruce, E. L., 1935; Little Long Lac gold area; Ontario Department Mines, v.44, pt.3, 1935, 60p.
- - - - - 1937; The eastern part of the Sturgeon River area; Ontario Department Mines, v.45, pt.2, 1936, p.1-59.
- Carlisle, D., 1963; Pillow breccias and their aquagene tuffs, Quadra Island, British Columbia; Jour. Geol., v.71, p.48-71.
- Ferguson, S. A., 1967; Leitch Gold Mines Limited, surface plan of eastern part of property, parts of Eva and Summers Townships, District of Thunder Bay; Ontario Department Mines, Geol. Map P.484.
- Goodwin, A. M., 1966; Archaean protocontinental growth and mineralization; Can. Min. Jour., v.87, No. 5, p.57-60.
- - - - - 1968; Evolution of the Canadian Shield; Proc. Geol. Assoc. Canada, v.19, p.1-14.
- Henderson, J.F., 1953; On the formation of pillow lavas and breccias; Trans. Roy. Soc. Canada, v.47, ser. III, Sec. 4, p.23-32.
- Henderson, J.F., & Brown, I.D., 1966; Geology and structure of the Yellowknife greenstone belt, District of Mackenzie; Geol. Surv. Canada, Bull. 141, 87 p.

- Horwood, H. C., 1948; General structural relationships of ore deposits in the Little Long Lac-Sturgeon River area; in Structural Geology of Canadian Ore Deposits; C.I.M.M.
- Horwood, H. C., & Pye, E. G., 1955; Geology of Ashmore Township; Ontario Department Mines, Vol. 60, pt. 5, 1951, 105p.
- Kalliokoski, J., 1968; Structural features and some metallogenic patterns in the southern part of the Superior Province, Canada; Can. Jour. Earth Sci., v.5, p.1199-1208.
- Laird, H. C., 1937; The western part of the Sturgeon River area; Ontario Department Mines, v.45, pt. 2, 1936, p.60-117.
- Langford, G. B., 1929; Geology at the Beardmore-Nezak Gold area; Ontario Department Mines, Vol. 37, pt.4, 1928, p.83-108.
- Macdonald, R. D., 1942; Geology of the Kenogamisis River area; Ontario Department Mines, v.49, pt.7, 1940, p.12-28.
- - - - -1943; Geology of the Hutchison Lake area; Ontario Department Mines, v. 50, pt. 3, 1941, 21p.
- Mackasey, W. O., 1968- Preliminary Maps of District of Thunder Bay
1970; Ontario Department Mines
Dorothea Tp. P479 1968
Sandra Tp. P480 1968
Irwin Tp. P481 1968
Walters Tp. P539 1969
Leduc Tp. P540 1969
Eva Tp. (in press)
Summers Tp. (in press)
- Peach, P. A., 1951; Preliminary report on the geology of the Blackwater-Beardmore area; Ontario Department Mines, Prel. Rept. 1951-7, 6p.
- Pettijohn, F. J., 1943; Archean sedimentation; Geol. Soc. America Bull., v.54, p.925-972.
- Pye, E. G., 1952; Geology of Errington Township, Little Long Lac area; Ontario Department Mines, v.60, pt. 6, 1951, 140p.
- Pye, E. G. 1952, & Harris, F. R., Fenwick K. G., & Baillie, J., 1966; Tashota-Geraldton sheet; Ontario Department Mines, Map 2102.

- Stockwell, C. H., 1964; Fourth report on structural provinces, orogenies, and time-classification of rocks of the Canadian Precambrian Shield, in Age determinations and geological studies, pt. II, geological studies; Geol. Surv. Canada, Pap. 64-17 (pt.II), p.1-21.
- Tanton, T. L., 1921; Explored routes in a belt traversed by the Canadian National Railway between Long Lac and Nipigon; Geol. Survey, Canada, Sum., Rept., 1917, pt. E. p.1-6.
- Tyson, A. E., 1945; Report on gold belts in the Little Longlac-Sturgeon River District; Can. Mining Jour., Vol. 66, no.12, p.839-850.
- Walker, J.W.R., 1967; Geology of the Jackfish-Middleton area; Ontario Department Mines, Geol. Rept. 50, 41 p.
- Wilson, A. G. W., 1910; Geology of the Nipigon Basin; Geol. Survey Can., Memoir 1.
- Zoltai, S.C., 1965; Surficial Geology, Thunder Bay District; Ontario Department Lands and Forests, Map S 265.

FIELD TRIP

The field trip has been designed as a one-day excursion starting from Geraldton, where some of the oldest rocks of the belt can be viewed, and finishing south of Beardmore at an exposure of the younger, Sibley Group rocks.

A cross-section of the belt, made by traversing north on secondary Highway 801 in Walters Township (near Jellicoe), has been chosen to show the variety of metasedimentary and meta-volcanic rocks types. Although some of the exposures along the highway are relatively small, larger outcrops occur along strike and, in some cases, can be reached by means of trails and/or boat.

The tour continues west to Beardmore, the Leitch Gold Mine area, and Lake Nipigon to examine Keweenaw diabase exposures, folded iron-rich metasediments, and volcanic structures.

Emphasis has been placed on the viewing of megascopic features and field relationships.

ROUTE

The Road Log has been set-up to enable use by others at a later date.

Location of all Stops are shown on map in Figure 1. The relative position of some Stops has also been located on the cross-section in Figure 2.

Time limitations may not allow viewing of all Stops listed. Some stops are intended for viewing from the bus only.

Conservation of Outcrop

Several groups will be making this tour in conjunction with the 1970 Lake Superior Institute, and possibly on an individual basis at a later date. Care should be taken to preserve the more delicate features when collecting specimens, making hardness tests, etc.

DESCRIPTION OF STOPS

Mileage

- 0.0 Leave junction of Highways 11 and 584 (south of Geraldton).
Head west on Highway 11 (Trans Canada Route).
- 2.5 Turn right and leave Highway 11.
- 0.0 Head northeast on gravel road.
- 0.6 South side of road under power line.
- STOP 1 This outcrop consists of fine grained clastic sediments
with interbedded conglomerate and iron formation.
Porphyry similar to that associated with the nearby gold
deposits can be found on the north side of the exposure.
Drag folds and crenulations reflect the regional structure.
- Note stretched pebbles, gentle plunges of crenulations,
and quartz veining.
- Backtrack to Highway 11.
- 0.0 Junction to Highway 11 and gravel road. Head west on
Highway 11.
- 4.0 South side of Highway 11 about 400 feet west of Magnet
Creek. Walk south on old bush road for about 400 feet
then turn west (right) at old headframe timbers and
continue for approximately 300 feet to outcrop area.
- STOP 2 This marks the location of the disconformity separating
group A and group B sediments as outlined by Pye (1952).
The thin bedded, fine grained clastics of group B
(lithologically similar to the Quetico metasediments) are
overlain by Timiskaming-type conglomerate. See Pye (1952, P17)
for photograph of lichen-free outcrop.
- 27.1 General store at Jellicoe (Rock and mineral dealer).
- 30.8 North side of Highway 11 near bush road.
- STOP 3 Road cut of Timiskaming-type greywacke succession sediments
with well developed graded bedding. These sediments form
part of the "Windigokan series" as mapped by Tanton in 1917.
- 33.0 Junction of Highways 11 and 801.

- 0.0 Head north on Highway 801 (gravel).
- 1.2 Road cut at crest of ridge.
- STOP 4 This stop illustrates the thin bedded aspect of the fine-grained "black slate" sediments in the area. Bedding is more easily recognized on the weathered surface along the top of the road cut.
- 1.4 Outcrops on the north side of the road, approximately 800 feet northwest, display well bedded argillite, siltstone and greywacke with thin iron-rich layers. The magnetic expression of this horizon can be traced for several miles west along strike, (see O.D.M.-G.S.C. Map 7102G, 1965).
- 2.4 North end of road cut on east side of Highway 801.
- STOP 5 Fine grained green lava with jasper amygdules. Breccia fragments are visible on weathered surface of outcrop.
- 2.8 On Highway 801, north and south of the gate to Pasha Lake Lodge.
- STOP 6 These relatively small exposures serve to illustrate facies changes in the sedimentary rocks.
- The southern exposure (broken outcrop) displays the blocky, massive nature of the sandstones in the area. The northern exposure is typical "Windigokan" conglomerate. Although jasper pebbles are readily apparent in the conglomerate, pebble counts indicate that jasper is only a minor constituent.
- These two rock units can be traced for several miles along strike.
- 4.3 The road cut at top of ridge.
- STOP 7 Massive mafic lava typical of the area. Note epidotic alteration and minor copper mineralization.
- The disrupted banded and massive cherty horizons present in this outcrop area can be found at several locations along strike, and are thought to be the result of fumerolic activity.
- 5.6 West end of Paint Lake.

STOP 8 (Paint Lake Fault). This lineament can be traced for several miles along strike and is considered a major fault zone. Pebbles and boulders in the sedimentary rocks on the south side of the fault have undergone marked plastic deformation.

6.2 Road cut at "S" turn on east side of Highway 801.

STOP 9 Stops 9 and 10 serve to illustrate the fragmental character of the volcanic rocks north of the Paint Lake Fault.

The weathered surface at the south end of the road cut reveals the agglomeratic nature of these volcanic rocks. The irregular and feathery edges of some fragments suggest that the pyroclastic material was in a plastic condition when deposited.

Note: Please do not damage the south part of the outcrop.

6.9 Outcrop on the east side of Highway 801.

STOP 10 Volcanic breccia containing "cigar-shaped" tapered fragments up to six inches long.

This marks the last stop of the cross-section on Highway 801. Now backtrack to Highway 11.

0.0 Junction of Highways 11 and 801. Head west on Highway 11.

12.0

STOP 11 Highway 11 passes through a wind gap in a north trending cuesta. The cuesta is formed by a west dipping diabase sheet which intrudes the Archean rocks.

14.7 Junction of Highways 11 and 580.

0.0 Turn right and continue on Highway 580. (This road heads west to Lake Nipigon).

4.4 Turn right at intersection and head northwest along gravel road entering Leitch Mine area.

4.5 Outcrop ridge approximately 200 feet south of gravel road. Scattered outcrops to north of road.

STOP 12 This stop illustrates tight drag folding in a unit composed of interbedded fine grained clastic sediments, jasper, and hematite-magnetite layers.

Note: If collecting specimens, please do not mar the the crenulated section of the southern exposure.

Most of the "mineral showings" near the mine have been covered with waste rock from underground workings.

Keep away from fenced off areas. Continue west on Highway 580. (Highway can be reached by following service road, or by backtracking).

6.4 Lake Nipigon (Poplar Lodge) and end of Highway 580.

0.0 Head north (right turn) along gravel road. Peninsula near large red-stained cottage. (Note: road conditions may require leaving vehicle up to 1000 feet south of here).

STOP 13 Excellent exposures of pillow lava, amygdaloidal lava and volcanic breccia can be found along the shore in this vicinity, and on the nearby islands.

Pillow breccia may be observed along the waterline of the northern tip of the peninsula. Here well packed pillow lava grades into breccia containing isolated pillows. This occurrence is similar to pillow breccia described by Henderson (1953), Henderson and Brown (1966) and Carlisle (1963).

Now return to Highway 11.

0.0 Junction of Highways 11 and 580. Head south on Highway 11 (cross Blackwater River).

0.8 Turn east (left) off Highway 11 and follow gravel road (Empire Mine Road). Cross railway track and continue east.

1.1 Power line. Examine exposures along power line clearing for approximately 1200 feet south of road. Footpath crosses some of the best exposures.

STOP 14 This Stop illustrates age relationships between two of the Proterozoic diabase intrusives, as well as their lithological differences.

Outcrops near the road are of a wide, north striking, porphyritic diabase dike that closely resembles Matachewan diabase. The altered green feldspar phenocrysts in the dike have given rise to the local term "Greenspar porphyry". Faulted offsets of what is believed to be the same dike, can be followed for more than ten miles to the north.

A contact between porphyritic diabase and younger massive diabase is exposed on the first main ridge south of the road. The younger diabase is believed to be a part of the same diabase sheet seen at STOP 11.

Inclusions of foliated mafic lava and rounded to angular fragments of granitic material and quartz can be observed further south along the footpath.

Return to Highway 11 and enter Beardmore.

0.0 Leave Beardmore and head south on Highway 11. Mileage count begins at railway crossing.

8.6 Road cut on east side of Highway 11.

STOP 15 This stop demonstrates the unconformable relationship existing between the Proterozoic strata of the region and the underlying Archean rocks.

Pink sandstone of the Sibley Group rests with angular unconformity on an eroded Quetico metasediment surface. Fragments of the underlying rock can be found suspended in what is a possible paleosol or limestone layer along the unconformity.

The pink colour of the sandstone is caused by the presence of approximately 0.1% hematite. (J. M. Franklin, personal communication).

THE PORT COLDWELL ALKALI COMPLEX

May 9, 1970

Prepared by

F. PUSKAS*

*Present address: The International Nickel Company of Canada Ltd.,
Copper Cliff, Ontario.

Guide to the Port Coldwell alkalic complex

INTRODUCTION:

The Port Coldwell Alkali Massif (Fig. 1) is located within an Archean volcanic-sedimentary belt extending along the North shore of Lake Superior near Marathon. Previous work on the complex consists of reconnaissance work by Kerr (1910), detailed mapping by Tuominen in 1958-1959 (O.D.M. Prelim. Map P 114) and by Puskas in 1960 (O.D.M. Prelim. Map P 114, revised). The western contact of the complex was mapped by Walker (1956); the eastern contact by Thomson (1931) and Milne (1964).

The present study was largely carried out by the writer and associates while employed by the Ontario Department of Mines. The author wishes to express his thanks to Professor Henri Loubat of Lakehead University and Clarence Kustra, Ontario Department of Mines, Resident Geologist, for their constant interest and co-operation. S. Spivak drafted the diagrams.

FIELD AND GENETIC RELATIONSHIPS

The Port Coldwell Alkali Massif (Fig. 1) lies within the eugeosynclinal portion of an Archean volcanosedimentary belt, approximately 18 miles wide and extending westward from White Lake, along the north shore of Lake Superior.

The volcanosediments have been tightly folded in a N 70°E direction; less important, more northerly trending, structures may be attributed to cross-folding.

The Archean rocks have been successively intruded by sill-like bodies of basic and ultrabasic composition, granitoids, dikes of diabasic composition, and lastly by the Port Coldwell Alkali Massif.

The Alkali Massif is a lopolith (Puskas, 1964; Corbett, 1968) circular in plan and approximately 580 sq. kilometers in area. The Massif is considered to typify the so-called (Benson) Laccomorphic class of emplacements.

The rocks of the massif can be divided into two groups called here the Main Group and the Secondary Group. However, in common with many intrusions of this type the long crystallisation history has resulted in numerous complex and sometimes confusing cross cutting relationships.

The Main Group is composed of gabbros, the oldest and more-peripherally located rock-type (Map unit 2), and laurvikites (Map unit 3). Both the gabbros and laurvikites can exhibit rhythmic layering which dips inward at moderate angles. The

laurvikites highest in the group are commonly porphyritic.

Several zones are recognized within the main group.

Upper Zone	massive laurvikite
Lower Zone	layered laurvikite
Inner Border Zone 'B'	layered gabbro
Inner Border Zone 'A'	massive gabbro
Outer Border Zone	chilled gabbro

The Secondary Group is composed of an older, saturated series which includes syenodiorites (Map Unit 4) and nordmarkites (Map Unit 5) and a younger, undersaturated, series with several varieties of feldspathoidal syenite (Map Unit 6). Generally, within this group, rocks comprising the saturated series are peripheral to the feldspathoidal syenites.

Except for the feldspathoidal syenites, which are layered at some localities, the rocks of the Secondary Group are massive and apparently structureless.

The Secondary Group is characteristically associated with xenolithic bodies. Although widespread, these bodies are thought to belong to one large unit, the so-called Coubran Lake meta-volcanic cap. Common variants, generally gradational one to the other, include aphanitic amygdular and diabasic volcanics. The 'cap' rocks and the rocks of the Secondary Group are preferentially concentrated in that portion of the massif which is west of Wolf Camp Lake. (ref to Stop 3, Fig 4).

It is noted that the 'cap' appears to be 'free-floating' in the north and 'attached' in the southern part.

These and other relationships suggest a near-roof situation of the present level of exposure.

The Port Coldwell magma, which apparently contained solid plagioclase feldspar, was emplaced (1) from a probable source located to the SSW, (2) by a process of doming, stoping, and forceful injection, and (3) at P-T conditions sufficient to generate a thermal aureole within the pyroxene-hornfels facies.

The rocks of the aureole show rheomorphic veining, and anatectites which commonly exhibit flow layering or schlieren trending parallel to the immediate gabbro contact. Areas of more intense migmatite development were probably controlled by the distribution pattern of favourable lithologies as modified by folding, faulting and emplacement characteristics of the massif. The coincidence of numerous geological contacts with lineaments is compatible with a magma cooling history involving doming and fissuring, with probable block subsidence, and the 'near-roof' level of Massif exposure.

AGE RELATIONSHIPS

The volcanosedimentary assemblage was intruded by various bodies which are as follows (oldest first): - sill-like bodies of basics and ultrabasics, granitoids, dikes of diabase, and the Port Coldwell Alkali Massif.

The diabase dikes are typical of those reported throughout the Superior Province and which have been dated at approximately 1700 m.y.

The author originally thought the Port Coldwell Alkali Massif to have been intruded in the northwest by a younger granitoid, the so-called Little Pic River batholith (Puskas, 1964). But the observed field relations are better explained by assuming the formation of a palinogenetic magma from an overlying granite.

Minerals from the massif give ages of 1065 m.y. (K-Ar, Rb-Sr ages on biotites from nepheline syenites from Stop 5) and 1225 m.y. (Rb-Sr age on perthite from the laurvikite) (Fairbairn et al, 1959). In view of the widespread contamination of the magma further work is necessary. However, the massif is similar in age to the widespread Keweenaw intrusives of the Superior Basin (1000± myrs) and may be from the same parental magma.

ECONOMIC GEOLOGY

The Port Coldwell Alkali Massif has been prospected for iron, base metals, radioactive minerals, nepheline, perthitic feldspar, and building stone. To date there has been no ore production.

Iron

The exposed gabbros along the periphery have been investigated for iron and base metals.

The iron occurs as ilmenomagnetite-enriched layers or bodies, one inch to 70 feet wide, predominantly conformable to the layering of the adjacent gabbros. The high titanium content, 5 to 8 percent, and sub-marginal tonnages make the deposits uneconomic at this time.

Base Metals

Base metal investigations by various companies, including Moneta Porcupine, Lakehead, Denison Mines, Keevil, Anaconda, and Conwest Exploration, have concentrated on the coarser grained, massive, gabbros (Inner Border zone 'A').

Stone

Small scale quarrying of both 'red' and 'black', i.e. dark varieties of laurvikite was begun in 1927 and continued into the 1930's on a property located approximately 2 3/4 miles north of

Marathon and transected by the C.P.R.

Although these syenites, particularly the 'dark' varieties, are similar to the famous laurvikites from Norway, no markets could be secured and maintained.

Nepheline

Denison Mines Limited in 1960 attempted to determine the nepheline potential of the feldspathoidal syenites from two areas located south of Highway 17 and west of Red Sucker Cove. However, nepheline separation proved hard to achieve, and iron content of the concentrate was too high, so the project was abandoned.

SELECTED REFERENCES

The following is a selected list of references pertaining to the geological features discussed in this report:

- Adams, F. P., 1900; On the Probable Occurrence of a Large Area of Nepheline-Bearing Rocks on the North-east Coast of Lake Superior, Journal of Geology, Vol. VIII, pp 322-325.
- Coleman A. P., 1898; Port Coldwell Region, Ann. Rep. Bur. of Mines, Ont., pp 146-149.
- Coleman A. P., 1899; Dyke Rocks near Heron Bay, Ann. Rep. Bur. of Mines, Ont., pp 172-174.
- Coleman A. P., 1899; A new Analcite Rock from Lake Superior, Journal of Geology, Vol. VII, pp 431-436.
- Coleman A. P., 1900; Heronite or Analcite Tinguaita, Ann. Rep. Bur. of Mines, Ont., pp 186-191.
- Coleman A. P., 1902; Syenites near Port Coldwell, Ann. Rep. Bur. of Mines, Ont., pp 208-213.
- Collins & Camsell, 1913; The Nepheline and Alkali Syenites of the Port Coldwell Area, Transcontinental Excursion Cl, Toronto to Victoria and return via Canadian Pacific and Canadian Northern Railways, Guide Book No. 8, Part 1, pp 16-24.
- Corbett, J., 1968; Paper presented to I.L.S. meeting at East Lansing.
- Farrand, W. R., 1960; Former Shorelines in Western and Northern Lake Superior Basin, Unpublished Ph.D., dissertation, Dept. of Geology, University of Michigan, Ann Arbor.

- Fairbairn, H. W.,
et al, 1959; Age investigations of syenites from Port
Coldwell, Ontario, Geol. Assoc. Canada,
Proc. Vol, 11, pp 141-144.
- Hough, J. L., 1958; Geology of the Great Lakes, University of
Illinois Press, Urbana, Illinois, Chapter II.
- Kerr, H. L., 1910; Nepheline Syenites of Port Coldwell, Ann
Rep. Bur. of Mines, Ont., pp 194-232, with
map.
- Logan, Sir Wm. E., 1847 Report of Progress, G. S. C. pp 29-30.
- Logan, Sir. Wm. E. 1863 Geology of Canada, pp 80-81, 480, 647.
- Milne, V. G., 1967; Geology of Cirrus Lake-Bamoos Lake area;
Ontario Department of Mines, Report 43.
- Puskas, F. P., 1964; Geology of the Port Coldwell Area, Open
File, O.D.M. T.B.
- Thomson, Jas. E., 1931; Geology of the Heron Bay Area, O.D.M.,
Vol. XL, pt 2.
- Thomson, Jas. E., 1934; Unpublished Ph.D. dissertation, Department
of Geology, Wisconsin University, Madison,
Wisc.
- Walker, T. L., &
Parsons A. L., 1927; University of Toronto Studies, Geol. Ser.
No. 24, pp 28-32.
- Walker, J. W. R., 1956; Geology of the Jackfish-Middleton Area,
District of Thunder Bay, Ont. O.D.M. Geol.
Cir. No. 4.

DESCRIPTION OF STOPS

The town of Marathon is at one of the few naturally protected harbours along this part of the North shore of Lake Superior.

An extensive sand and gravel deposit underlies the townsite and extends eastward to Heron Bay and northward approximately 2½ miles. To the north these sand and gravel deposits are seen to overlay a broad terrace of varved clays which trends parallel to the present course of the Big Pic River for more than 50 miles (Farrand, 1960).

There are at least six beach terraces at Marathon (Thomson, 1934; Puskas, 1964). The highest beach is 710 feet above Mean Sea Level or 108 feet above the present surface of Lake Superior (Hough, 1958). The vertical interval between these beach terraces is 5 to 45 feet. Walker (1956) states that the vertical interval between terraces occurring 20 or more miles to the west is 5 to 10 feet. These differences may indicate a relative increase in the rate of post glacial isostatic adjustment to the east in direction of the Marathon area.

Mileage

- 0.0 Intersection of Highway 17 and turn off to Marathon. Continue south east on Highway 17.
- 2.4 Eastern contact of Massif with country rock.

STOP 1 (Fig. 1 & 2) is a 2 mile traverse across the eastern part of the massif beginning at the contact of gabbro and anatexite. (Fig. 2)

Because of the close proximity of the country rocks to a considerable portion of the traversed gabbros, the gabbros are highly charged with xenoliths, variably assimilated, and variably hybridized.

STOP 1A EASTERN CONTACT OF MASSIF (Fig. 2).

The local contact zone between gabbro, occurring as a topographic 'high', and anatexites shows the following features;

- (1) in plan, the contact appears flexured or arcuate.
- (2) dip relations of contact indicate 'on-lap' by anatexite.

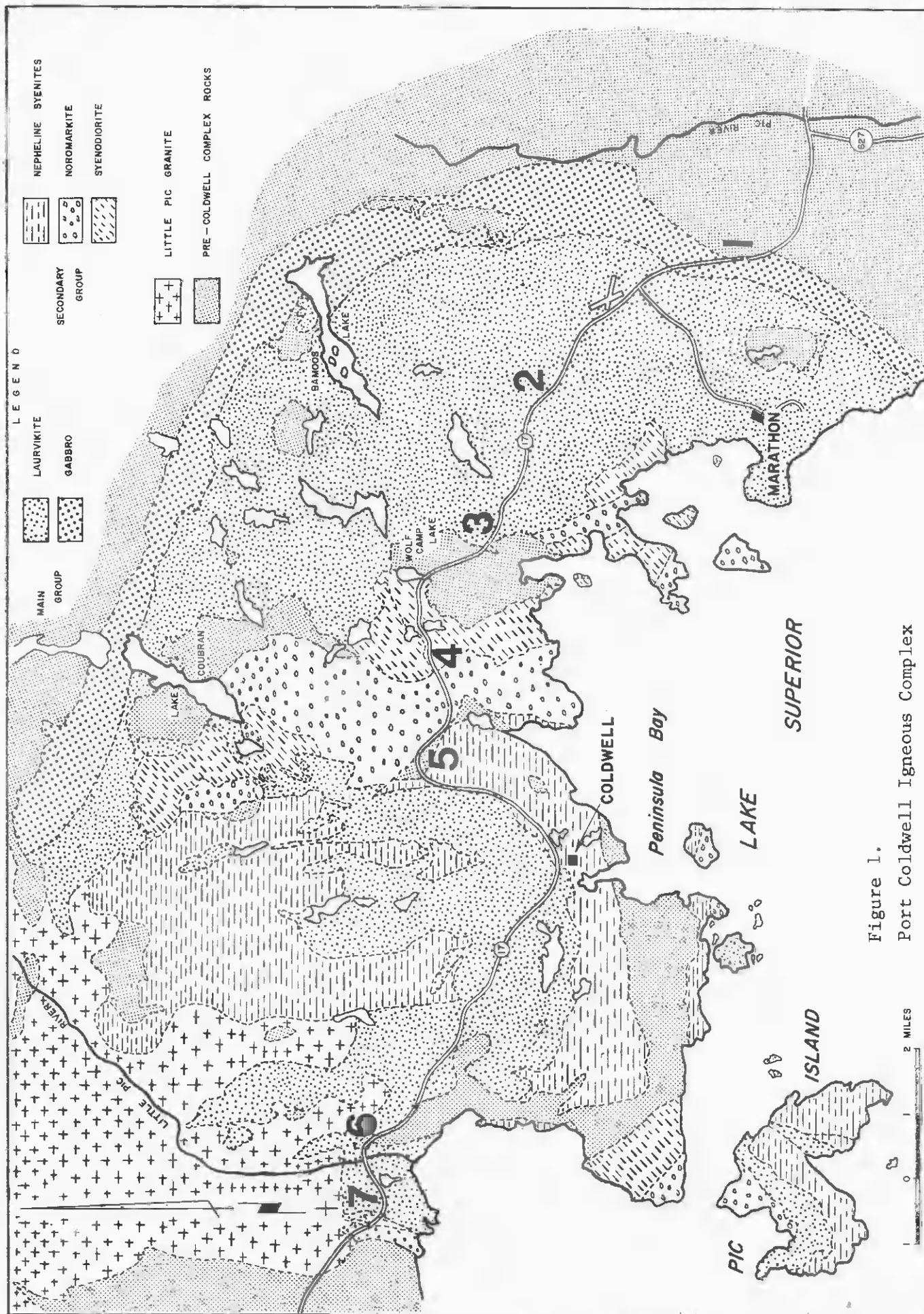


Figure 1.
Port Coldwell Igneous Complex

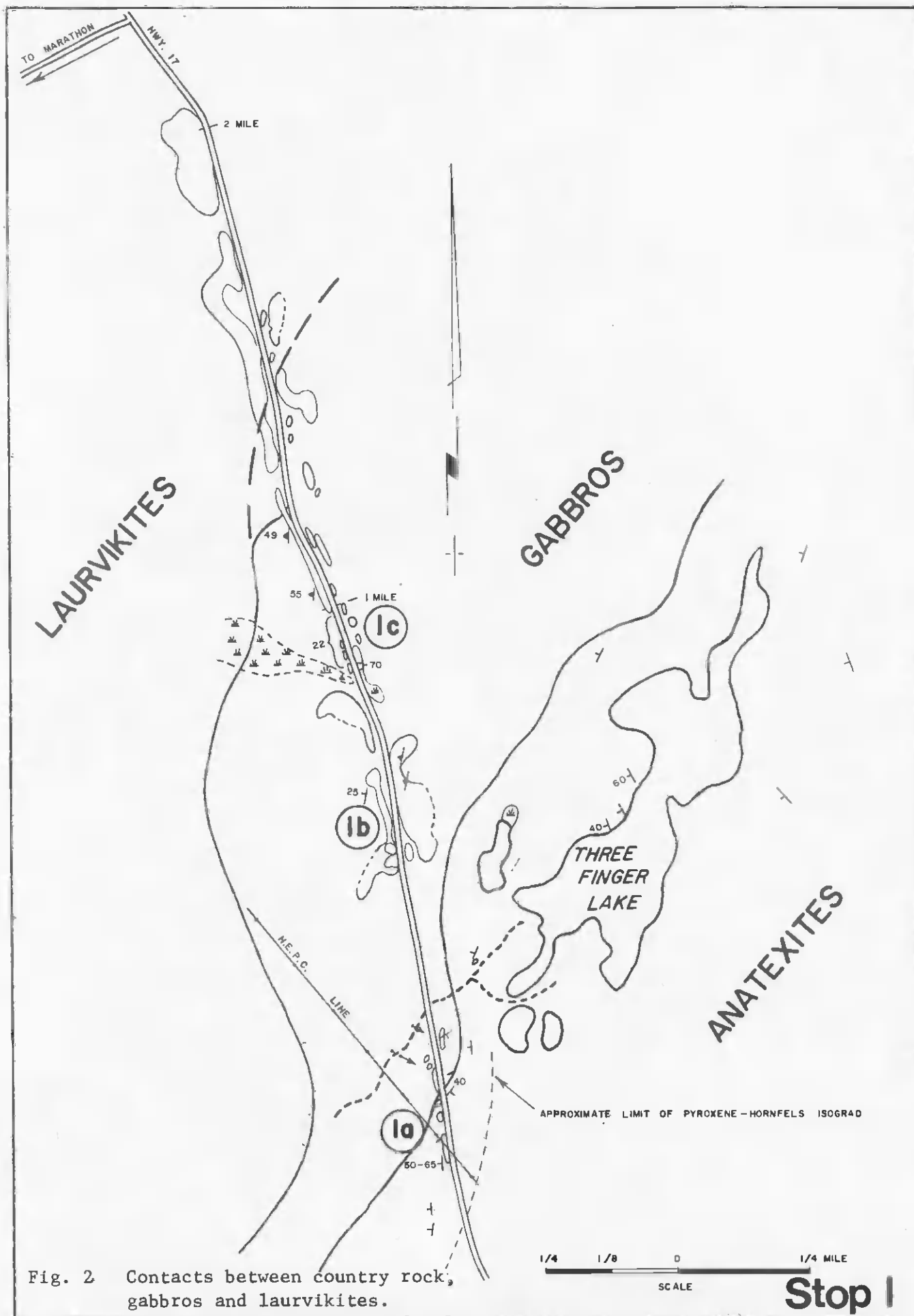


Fig. 2 Contacts between country rock, gabbros and laurvikites.

Stop 1

(3) 'flow-layering' exhibited by anatexite are parallel to the contact and contact irregularities.

(4) presence of areas of breccia development.

These field relations, schematically illustrated in Fig. 3, can best be explained by assuming the peripheral development of migma in the country rocks surrounding the cupola of gabbro.

Breccia development appears to be, in part, the product of an irregular cooling history involving magma pulsation followed by fissuring and intrusion of more-peripheral areas.

Note the abundant xenoliths in the gabbro (apparently reflecting the 'high' level of cupola exposure); the rheomorphic dikes of granophyre with tourmaline+prehnite in the anatexites; and dikes of laurvikite in the gabbros.

The laurvikite dikes commonly show;

- (1) angular inclusions of gabbro, obviously locally derived;
- (2) contact relations indicative of emplacement during periods of extension;
- (3) composite appearance.

Thin sections of the anatexites show porphyroblasts of (in decreasing order of relative abundance); clinopyroxene, K-spar, quartz, orthopyroxene (Fs 25-35), biotite, oxides, and sulfides. Mineralogically the anatexites lie within the orthopyroxene clinopyroxene - plagioclase triangular field of an ACF plot for the pyroxene-hornfels facies. Physical and/or optical alignment of some of the minerals especially plagioclase (An₂₀ to An₄₀), is not uncommon.

The gabbros vary from fine to coarse grained but all varieties are essentially anhydrous two pyroxene gabbros with or without phenocrysts of plagioclase of (An₆₅₋₇₀). The medium to coarse gabbros of 'Inner Border Zone A' show anomalous amounts of quartz and K-spar, probably due to assimilation.

Thin sections of the syenite dikes, generally composite, show perthites (generally extensively exsolved, patch perthite) with varying proportions of aegirine-augite, riebeckite, calcite, zircon, fluorite, quartz, and oxide (ilmenite ± magnetite). These dikes are considered to be apophyses from the main body of laurvikite.

0.0 Turn round and proceed north towards Marathon.

STOP 1B XENOLITH-HYBRIDIZED GABBRO-BANDED GABBRO (Fig. 2)

A large, relatively inhomogeneous, xenolith of anatexite appears to be engulfed within massive, inclusion-bearing, hybridized gabbro.

Massive gabbro is overlain by gabbro with discontinuous and/or disturbed layering, and moderately well developed foliation of plagioclase. These gabbros are essentially two pyroxene, olivine poor, biotite-oxide (magnetite present up to 15 percent) rich, rocks.

STOP 1C GABBROS - LAURVIKITES (Fig. 2).

Continuation of traverse northward, along Highway 17, across layered gabbros, with zones of anatexite and intruded by dikes of laurvikite; and layered laurvikites.

The gabbros show;

- (1) rhythmic (and cryptic) layering;
- (2) foliated and possibly lineated fabric as exhibited by plagioclase and clinopyroxene;
- (3) zones of reaction inclusions;
- (4) several ring (?) dikes, with associated apophyses, of laurvikite.

Greater volume of dikes is indicative of the nearness of contact with overlying laurvikites. Dike emplacement occurred during periods of gabbro extension.

The gabbros contain plagioclase, clinopyroxene, olivine (up to $Fa_{75\pm5}$) with minor, but significant amounts of ilmenomagnetite, biotite, sodic amphibole, apatite, iddingsite, sulfides, and antigorite.

The contact between overlying, layered laurvikites and layered gabbros appears conformable and gradational over a short distance.

The laurvikites show;

- (1) zones of abundant xenoliths;
- (2) colour variation from dark green to red corresponding to a transition, apparently gradational and cyclic, from a more melanocratic, anhydrous mineralogy, further characterized by the presence of hematite perthite;

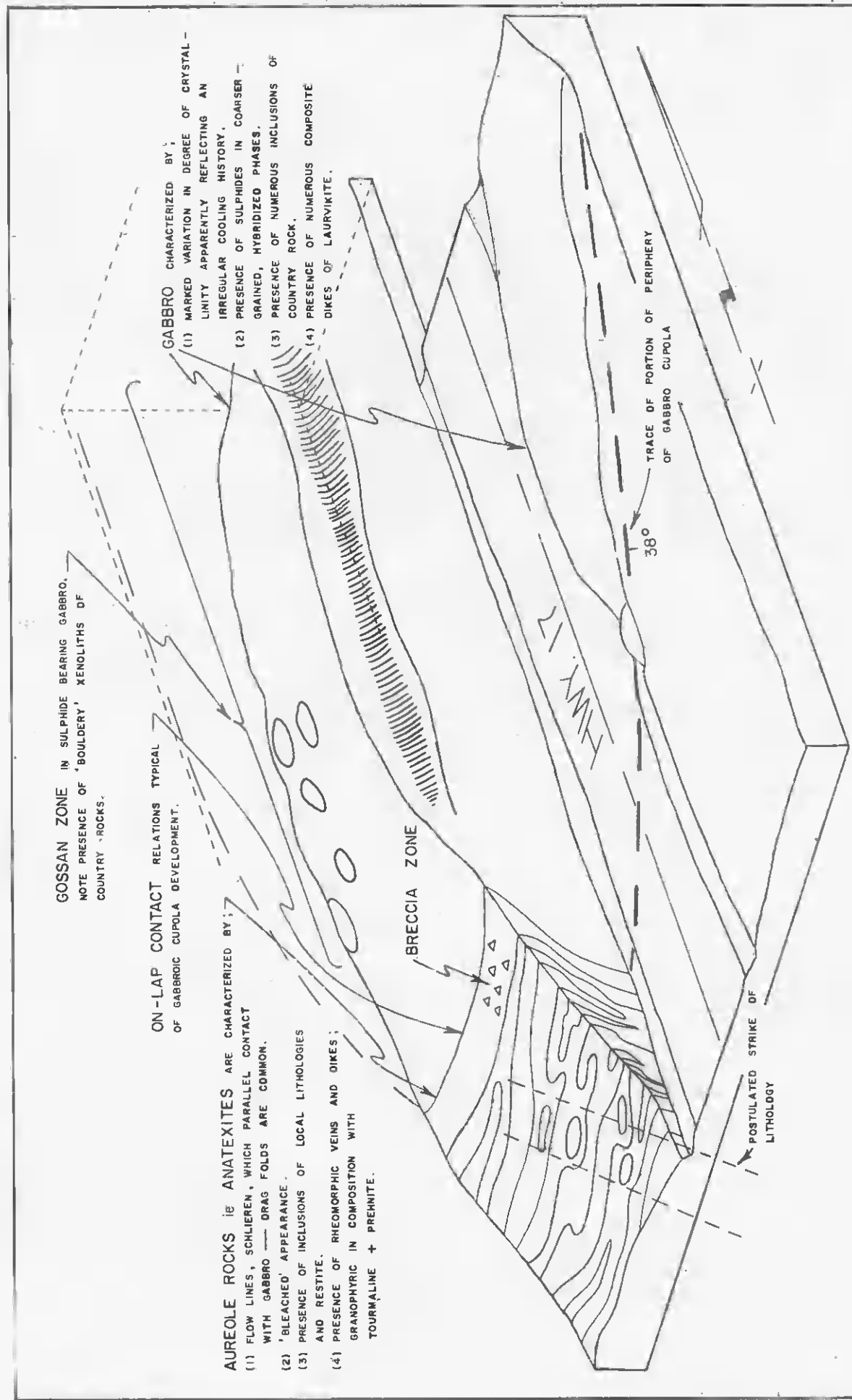


Fig. 3 Contact relations shown at Stop 1a.

Stop 1a

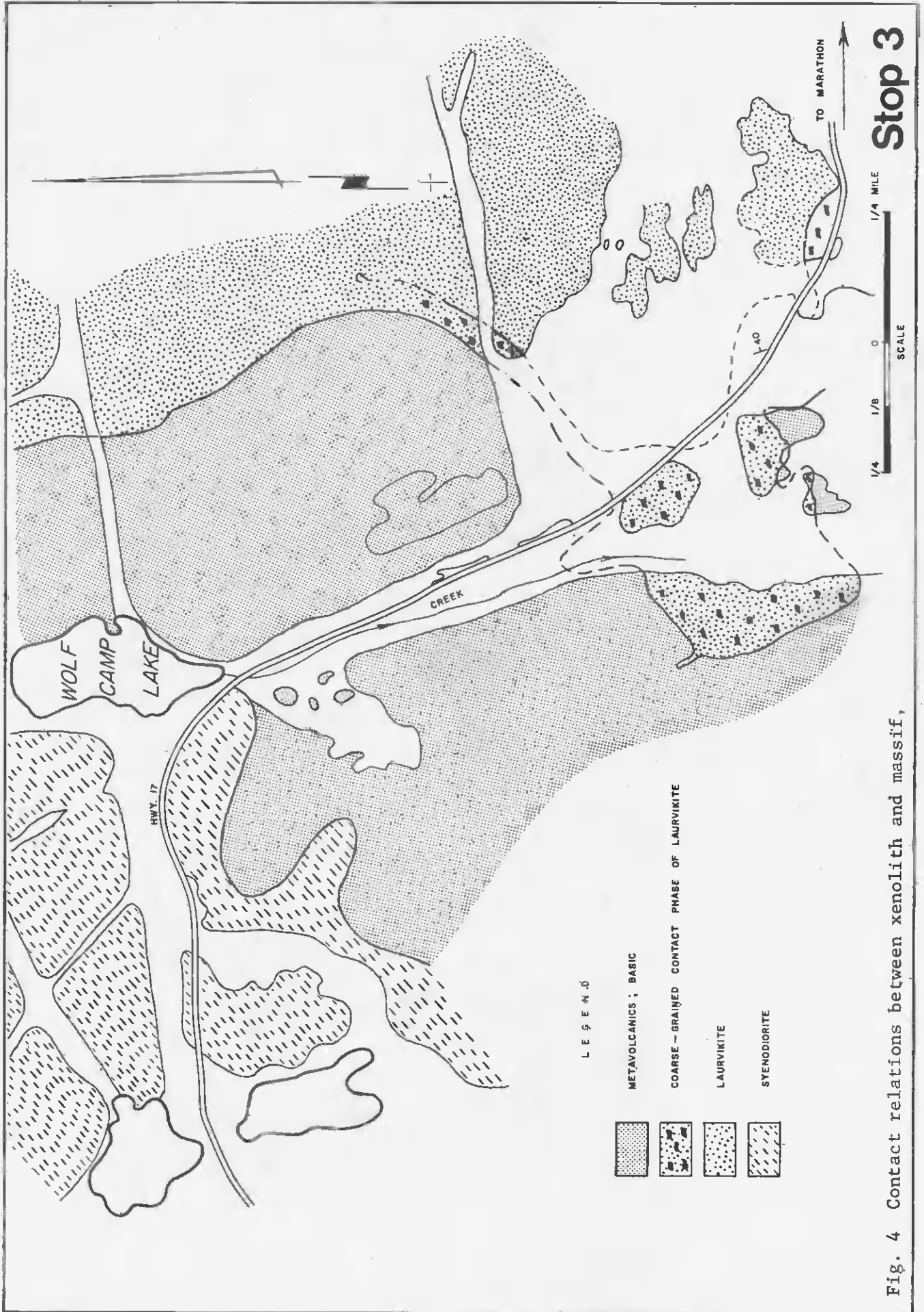


Fig. 4 Contact relations between xenolith and massif,

Stop 3

- (3) feldspars variably foliated;
- (4) mafic schlieren, the attitude of which is conformable with the attitude of layering;
- (5) gradation into more pegmatitic or porphyritic varieties.

The laurvikites are primarily composed of perthitic feldspar, with variable amounts of aegirine-augite, olivine (up to Fa_{100}), barkevikitic amphibole, biotite, iddingsite, quartz, zircon, fluorite and calcite. Variations in mineral compositions, and in the thermal histories of alkali feldspars may be cyclic.

2.4 Marathon turn-off.

0.0 Continue west on Highway 17.

2.3

STOP 2 DARK GREEN LAURVIKITE - LAURVIKITE PEGMATITE (Fig. 1)

These rocks are similar to the laurvikites from Oslo. The perthites from the pegmatites are extensively exsolved, patch perthites, which are more sodic (Or_{27}) than the less exsolved, braided perthites (Or_{62}) from the less-pegmatitic, laurvikitic host.

4.7

STOP 3 CONTACT BETWEEN LAURVIKITE AND BASIC METAVOLCANIC XENOLITH. (Fig. 1 & 4).

This section of the highway reveals a broad exposure of the contact phase of syenite which can be seen to grade into more normal laurvikite.

The basic metavolcanic is basaltic in composition and comprises a portion of the so-called Coubran Lake metavolcanic cap. Although more commonly amygdular in appearance, fine grained to aphanitic phases are distributed in such a manner as to suggest the contacts are flat lying.

The contact between the overlying basaltic cap and the medium to coarse-grained, red coloured, hornblende-rich syenite is generally sharp and fragmented. The syenite, which is a hydrated equivalent of the laurvikite, contains abundant mafic clots, stringers, wisps and veinlets from 2 to 6 inches in size. These 'enclaves', which are amphibolite or syenodioritic in composition, tend to be aligned parallel to the contact.

6.5

STOP 4 TRANSITIONAL PHASE OF LAURVIKITE (Fig. 1).

To the south similar rocks reportedly (Tuominen)

exhibit both gradational and sharp contact relations to an overlying "syenodiorite" phase of metavolcanic cap rock. Because of the gradational relations the syenites were included with the syenodiorites on the revised map.

Thin sections show phenocrysts of alkali feldspar (unexsolved) in a fine-grained groundmass of alkali feldspar (highly exsolved) ophitically enclosed by barkevikite. Relict clinopyroxene (variety augite - sodic augite) has been observed. Hematite staining of feldspars is generally extensive.

This mineral assemblage is not much different from the 'darker' varieties of porphyritic laurvikite and likewise this rock type appears to represent a 'high' level variety.

8.6

STOP 5 NEPHELINE SYENITE (Fig. 1, 5 & 6).

This outcrop (Fig. 5) is typical of nepheline syenites where in contact with 'diabasic' lava. The gross zonation within the feldspathoidal body is generally parallel to the contact with the 'diabase'. The diabase is variably nephelinized.

One can conclude that,

- (1) there were at least two periods of dilation and emplacement (Fig. 61);
- (2) emplacement of feldspathoidal magma was controlled by jointing within the 'diabase' (see Figs. 6a, 6b, 6c);
- (3) emplacements along the more vertical joints preceded those along flats lying joints (Fig. 6c);
- (4) where present, the later feldspathoidal intrusions show nepheline pseudomorphed by the zeolite natrolite (with associated thomsonite) which is orange in colour.

16.8

STOP 6 LAURVIKITE (Fig. 1)

'Red' contact variety of laurvikite highly charged with inclusions of nearby 'diabase'.

18.4

STOP 7 PEGMATITE (Fig. 1 & 7).

Traverse along a composite, nepheline (zeolitized) pegmatite emplaced into gabbros (Fig. 7).

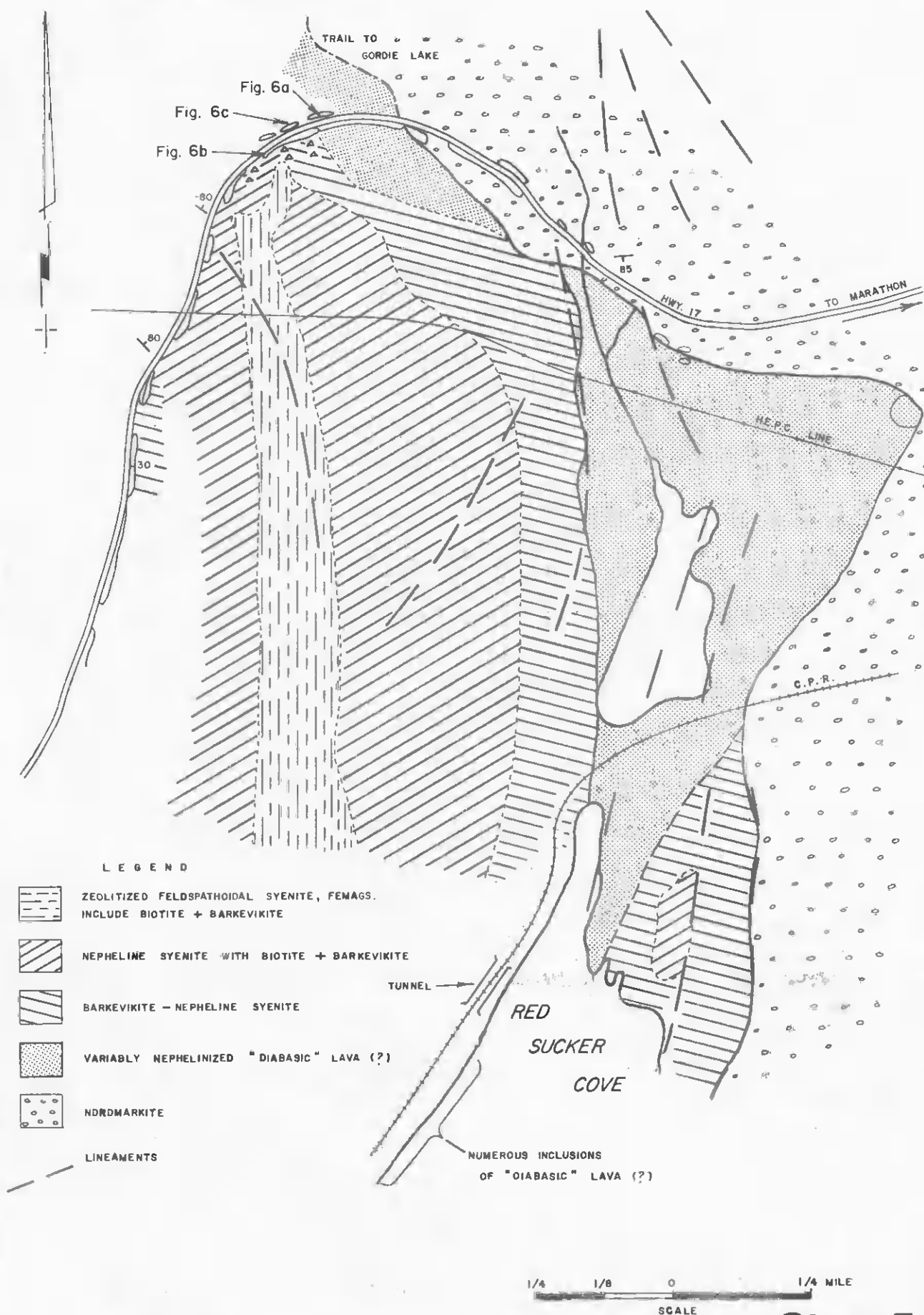


Fig. 5 Nepheline syenite - "Diabase" contacts.

Stop 5

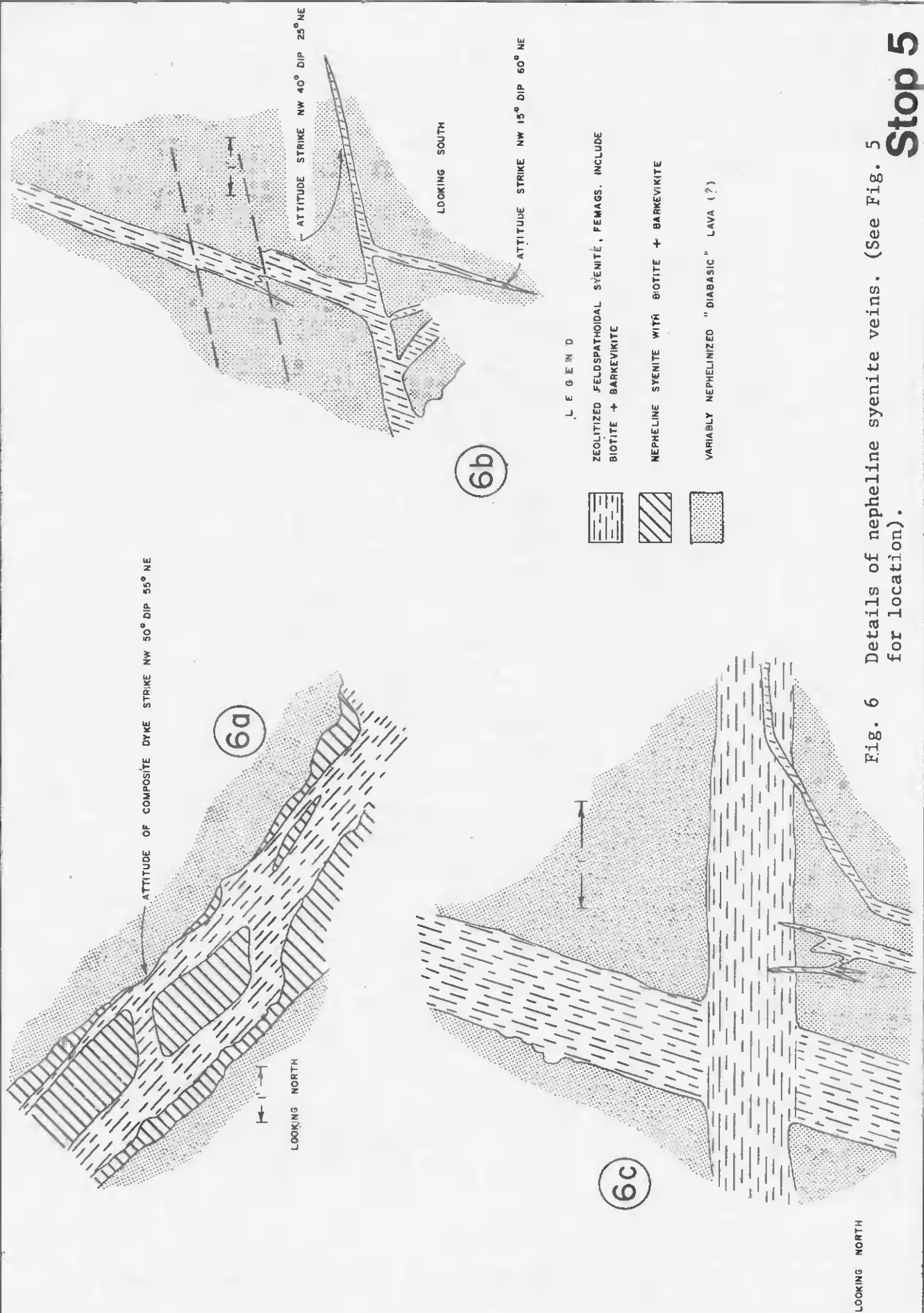
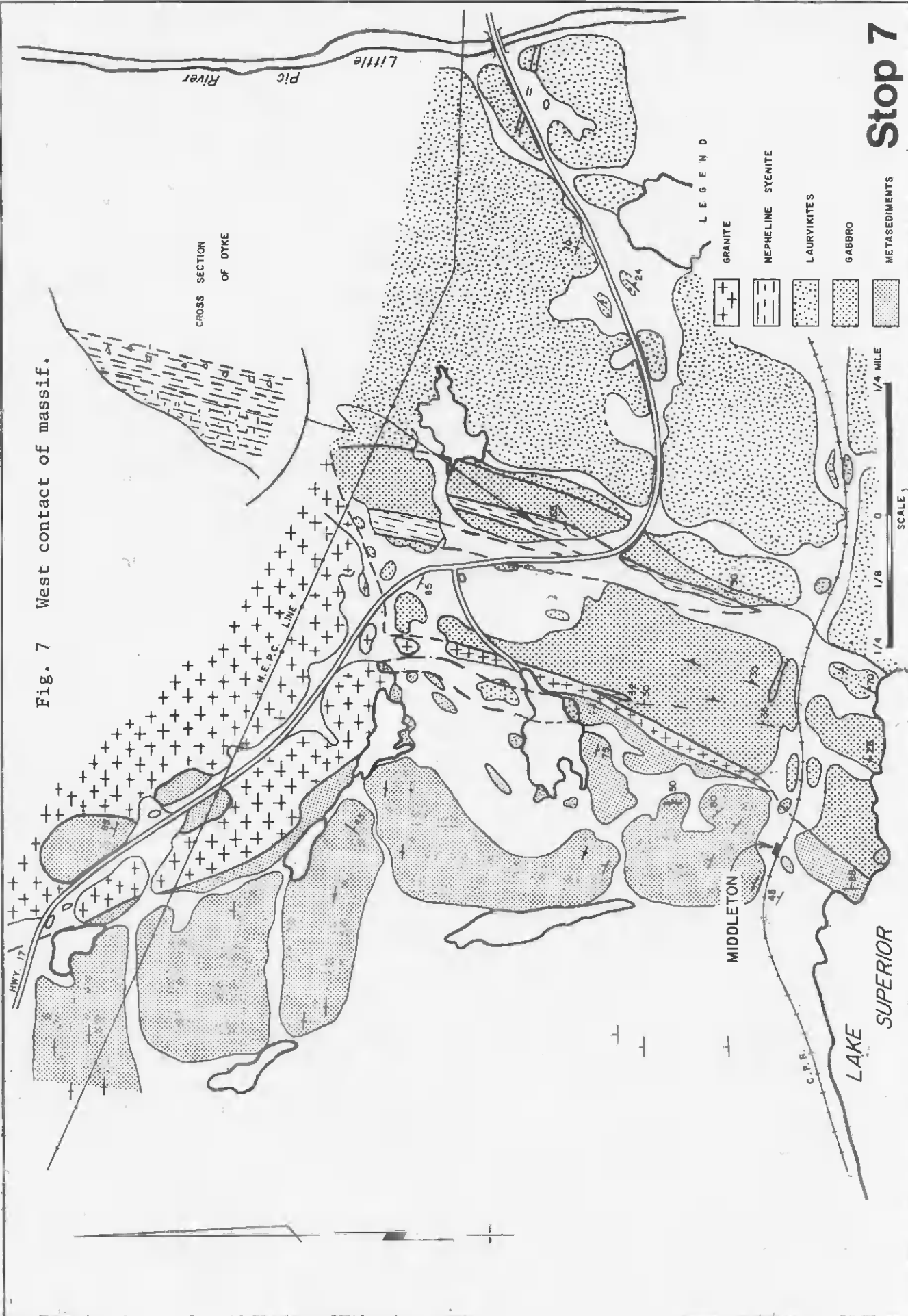


Fig. 6 Details of nepheline syenite veins. (See Fig. 5 for location).

Stop 5

Fig. 7 West contact of massif.



ACKNOWLEDGMENTS

Front Cover Photo.

Sibley Park, near Thunder Bay, Ontario.

Courtesy of Ontario Department of Travel & Publicity

Geological Maps.

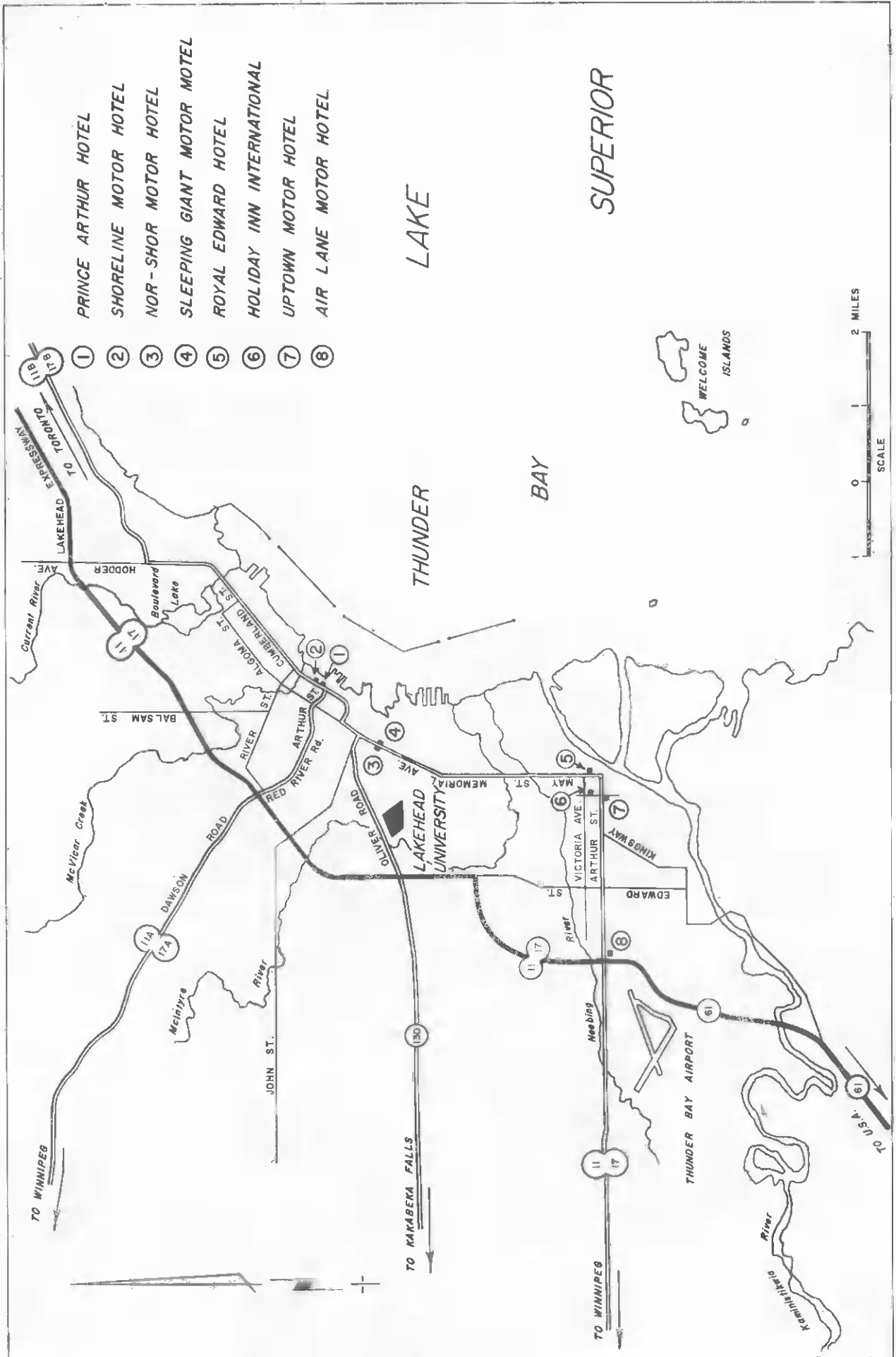
All maps used in the field guides were modified from Ontario Department of Mines maps.

Maps covering the Field Trips are:-

Atikokan - Lakehead	ODM Map 2065
Nipigon - Schreiber	ODM Map 2137
Tashota - Geraldton	ODM Map 2102
Port Coldwell	ODM Prelim Map 114

Mr. Sam Spivak drafted all of the diagrams except those on pages 41 & 42. Many of these diagrams were compiled by Mr. Spivak from several sources, and many of the originals were rough field sketches. His patience and resourcefulness is duly acknowledged by the editors.

The Committee would also like to acknowledge the secretarial services of Mrs. Jean Helliwell, for so ably organizing us in assembling the manuscript and pushing us towards the deadlines.



- 1 PRINCE ARTHUR HOTEL
- 2 SHORELINE MOTOR HOTEL
- 3 NOR-SHOR MOTOR HOTEL
- 4 SLEEPING GIANT MOTOR HOTEL
- 5 ROYAL EDWARD HOTEL
- 6 HOLIDAY INN INTERNATIONAL
- 7 UPTOWN MOTOR HOTEL
- 8 AIR LANE MOTOR HOTEL

LAKE

THUNDER BAY

SUPERIOR

