

INSTITUTE ON
LAKE SUPERIOR GEOLOGY
TWENTIETH ANNUAL MEETING
SAULT STE MARIE, ONTARIO
MAY 1-5, 1974

WILSON & WILSON
2571 & 2573 FALCON ST.
MONTREAL, P.Q. H3T 1S1

PROGRAM

ABSTRACTS

and

FIELD GUIDES

for

20TH ANNUAL

INSTITUTE ON LAKE SUPERIOR GEOLOGY

held at

SAULT COLLEGE OF APPLIED ARTS AND TECHNOLOGY

Sault Ste. Marie, Ontario

May 1-5, 1974

Edited by

P. E. GIBLIN, G. BENNETT, E. J. LEAHY

TABLE OF CONTENTS

	<u>Page No.</u>
INSTITUTE BOARD OF DIRECTORS	i
LOCAL COMMITTEE	ii
SESSIONS CHAIRMEN	iii
ACKNOWLEDGEMENTS	iii
PROGRAM	iv
ABSTRACTS OF TECHNICAL SESSIONS	1
FIELD TRIPS	
1 Middle Keweenawan Rocks of the Batchawana - Mamainse Point Area.	39
3 Precambrian Igneous Rocks of the North Shore of Lake Huron Region.	68
4 Stratigraphy and Sedimentation of the Huronian Supergroup.	94
5 The Michipicoten Greenstone Belt.	117

20th Annual

INSTITUTE ON LAKE SUPERIOR GEOLOGY

Sault College of Applied Arts and Technology

Sault Ste. Marie, Ontario

May 1-5, 1974

INSTITUTE BOARD OF DIRECTORS

- M. E. Ostrom, Wisconsin Geological and Natural History Survey, Madison, Wisconsin.
- J. Kalliokoski, Department of Geology and Geological Engineering, Michigan Technological University, Houghton, Michigan.
- D. M. Davidson, Jr., Department of Geology, University of Minnesota at Duluth, Duluth, Minnesota.
- * R. C. Reed, (Secretary-Treasurer) Geological Survey Division, Department of Natural Resources, Lansing, Michigan.
- P. E. Giblin, Ontario Division of Mines, Ministry of Natural Resources, Sault Ste. Marie, Ontario.

* Permanent member.

LOCAL COMMITTEE

Conference Chairman

P. E. Giblin, Ontario Division of Mines, Ministry of Natural Resources, Sault Ste. Marie, Ontario.

Secretary

E. J. Leahy, Ontario Division of Mines, Ministry of Natural Resources, Sault Ste. Marie, Ontario.

Technical Program

G. Bennett (Chairman), Ontario Division of Mines, Ministry of Natural Resources, Sault Ste. Marie, Ontario.

J. V. Huddart, The Algoma Steel Corporation Limited, Sault Ste. Marie, Ontario.

V. R. Venn, Sault College of Applied Arts and Technology, Sault Ste. Marie, Ontario.

Field Trips

J. F. Giguere (Co-ordinator), Sault College of Applied Arts and Technology, Sault Ste. Marie, Ontario.

G. Bennett, Ontario Division of Mines, Ministry of Natural Resources, Sault Ste. Marie, Ontario.

K. D. Card, Ontario Division of Mines, Ministry of Natural Resources, Toronto, Ontario.

M. J. Frarey, Geological Survey of Canada, Ottawa, Ontario.

D. G. Innes, Ontario Division of Mines, Ministry of Natural Resources, Sudbury, Ontario.

E. J. Leahy, Ontario Division of Mines, Ministry of Natural Resources, Sault Ste. Marie, Ontario.

E. F. Pattison, The International Nickel Company of Canada Limited, Sudbury, Ontario.

D. A. B. Pearson, Laurentian University, Sudbury, Ontario.

J. A. Robertson, Ontario Division of Mines, Ministry of Natural Resources, Toronto, Ontario.

R. J. Rupert, Consulting Geologist, Sault Ste. Marie, Ontario.

Physical Arrangements

- N. Shulman, Sault College of Applied Arts and Technology,
Sault Ste. Marie, Ontario.
- V. R. Venn, Sault College of Applied Arts and Technology,
Sault Ste. Marie, Ontario.

SESSIONS CHAIRMEN

- F. Q. Barnes, D. S. Robertson and Associates, Blind River,
Ontario.
- E. J. Debicki, The International Nickel Company of Canada
Limited, Sudbury, Ontario.
- R. L. Debicki, Ontario Division of Mines, Ministry of Natural
Resources, Sudbury, Ontario.
- J. M. Franklin, Lakehead University, Thunder Bay, Ontario.
- J. C. Green, University of Minnesota-Duluth, Duluth, Minnesota.
- C. E. Kemp, Lake Superior State College, Sault Ste. Marie, Michigan.
- R. W. Ojakangas, University of Minnesota-Duluth, Duluth, Minnesota.
- K. M. Siematkowska, Ontario Division of Mines, Ministry of
Natural Resources, Toronto, Ontario.

ACKNOWLEDGEMENTS

The local committee gratefully acknowledges the assistance and facilities generously given by G. R. Lawson, President, and the staff of Sault College of Applied Arts and Technology; the generous financial assistance of The Algoma Steel Corporation Limited; and the forbearance and dedicated assistance of Mrs. G. Nivins and Mrs. H. M. Giblin who typed the field guide manuscripts.

Cover: The Agawa Cliff

Photo by P. E. Giblin

P R O G R A M

Wednesday, May 1, 1974

- 8:00 a.m. Field trip 1 (Batchawana - Mamainse Point)
leaves Sault College. Returns about 6:00 p.m.
- 7:00 p.m. Institute registration - Auditorium lobby,
Sault College. Reception in The Gallery,
sponsored by Sault College.

Thursday, May 2, 1974

- 7:30 a.m. Institute registration - Auditorium lobby,
to
9:00 a.m. Sault College.

S E S S I O N 1

Morning

Thursday, May 2, 1974

Auditorium - Sault College

Co-chairmen: R. L. Debicki and K. M. Siemiatkowska

- | | | |
|-------|----------------------------------|--|
| 8:15 | P. E. Giblin | Opening Remarks. |
| | G. R. Lawson | Welcoming address by President,
Sault College. |
| 8:25 | W. F. Cannon | Tectonic setting of deposition
of the Marquette Range Super-
group and its bearing on
Precambrian global tectonics. |
| 8:50 | D. G. Innes | Proterozoic volcanism and
associated sulphide-bearing
metasedimentary rocks in the
Sudbury area. |
| 9:15 | L. L. Babcock | Jacobsville sandstone: A
Lower-Middle Keweenawan red
bed sequence. |
| 9:40 | H. C. Halls | A Keweenawan volcanic sequence
from the Slate Islands, northern
Lake Superior. |
| 10:05 | | Coffee. |
| 10:20 | J.B. Heslop &
W.M. Tupper | Geology, mineralogy and textural
relationships of the Coppercorp
deposit, Mamainse Point area,
Ontario. |
| 10:45 | J. L. Clark | Distribution and mode of
occurrence of copper sulfides
in the Kona Dolomite, Marquette
County, Michigan. |
| 11:10 | D. I. Norman | Fluid inclusion study of the
Tribag Mine, Batchawana Bay,
Ontario. |
| 11:35 | M.S. Loughheed
& J.J. Mancuso | The origin of magnetite in
iron-formation. |
| 12:00 | NOON | Lunch at student cafeteria. |

S E S S I O N 2

Afternoon

Thursday, May 2, 1974

Auditorium - Sault College

Co-chairmen: J. M. Franklin and R. W. Ojakangas

- 1:15 Business Meeting
- 1:30 J. Kalliokoski Relationship between regional geology and fracture patterns, Precambrian section, Upper Peninsula of Michigan.
- 1:55 R. F. Bacon Geological modeling of gravity features, northeastern Marquette County, Michigan.
- 2:20 P.I. Wallace, J.W. Cosgrove & P.M. Clifford A study of strain variation in supracrustal rocks at Upper Manitou Lake, N.W. Ontario.
- 2:45 R. V. Oja Granite batholiths: Where are they?
- 3:10 Coffee.
- 3:25 J.M. Robertson Major and minor element geochemistry of some Late Precambrian dikes, Keweenaw County, Michigan.
- 3:50 T.J. Bornhorst Geology and geochemistry of the Fish Cove rhyolite, Keweenaw County, Michigan.
- 4:15 J. C. Green Basaltic komatiites in the Vermilion district, Minnesota.

Evening

6:30 p.m. Cocktail hour (cash bar): Poolside, Water Tower Inn.

7:30 p.m. Banquet: Tarentorus Room, Water Tower Inn.

Address: J. Tuzo Wilson, Principal, Erindale College, University of Toronto.

"Some Recent Ideas on Plate Tectonics and Possible Driving Mechanisms".

S E S S I O N 3

Morning

Friday, May 3, 1974

Auditorium - Sault College

Co-chairmen: E. J. Debicki and J. C. Green

- | | | |
|-------|---------------------------------|--|
| 8:30 | M. A. Vos | Intergrowth textures in norite at Strathcona and their interpretation. |
| 8:55 | A. R. Coyner | Geology of copper and cobalt veins, Loon Lake, Minnesota. |
| 9:20 | P.C. Thurston | The Shawmere anorthosite complex: General geology and regional setting. |
| 9:45 | P.R. Mainwaring & A.J. Naldrett | The Water Hen intrusion - A discrete layered body in the troctolitic series of the Duluth Complex. |
| 10:10 | | Coffee. |
| 10:25 | R.W. Seasor | Re-interpretation of structure, White Pine Mine, White Pine, Michigan. |
| 10:50 | W.H. Listerud | The geology of a sulphide deposit in Lower Precambrian metavolcanic-metasedimentary rocks near Birchdale, Koochiching County, Minnesota. |
| 11:15 | R.W. Ojakangas | Puerto Rican island arc geology: A comparison with an Archean volcanic-sedimentary belt. |
| 11:40 | B.A. Carlson & W.J. Hinze | Gravity correlation with rock types in northeastern Wisconsin. |
| 12:05 | NOON | - Lunch at student cafeteria. |

S E S S I O N 4

Afternoon

Friday, May 3, 1974

Auditorium - Sault College

Co-chairmen: F. Q. Barnes and C. E. Kemp

- | | | |
|------|---|---|
| 1:15 | K.J. Freeman,
T.A. Vogel &
G.L. LaBerge | A quantitative textural analysis of
a north central Wisconsin shear
zone. |
| 1:40 | D.H. Watkinson
& J.H. Grimes | The Spanish River alkaline rock-
carbonatite complex, Townships
107 and 108, Ontario. |
| 2:05 | R.L. Bauer | Superimposed folding in the
Granite Falls-Montevideo area,
southwestern Minnesota. |
| 2:30 | A.P. Ruotsala | Composition and tectonic setting
of Middle Precambrian lavas,
Crystal Falls area, Michigan. |
| 2:55 | | Coffee. |
| 3:10 | E. Booy | A review of contributions to
improvement of iron-mining
environmental management, Upper
Peninsula of Michigan. |
| 3:35 | C.A. Salotti
& D. Weirauch | The economic potential of
sideritic cherts as a source of
elemental iron and silica. |
| 4:00 | S.C. Nordeng | Glacial sediments of the Huron
Mountain area, Michigan. |
| 4:25 | N.F. Trowell | An unusual carbonate breccia
unit at Sturgeon Lake, northwestern
Ontario. |
| 4:50 | <u>END OF TECHNICAL SESSIONS</u> | |

Evening

Friday, May 3, 1974

- 5:00 Dinner in the Courtyard or Rotunda, Sault College.
- 7:00 Departure for Field Trip 3 (North Shore Lake Huron).
Field Trip 4 (Huronian Supergroup).
Field Trip 5 (Michipicoten).

Buses will depart from Sault College. Cars may be left overnight in student parking lot on May 3rd and May 4th.

Sunday, May 5, 1974

- 6:00 p.m. (approx.) Return of Field Trips 3, 4, and 5.

JACOBSTOWN SANDSTONE: A LOWER-MIDDLE KEWEENAWAN RED BED SEQUENCE

L. L. Babcock, Institute of Mineral Research, Michigan Technological University, Houghton, Michigan 49931

ABSTRACT

Results of study indicate the Jacobstown sandstone (JS) is a red bed sequence younger than the South Range Lava Series (SRLS) and older than the Portage Lake Lava Series (PLLS). These findings are in accord with independent evidence presented by Hubbard (1968).

Nine sections were investigated in the Laurium Quadrangle along the trace of the Keweenaw fault. The JS and PLLS exhibit two types of interbedding locally: 1) conglomerates with similar pebble-boulder lithologies and 2) quartzose JS-type silty sandstones within the lowermost PLLS. Friable conglomerates and mudstones are present in all but the two most southerly sections. These sediments, of mudflow and/or channel origin, were deposited on alluvial fans whose apices were located towards the west in the region now occupied by the PLLS and overlying Upper Keweenaw sediments. Undisturbed exposures of pebble conglomerates (9.5 m) and mudstones (11 m) are present at Hungarian Falls in the Dover Creek section. However, about 9 km to the north at Natural Wall Ravine, similar sediments have been folded into an asymmetrical south-plunging anticline.

The Keweenaw fault is considered to represent a disturbed zone at the interface of a thick sedimentary sequence (JS) and an even thicker volcanic series (PLLS). This zone defines a marginal hinge line of the basin where in the PLLS was deposited. Structure in the Natural Wall Ravine-Mayflower mine area is interpreted as a buttress-type anticline along the basin margin formed as a direct result of progressive rifting.

The JS is believed to have been deposited in a fault-bounded intercratonic trough. Red bed sequences of this type, ranging in age from Precambrian to Triassic, are often interbedded with volcanics which erupted along marginal faults (Selley, 1970).

References

- Hubbard, H. A., 1968: Stratigraphic relationships of some Keweenaw rocks of Michigan and Wisconsin, 14th Ann. Inst. on Lake Superior Geol., Superior, Wisconsin, pp. 35-37.
- Selley, R. C., 1970: Ancient sedimentary environments - A brief survey, Cornell Univ. Press, Ithaca, New York, 237 p.

GEOLOGICAL MODELING OF GRAVITY FEATURES,
NORTHEASTERN MARQUETTE COUNTY, MICHIGAN

Ronald F. Bacon, Department of Geology and Geological Engineering,
Michigan Technological University, Houghton, Michigan 49931.

ABSTRACT

The geology of northern Marquette County, as detected on present geological maps is at best a good approximation due to the heavy overburden conditions and the lack of good geological data. Thus, in order to better define the geologic structure, approximately 530 gravity stations were occupied in the summer of 1973. This data is currently being used to model the structure of the area, using measured rock densities and a rough overburden thickness map compiled from well data.

The prominent gravity gradients resemble those mapped by Bacon in 1953. However, the new work has disclosed a gradient that parallels the shore of Lake Superior.

SUPERIMPOSED FOLDING IN THE GRANITE FALLS-
MONTEVIDEO AREA, SOUTHWESTERN MINNESOTA

R.L. Bauer, Department of Geology, University of Missouri-
Columbia, Columbia, Missouri 65201.

ABSTRACT

An analysis of the orientation and distribution of minor structures and their mutual relationships indicates that the Early Precambrian granulite-migmatite terrain in the Granite Falls-Montevideo area has been subjected to three phases of deformation. The oldest recognizable deformation formed the most prominent structural feature in the area, a gently eastward plunging antiform in the Granite Falls area, and an inferred synform between the outcrops north of Granite Falls and the outcrops south of Montevideo. The axial plane of the major antiform trends E-W and dips steeply to the south. Where unaffected by later folding, most minor F1 folds bear orientations consistent with this major structure.

The dominant structures developed during the second and third periods of deformation are minor folds which cannot be related to any large scale folding in the area. The orientation of the axes of F2 and F3 folds vary with their position on the major F1 structure, and concentrate along the line formed by the intersection of the F2 or F3 axial planes and the local foliation planes.

The axial planes of F2 folds trend NE-SW with a moderate to steep southeast dip. Axes of F2 folds on the northeast dipping limb of the major antiform plunge gently to moderately ENE, and are generally coincident with axial plane-foliation intersections. Large variations in the axial trends and plunge of F2 folds on the southeast dipping outcrops south of Montevideo and the southeast dipping limb of the Granite Falls antiform are attributed to the near coincidence of the F2 axial planes and the foliation in these areas.

Folding associated with the third deformation is well developed only in the Montevideo area. The axial planes of the F3 folds trend NW-SE and are moderately inclined to the northeast. The F3 fold axes plunge moderately ESE, consistent with axial plane-foliation intersection in the area. Sparse north and northwest trending folds north of Granite Falls may be the only evidence of F3 folding in the Granite Falls area.

REVIEW OF CONTRIBUTIONS TO THE IMPROVEMENT
OF IRON-MINING ENVIRONMENTAL MANAGEMENT,
UPPER PENINSULA OF MICHIGAN

Emmy Booy, Department of Geology and Geological Engineering,
Michigan Technological University, Houghton, Michigan 49931.

ABSTRACT

The current emphasis on environmental impact of mining activities has required efforts to provide both base-line and subsequent data showing the effects of various facets of mining operations on the original surroundings. Although various governmental agencies have been concerned with a variety of air, land, and water effects of mining in the past, new regulations are having a major impact on methods of disposal of wastes from existing as well as planned mines.

Because of the great variability of materials being mined (both ore and waste), as well as topographic and climatic factors, solutions which are economical and beneficial in one mine or region may be neither in another. Some extrapolation from region to region of a type of mine or from mine to mine in a region is possible, but there are no guaranteed solutions in the light of current knowledge.

On mine lands belonging to the Cleveland Cliffs Iron Company in the Upper Peninsula of Michigan studies of the effects of mining on land, water, and air have been and are being carried out. The effects of introduction of mine waste waters on vertebrate and invertebrate stream life include potential increases in trout habitat in some instances. Utilization of mine tailings themselves in construction of tailings dams will reduce the need for construction material from other sources. Revegetation of the solid wastes not only stabilizes the tailings with respect to wind and water erosion, but also provides wildlife habitat and may improve the aesthetic appeal of the mine area.

In all instances the systems under study are complex and side effects of proposed disposal of mine waste products require intensive and continuous monitoring. Environmental changes beneficial to some species may be deleterious to others; oversimplification must be avoided in efforts to improve the mining environment as a whole.

GEOLOGY AND GEOCHEMISTRY OF THE FISH COVE RHYOLITE, KEWEENAW COUNTY, MICHIGAN

Theodore J. Bornhorst, Department of Geology and Geological Engineering, Michigan Technological University, Houghton, Michigan 49931.

ABSTRACT

The Fish Cove rhyolite outcrops in an area approximately 1200 ft. by 600 ft. within the lower portion of the Portage Lake Lava Series about 9 miles east of Lac La Belle on the shore of Lake Superior. The highly jointed rhyolite body is bounded on its northwest and southeast sides by two approximately parallel lineaments trending N45°E and is cut by a north-south trending fault. The jointing within the rhyolite appears to be closely related to these structures.

Twenty-one rock samples from the Fish Cove rhyolite body were analyzed for Ba, Mn, Rb, Sr, Zr, Ca, Ti, K, and total Fe. The Ba, Rb, and K data show significant and correlatable areal variations. The chemical variation suggests a possible model for the crystallization of the rhyolite body which is similar to the model proposed by Hart and others (1971) for the crystallization of an Icelandic basalt lava flow.

Keeping in mind that certain of the elements show large variation, the average composition determined for the Fish Cove rhyolite is: SiO₂ 75.4, Al₂O₃=13.7, Fe as Fe₂O₃=1.3, MgO=0.3, CaO=0.1, Na₂O=4.5, K₂O=4.2, TiO₂=0.1, H₂O=0.4 in weight percent and Ba=920, Mn=260, Rb=100, Sr=70, Zr=180 in ppm.

Data from chemical analyses of 7 other rhyolite bodies in the Portage Lake Lava Series indicates that the Fish Cove rhyolite is unique in terms of trace element chemistry which suggests that its magma source may be different from the others. It appears that this type of chemical "fingerprinting" which was used by Jack and Carmichael (1969) in California is applicable for the "fingerprinting" of the rhyolites in the Portage Lake Lava Series.

References

- Hart, S.R., Gunn, B.M., and Watkins, N.D., 1971, Intralava variation of alkali elements in Icelandic basalt: *Am. Journ. Sci.*, v. 270, p. 315-318.
- Jack, R.N., and Carmichael, I.S.E., 1969, The chemical "fingerprinting" of acid volcanic rocks: *California Div. Mines and Geology, Spec. Rept. 100*, p. 17-32.

TECTONIC SETTING OF DEPOSITION OF THE MARQUETTE RANGE
SUPERGROUP AND ITS BEARING ON PRECAMBRIAN GLOBAL TECTONICS

W.F. Cannon, U.S. Geological Survey, Reston, Virginia 22092

ABSTRACT

The Marquette Range Supergroup in the northern peninsula of Michigan is divisible into three major assemblages, each deposited in a distinct tectonic regime: 1) a relatively thin shelf assemblage of orthoquartzite, carbonate, and shale; 2) a somewhat thicker miogeosynclinal assemblage of quartzite, shale, iron-formation, and minor mafic volcanic rocks; 3) a very thick eugeosynclinal assemblage of graywacke, shale, iron-formation, and submarine volcanic rocks.

The assemblages were deposited sequentially. The basal shelf is overlain with low-angle unconformity by the miogeosynclinal assemblage, which is in turn overlain with low-angle unconformity by the eugeosynclinal assemblage. Later tectonism and erosion have exposed the pre-Marquette Range basement on many structural uplifts throughout much of northern Michigan and parts of northern Wisconsin. The exposures clearly show that the supergroup was deposited unconformably on deeply eroded Archean sialic rocks.

During the past several years many crustal features and processes in Phanerozoic rocks have been related to the systematic concept of plate tectonics, and it is only natural that this concept should have been extended in an attempt to explain the evolution of the Precambrian crust. Paramount in such studies is the development of criteria by which relict plate margins can be recognized within Precambrian shields. One criterion suggested by some investigators is the lateral change in sedimentary facies from a shelf or miogeosynclinal assemblage to a eugeosynclinal assemblage. This criterion is based on the assumption, possibly valid for Phanerozoic rocks, that shelf and miogeosynclinal assemblages are deposited on a continental (sialic) plate or plate segment, whereas eugeosynclinal assemblages are deposited on an oceanic (simatic) plate or plate segment. If this assumption were valid for Precambrian rocks, the transition from shelf or miogeosyncline to eugeosyncline would be prima-facie evidence of the former existence of a contact between continental and oceanic crust, but relationships in the Marquette Range Supergroup show that thick eugeosynclinal assemblages can accumulate on continental crust and that a transition from shelf or miogeosyncline to eugeosyncline need not be associated with a plate margin.

A paleotectonic reconstruction of the central United States and Canada in which the Marquette Range Supergroup was deposited in an ensialic eugeosyncline within a very large Archean shield is at least as consistent with known geology as are alternate reconstructions involving large lateral plate motions.

GRAVITY CORRELATIONS WITH ROCK TYPES IN NORTHEASTERN WISCONSIN

B.A. Carlson, Department of Geology, Delta College, University Center, Michigan 48710; and W.J. Hinze, Department of Geosciences, Purdue University, Lafayette, Indiana 47907.

ABSTRACT

A gravity investigation of northeastern Wisconsin, approximately north of 45° N. lat and east of 89° W. long, was made using LaCoste and Romberg gravimeters. Over 3500 observations were made at 1.61-km intervals along all available roads. A Bouguer gravity anomaly map contoured with a 2-mgal interval is available (Carlson, 1972). Correlation of this map with available bedrock geologic data shows several interesting relationships.

The existence of the Quinnesec and Waupee greenstone belts as separate bodies is supported by the Bouguer gravity anomaly map. The Waupee exposures in the Mountain area appear to be the exposed western portion of a much larger greenstone belt.

Three ages of intrusive igneous activity have been delineated in northeastern Wisconsin (Van Schmus, 1973). The Northeast Complex, the oldest of the granitic rocks at 1850-1900 m.y. is well defined by gravity in the Pembine area where most of its various units have been defined by geologic mapping. A strong negative Bouguer anomaly extends from Pembine westward across the entire study area, suggesting the existence of an igneous complex of batholithic proportions. The gravity expression of the Wolf River Batholith, the youngest of the granitic rocks at 1450-1500 m.y., correlates well with its distribution as shown by Medaris and others (1973). The intermediate age granitic rocks with ages of 1650 to 1700 m.y. do not appear to be represented by major gravity anomalies.

References

- Carlson, B.A., 1972, Bouguer Gravity Anomaly Map, Northeastern Wisconsin: Wisconsin Geological Survey.
- Medaris, L.G., Jr., Anderson, J.L., and Myles, J.R., 1973, The Wolf River Batholith - A Late Precambrian Rapakivi Massif in Northeastern Wisconsin: 19th Ann. Inst. on Lake Superior Geology Guidebook, p. 9-29.
- Van Schmus, W.R., 1973, Geochronology of Precambrian Rocks in Eastern Wisconsin: 19th Ann. Inst. on Lake Superior Geology Abstracts, p. 41.

DISTRIBUTION AND MODE OF OCCURRENCE OF COPPER
SULFIDES IN THE KONA DOLOMITE
MARQUETTE COUNTY, MICHIGAN

Jeffrey L. Clark, Department of Geology and Geological Engineering,
Michigan Technological University, Houghton, Michigan 49931.

ABSTRACT

Copper sulfides occur in economically interesting concentrations near the base of the Kona Dolomite of middle Precambrian age in the eastern end of the Marquette Trough. Diagenetic chalcocite, bornite, and chalcopyrite occur with syngenetic pyrite in a 10 meter thick unit within the Lower Quartzite Member (Taylor, 1972), consisting of a pink dolomitic quartzite bounded on top and bottom by green argillite.

Pyrite occurs as .01 mm-5.0 mm euhedral cubes, pyritohedron, and framboidal clusters throughout the entire areal extent of the mineralized beds. It is more common within the silty lamina of the argillites and cherty sections of the dolomitic quartzite. Chalcocite, bornite, and chalcopyrite occur as intergranular subhedral to anhedral masses of .01 mm-5.0 mm in the more silty lamina of the argillites, interstitially with the dolomite cement, and as fracture fillings throughout. Pseudomorphs of .05 mm-5.0 mm chalcocite after pyrite are common.

The copper mineralization is more extensive in the eastern extent of the member and its grade appears to be a function of the abundance of syngenetic pyrite and the original porosity of the host rock. Vertical and horizontal zonation of copper, sulfur, and sulfide species suggest that the dolomitic quartzite bed may have acted as an aquifer for the mineralizing solutions. Where these solutions came in contact with pyrite-bearing host rock, copper sulfides either replaced the syngenetic pyrite or were precipitated in its presence.

References

- Taylor, G. Lynn, 1972, Stratigraphy, Sedimentology, and Sulfide Mineralization of the Kona Dolomite, Unpub. Ph. D. dissertation, Michigan Technological University.

GEOLOGY OF COPPER AND COBALT VEINS, LOON LAKE, MINNESOTA

A.R. Coyner, Department of Geology, University of Minnesota-Duluth, Duluth, Minnesota 55812.

ABSTRACT

Several small sulfide veins with significant copper and cobalt values occur on the Blankenburg-Whiteside Property located in Sec. 34, T65N, R3W, Cook County, Minnesota. The area is along the Gunflint Trail approximately 38 miles northwest of Grand Marais, Minnesota. The mineralized veins are in diabase sills of the Keweenaw, Logan intrusions. The sills form ridges with the sedimentary Middle Precambrian Rove Formation in the valleys. About one quarter mile to the south is layered series of the Keweenaw Duluth Complex.

Scattered areas of sulfide mineralization have been known in northern Cook County for some time. Northeastward in Ontario, Canada, similar sulfide deposits have been mined in the early 1900's, principally for silver. The deposits occur in a fracture zone at or near the basal contact of a diabase sill. The veins on the Blankenburg-Whiteside Property are located in the base of a 150 foot thick diabase sill at or near the contact with the Rove Formation. The diabase sills and Rove Formation increase in dip from 25° to 60° as they near the Duluth Complex. This forms a monoclinial hinge line along which the fracturing occurred that localized the sulfide mineralization. Sulfides include abundant arsenopyrite, minor chalcopyrite, some pyrite, pyrrhotite, and iron oxides. The cobalt occurs in the arsenopyrite.

A test pit on the east end of the property shows a 20 foot mineralized zone. Selected samples contain up to 5.04% copper and 1.08% cobalt. Studies are being made to show the distribution of Cu, Ni, Zn, and Co in the veins and country rock.

A QUANTITATIVE TEXTURAL ANALYSIS OF A
NORTH CENTRAL WISCONSIN SHEAR ZONE

K.J. Freeman and T.A. Vogel, Geology Department, Michigan State University, East Lansing, Michigan 48824; G.L. LaBerge, Geology Department, University of Wisconsin-Oshkosh, Oshkosh, Wisconsin 54901.

ABSTRACT

A shear zone in north central Wisconsin trending approximately N 30° E and intersecting the western boundary of the Wolf River pluton in the Hogarty Hornblende Granite has been reported by LaBerge (1972) and LaBerge and Myers (1973). Megascopic textural variation occurs over a relatively short distance (about 1 mile) in the sheared granite, demonstrating a transition from relatively unsheared parent rock to an extremely fine-grained mylonite. The purpose of this paper is to quantitatively document the textural readjustment of an originally homogeneous rock unit to the increased temperature and strain rate associated with large-scale shearing, and to correlate the textural changes with plagioclase composition.

Ehrlich, *et al.* (1972) have discussed the technique and application of surface area measurements to textural analyses of rocks. Both total rock intergranular surface area and the partitioned component, plagioclase-plagioclase surface area, increase in a systematic manner. Total rock intergranular surface area varies from 12.37 mm²/mm³ in the least sheared sample to 82.84 mm²/mm³ in the finest grained mylonite; concomitantly plagioclase-plagioclase surface area ranges from 0.77 mm²/mm³ to 31.47 mm²/mm³ respectively. Quartz-quartz surface area in the least sheared sample is 0.70 mm²/mm³ and increases in the most severely sheared sample to 12.84 mm²/mm³. These results reflect the degree of granulation associated with the development of the mylonitic zone.

Plagioclase compositional data determined by microprobe analyses show that unsheared samples of Hogarty hornblende granite exhibit zoned plagioclases ranging from 13 - 27% An with a mean composition of 22% An, whereas in a slightly granulated sample, with zoning still evident, the range is 10 - 18% An and the mean is 16% An. The peristerite solvus is intersected with increased shearing and a distinctly heterogeneous plagioclase compositional population develops. In the most severely sheared sample, plagioclases of both 5% An and 13% An have been observed, and many grains exhibit compositional variations which may indicate local nonstoichiometry. Plagioclase compositional variation indicates that kinetic factors have led to chemical disequilibrium throughout the shear zone, although the margins of the zone are at greater disequilibrium than the interior. The tendency for plagioclase to adjust to the temperatures associated with low-grade metamorphism by decalcification was kinetically enhanced by increasing granulation.

The data suggest that both granulation and diffusive mass transfer have contributed to the mylonite development, but that the predominant deformational mechanism was granulation. With increased frictional heating, plagioclase compositions were primarily controlled by the peristerite solvus, indicating that diffusional processes were involved. The rate of diffusion-controlled grain growth was exceeded by the rate of granulation associated with the mylonitization.

It is evident that the NE-trending mylonite belts of central Wisconsin reflect zones of extremely high strain rates in which enough heat was generated to produce significant diffusion, but that grain growth could not keep pace with the granulation induced by the intense shearing.

BIBLIOGRAPHY

- Ehrlich, Robert, Thomas A. Vogel, Bernhard Weinberg, Diana Chapman Kamilli, Gary Byerly, and Howard Richter, 1972, Textural variation in Petrogenetic Analyses, Geol. Soc. Am. Bull. v. 83, pp. 665-676.
- LaBerge, G., 1972, Lineaments and Mylonite zones in the PreCambrian of Northern Wisconsin, abs., 18th Annual Institute on Lake Superior Geology, p. 27.
- LaBerge, G. and P. Myers, 1973, PreCambrian Geology of Marathon County, Guidebook to the PreCambrian Geology of Northeastern and North Central Wisconsin, 19th Annual Institute on Lake Superior Geology, pp. 31-36.

BASALTIC KOMATIITES IN THE VERMILION DISTRICT, MINNESOTA

J. C. Green, Department of Geology, University of Minnesota-Duluth,
Duluth, Minnesota 55812.

ABSTRACT

Mapping in the Lower Precambrian Newton Lake Formation of the Vermilion District near Ely, northeastern Minnesota, has uncovered pillowed lavas of peculiar shape, color, and texture which have a composition very close to the Viljoens' Barberton-type basaltic komatiites. They appear to be among the least metamorphosed of the Archean komatiites described to date from several continental shield areas. They form irregularly shaped, thin-rinded pillows and have a dark green to black color and a texture characterized by dark green amphibole needles up to 3 mm long, much larger than in ordinary pillowed basalts. In the microscope the needles are seen to be actinolite pseudomorphs after quench pyroxenes, in an aphanitic groundmass of actinolite, chlorite, and minor amounts of epidote and plagioclase. Skeletal relict augite is locally present within the actinolite needles, confirming their origin as primary igneous quench crystals and not metamorphic porphyroblasts.

These rocks resemble other basaltic komatiites in having approximately equal weight percentages of CaO and Al_2O_3 but are less siliceous and have a lower Mg/Fe ratio than other reported examples. They show normative contents of 27% plagioclase and 69% mafic minerals, and are intermediate between olivine-bearing ultramafic lavas of other districts (such as Munro Township, Ontario) and the much more common tholeiitic basalts of the greenstone belts.

A KEWEENAWAN VOLCANIC SEQUENCE FROM THE SLATE ISLANDS,
NORTHERN LAKE SUPERIOR

H.C. Halls, Department of Geology, Erindale College, University of
Toronto

ABSTRACT

A reconnaissance shoreline survey of the southern half of Patterson Island, the largest of the Slate Islands, has found a Keweenawan volcanic sequence exposed along the western side of the island. The sequence is about 400 feet thick and comprises 20 amygdaloidal basaltic flows, the thickest of which is about 50 feet. Flows dip lakeward at angles ranging from 30 to 80°, the dips increasing toward the base of the sequence. The flows rest unconformably on Archean metasediments, although at the extreme southern end of the volcanic belt, where dips are steepest, a layer composed of angular Archean metasedimentary fragments intervenes. The layer, which is about 10 feet thick may either represent a Keweenawan regolith or a fault breccia.

Paleomagnetic data show that the lavas are reversely magnetized and thus correlatable with the lower part of the Osler Group exposed on the Lake Superior mainland to the west. Alternating field demagnetization reveals a prominent secondary remanence with southeasterly declination which in many samples survives peak alternating fields of 1000 oe. The volcanics are extensively sheared so that it is possible that the secondary component was introduced at the time of shearing.

The island is riddled with Keweenawan diabase feeder dikes, which form spectacular ridges and pinnacles. The dikes strike easterly or northeasterly, and there are at least a hundred of them exposed around the southern half of the island.

GEOLOGY, MINERALOGY AND TEXTURAL RELATIONSHIPS OF THE
COPPERCORP DEPOSIT, MAMAINSE POINT AREA, ONTARIO.

J.B. Heslop and Dr. W.M. Tupper, Department of Geology,
Carleton University, Ottawa, Ontario K1S 5B6.

ABSTRACT

The deposit is a series of veins in a thick section of alternating amygdaloidal basalts and conglomerates of Keweenawan age. The Keweenawan rocks unconformably overlie Archean metavolcanics and metasediments and are themselves unconformably overlain by Cambrian sediments. Felsites and diabbases intrude the basalts and conglomerates.

Four periods of faulting and several periods of brecciation, ore, dike and calcite emplacement are recognised. Ore assemblages occur as open space fillings of dilatant fault zones. The ore mineral assemblage includes chalcocite, chalcopyrite, bornite, hematite, digenite, covellite, pyrite, native copper and gold, tetrahedrite, algodonite, domeykite, arsenian copper, wittichenite and clausthalite. These minerals occur in a quartz-calcite gangue.

The paragenetic sequence indicates that the non-oxide metallic phases underwent an increase in copper content during crystallization and the last stages involved deposition of native copper. Later supergene alteration led to the formation of digenite and covellite in the upper parts of the deposit.

Basalts adjacent to the veins are enriched in copper indicating that copper migrated from the veins into the wall rocks. The deposit may have formed from solutions moving updip from underlying, relatively permeable conglomerate beds.

PROTEROZOIC VOLCANISM AND ASSOCIATED SULPHIDE-BEARING METASEDIMENTARY ROCKS IN THE SUDBURY AREA

D. G. Innes, Ministry of Natural Resources, Sudbury, Ont.

Proterozoic-Aphebian metavolcanic and associated metasedimentary rocks of the Sudbury area occur in an east-to northeast-trending belt, south of and in contact with rocks of the Nickel Irruption in the east and granitic rocks of the Superior Province in the west. The volcano-sedimentary sequence is part of the Elliot Lake Group of the Huronian Supergroup and consists of several thousand feet of mafic metavolcanic and intercalated metasedimentary rocks of the Elsie Mountain and Stobie Fms., overlain by felsic metavolcanic rocks of the Copper Cliff Fm. These metavolcanic accumulations may be the result of fissure type eruptions and are possibly related to early faulting along the margins of an early (subsiding) Huronian basin. Thick accumulations of pelitic metasedimentary rocks of the McKim Fm., overlie the metavolcanic sequence. Associated mafic and felsic intrusions occur within the volcanic-sediment pile.

Chemical data suggests that the metavolcanic rocks are a subalkaline-tholeiitic sequence of slightly potassic metabasalts, (andesites?), dacites, rhyolites and associated pyroclastics. Salient features of the chemistry of the metavolcanic sequence are:

- (1) Increasing SiO_2 , K_2O and possibly Na_2O with stratigraphic height.
- (2) Decreasing Al_2O_3 , CaO , MgO , MnO , TiO_2 , Fe_2O_3 and FeO with stratigraphic height.
- (3) An increase in SiO_2 generally corresponds to a decrease in Al_2O_3 and Na_2O and an increase in K_2O .

Volcanogenic metasedimentary rocks show important facies changes within the Sudbury area suggesting that this region was a positive element and a centre of eugeosynclinal volcanism in lower Huronian time. Volcanic and sedimentary rocks of the Stobie Fm., display a cyclical development and host stratiform iron and copper sulphides. It is suggested that sulphur metasomatism, extracting and scavenging iron and copper from the metabasalts, in an early stage sulfataric exhalation process was responsible for the stratabound sulphide mineralization.

RELATIONSHIP BETWEEN REGIONAL GEOLOGY AND
FRACTURE PATTERNS, PRECAMBRIAN SECTION,
UPPER PENINSULA OF MICHIGAN

J. Kalliokoski, Department of Geology and Geological Engineering,
Michigan Technological University, Houghton, Michigan 49931.

ABSTRACT

Plastic relief topographic maps photographed under oblique illumination provide images that are a simplification of the original aerial photographs. Such "pseudo-radar" photographs of the Precambrian area of Michigan's Upper Peninsula discloses a fracture pattern that coincides with the distribution of the major rock units.

Archean areas are more jointed than are the surrounding Middle Precambrian and Keweenawan terrains. Some of the faults in the Middle Precambrian rocks may be reactivated Archean joints, and one lineament not recognized in any of the previous mapping, appears to represent a fault that extends northerly from the east end of the U-shaped Wolf Lake anticline, across the Jacobsville terrain to the Keweenaw fault. Interestingly, none of the regional joints can be ascribed to Keweenawan diabase dikes, suggesting that the Keweenawan stress system differed in orientation from the earlier one. In the eastern part of the area Paleozoic rocks have inherited the older Archean joint pattern.

Many major lineaments remain unexplained because of the lack of previous mapping, or in some places, because these features are too broad or indistinct to be recognized readily in the field, or on maps or air photographs. This new information (data) tends to be equivocal on the question of whether the northerly trending components of the joint and fault systems can be correlated with northerly trending gravity features in Lake Superior, or that they are a part of the Kapuskasing Lineament.

THE GEOLOGY OF A SULFIDE DEPOSIT IN LOWER PRECAMBRIAN METAVOLCANIC-METASEDIMENTARY ROCKS NEAR BIRCHDALE, KOOCHICHING COUNTY, MINNESOTA

William H. Listerud, Exploration Geologist, State of Minnesota, Department of Natural Resources, Division of Waters, Soils and Minerals, Hibbing, Minnesota 55746

ABSTRACT

The Birchdale area lies near the southern edge of the Superior Province of the Canadian Shield. The rocks are felsic-intermediate metatuffs, metasediments, granite and mafic intrusives. The rocks are in a northwest dipping, northeast trending monocline which is on the southern margin of a small granitic pluton, the Birchdale Granite. The greenstone rocks have been metamorphosed twice, first to upper greenschist or lower amphibolite facies during the regional metamorphism, and then to albite-epidote hornfels facies as a result of the intrusion of the Birchdale Granite. The two metamorphic events have obscured much of the original textures and structures of the rocks and made the origin of the sulfides more difficult to determine.

The sulfides of the Birchdale anomaly area are pyrrhotite, pyrite, chalcopyrite, sphalerite, pentlandite and marcasite. The main sulfide horizon is in a series of interbedded metatuffs and graphitic metasediments, although disseminated sulfides are found throughout the section. Pyrrhotite is the principal sulfide, with only minor amounts of the other phases. The main sulfide horizon thickens, increases in sulfide content, and increases in graphitic material northeastward along strike. Trace element work has shown apparent increases in cobalt and nickel, and an enrichment of copper over zinc northeastward. The sulfides appear to be syngenetic, based on their position in the sequence and their relationships with the enclosing rocks. The sulfides now show mineralogy, textures, and structures related to the metamorphic episodes.

The best mineralization intersected in this area was a two-foot thick 4% zinc zone. This zone occurred above the main sulfide horizon. This section of core was unavailable for observation during this study and details of this occurrence are poorly known.

THE ORIGIN OF MAGNETITE IN IRON-FORMATION

M. S. Lougheed and J. J. Mancuso
Department of Geology, Bowling Green
State University, Bowling Green, Ohio 43403.

ABSTRACT

The essential primary (initial) components which produce iron-formation are biogenically precipitated carbonate (calcite or aragonite); opaline tests of microorganisms; microorganisms in decaying organic material; carbonate precipitating bacteria of which some may be symbiotic; iron precipitating bacteria; and water having dissolved compounds of calcium, silicon, ferrous iron, and magnesium.

Most calcium carbonate is biologically produced by algae in the form of microspheres, which average 75 microns in diameter. The microspheres are built by successive layers of algae and calcium carbonate, seven layers being most common but ranging in number from two to eleven.

Lesser amounts of calcium carbonate are produced by the following: an organism with a single layer spherical test averaging 16 microns in diameter, composed of discrete submicron grains of carbonate; carbonate bacteria within the body cavity of organisms with discus or ellipsoidal opaline tests, which average 20 x 12 microns in the two dimensions; and by carbonate bacteria in decaying organic material.

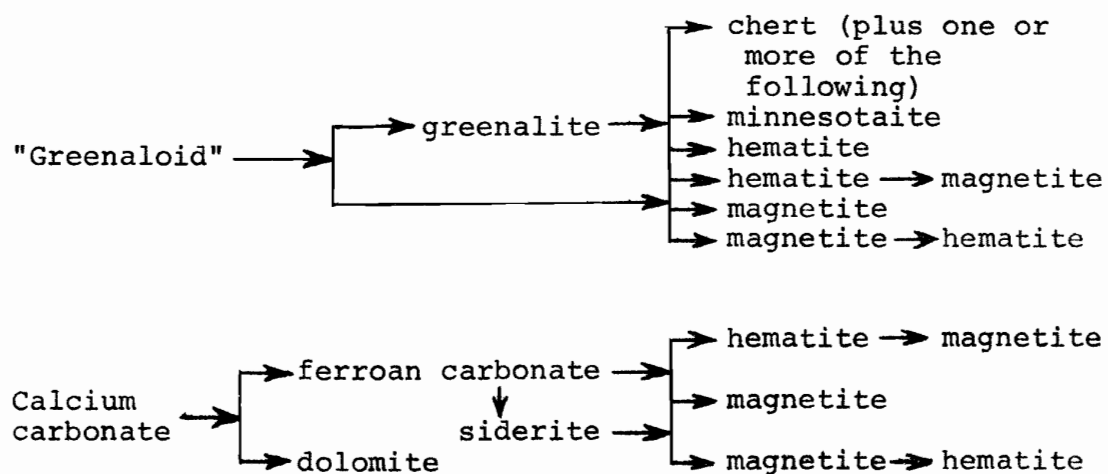
Comminuted opaline tests mixed with decaying organic material and attendant iron bacteria produce a "hydrous silica-ferrous iron gel". We propose the term "greenaloid" for this gel of variable and complex nature.

Before or during early diagenesis greenaloid produces greenalite (iron antigorite) or isotropic iron serpophite. Carbonate bacteria may be present producing calcium carbonate, which is a commonly associated mineral.

Iron bacteria may precipitate magnetite, but our observation of this possibility is equivocal and is more easily interpreted by sequences listed below. Biogenically produced pyrite may subsequently be oxidized to hematite and then reduced to magnetite. This sequence appears to be of minor importance.

Two major sequences occur which will produce magnetite. The various steps in these sequences are controlled by Eh and pH conditions in microenvironments prior to deposition, during deposition, and in the early stages of diagenesis. The initial biogenic accumulate is variable and the chemical sequences that follow may be interrupted at any stage, which accounts for the various mineralogic facies of iron-formation.

The two major sequences are as follows:



THE WATER HEN INTRUSION-A DISCRETE LAYERED BODY IN
THE TROCTOLITIC SERIES OF THE DULUTH COMPLEX

P.R.Mainwaring, University of Toronto, Toronto 181, Ont.

A.J.Naldrett, University of Toronto, Toronto 181, Ont.

Abstract

The Duluth Complex in north-eastern Minnesota forms an arcuate composite intrusion 130 miles in maximum dimension. It is underlain in the south by Middle Precambrian metasediments locally known as the Thomson or Virginian formation and in the north by Archean basement, Basaltic flows overlies the entire complex.

Roughly, the Duluth Complex is divisible into two parts. The easterly Anorthositic series, rocks in which plagioclase (An70) is the only cumulus mineral - olivine and pyroxenes being intercumulus and the younger Troctolitic Series rocks to the west which contain cumulus olivine (Fo57) pyroxene (Wo40Fs16) and plagioclase (An64).

The Water Hen Creek Intrusion is a relatively small body which has been emplaced along the Middle Precambrian footwall-Troctolitic Series contact and consists of layered cumulates. Dunite, peridotite, ilmenite peridotite and troctolite with minor anorthosite comprise the greater part of the intrusion.

Layering is defined by cyclical repetitions of mineral graded layers most of which exhibit little lateral continuity. Groups of layers and other marker horizons in drill core have been used to delineate the structure in the absence of outcrop. Phase layering is rare as are orthopyroxene cumulates. Olivine is unzoned and compositions range between Fo63 in the dunite to Fo46 in some contaminated rocks. Cycles that have cumulus augite are rare while zoned intercumulus augite (Wo42Fs16) is very common. Cumulus ilmenite is homogeneous while coexisting magnetite is totally absent.

Abundant intercumulus sulfide occurs in most dunites whereas it is virtually absent in the more feldspathic rocks. This contrasts strongly with the known mineralization in the feldspathic rocks near Ely, Minn. in the north part of the Duluth Complex. Sulfide mineralization in the Water Hen Intrusion also occurs in rocks that show evidence of contamination by Thomson or Virginia slates. Partial assimilation is evidenced by the formation of cordierite-hypersthene rich inclusions and advanced assimilation by cordierite-graphite inclusions usually with small amounts of sulfide development. Sulfur isotope data suggest that at least some of the sulfides have been derived from isotopically related sulfur sources such as those found in metasediments in the footwall of the Complex. It is believed that the parent magma which produced the Water Hen Intrusion was slightly olivine normative while local contamination has produced a hypersthene normative liquid.

GLACIAL SEDIMENTS OF THE HURON MOUNTAIN AREA, MICHIGAN

S. C. Nordeng, Department of Geology and Geological Engineering,
Michigan Technological University, Houghton, Michigan 49931

ABSTRACT

During the summer of 1973, over one hundred trailer-mounted auger drill holes were drilled to basement in the northern part of Baraga and Marquette Counties as part of the environmental impact studies carried out in connection with Project Sanguine.

Study of samples collected at five foot intervals in each hole shows the necessity for combining sedimentological and stratigraphic studies with land form analysis in investigation of the glacial geology of an area.

Areas mapped as moraine were found to contain material with sedimentary parameters consistent with fluvial origin and which formed a fining-upward sequence in sharp contrast with the coarsening-upward sequence and poorer sorting prevalent in areas of outwash. These ridges are believed to have formed as ice-contact features in ice walled channels which left ridges of sediment on melting.

FLUID INCLUSION STUDY OF THE TRIBAG MINE,
BATCHAWANA BAY, ONTARIO

David I. Norman, University of Minnesota, Minneapolis,
Minnesota 55455.

ABSTRACT

The Tribag mining property consists of five, closely spaced, Keweenaw-age breccia pipes located along major fracture zones in Archean metavolcanics and granite. Analysis of fluid inclusions in quartz and calcite from the three mineralized pipes, along with paragenesis, suggest five stages in the brecciation, void filling and mineralization of the Tribag breccias.

1. Boiling fluids above 400°C , containing salts 8-9 eq. wt. % NaCl, and supersaturated with CO_2 deposited the finely disseminated Cu and Mo sulphides in the East breccia. Similar waters were responsible for the emplacement of the quartz-Mo veins which cut the general area preceding the formation of the other breccias.

2. Subsequent to and possibly during the formation of the Breton breccia, the void spaces were nearly filled with quartz from boiling solutions $350-400^{\circ}\text{C}$, salinity 7-8% and saturated with CO_2 . Calcite deposition followed from 325°C fluids.

3. Boiling hydrothermal water $300-320^{\circ}\text{C}$, salinity 1-5%, with little CO_2 deposited the quartz, which makes up almost the entire matrix of the West breccia.

4. The major sulphide deposition in the Breton breccia and surrounding granite plus the West breccia resulted from hydrothermal fluids $250-300^{\circ}\text{C}$, salinity varying between 7 and 17%, and with considerable CO_2 .

5. Waters with temperatures decreasing to 140°C , salinity oscillating between 5 and 12% were responsible for the late stage galena, quartz and calcite.

Two general observations may be made. Brecciation was accompanied or subsequently followed by superheated waters, boiling perhaps vigorously. The main sulphide mineralization in the Breton and West breccias followed from cooler waters of varying salinity.

The high temperatures, CO₂ content, and salinity suggest a nearby magmatic source. Time-related changes in the character of the hydrothermal fluids may be attributed to the mixing of saline, CO₂-rich magmatic water with local ground water.

GRANITE BATHOLITHS, WHERE ARE THEY?

R.V. Oja, Oja Limited, Thunder Bay, Ontario P7A 4V5.

ABSTRACT

Although approximately 85 percent of the Early Precambrian of Northwestern Ontario, an area of approximately 250,000 square miles are composed of granitic rocks as shown on maps of the Ontario Division of Mines, very little research has been conducted on this vast volume of rock that has been dated at approximately 2,500 m.y. and variously designated as Laurentian, Algoman or Kenoran.

Even a cursory field investigation immediately reveals the fact that these rocks are not true granites at all, but are largely granitized formations which still contain relic sedimentary structures, generally designated as granite gneisses, migmatites, granitized sediments or lit par lit injections. While intrusive granite stocks and batholiths are described in numerous reports, even these areas extend into granitized border zones where foliation parallels that of surrounding granitized country rocks. From the above, it appears that nearly all the granites in Northwestern Ontario were derived through simple anatexis, and only scattered areas arrived at a point of complete melting or magmatization which now exhibit chilled edges, whereas most other contact zones are in a frozen state of partial melting of the pre-existing sedimentary formations.

Many basic intrusives throughout the Precambrian Shield are surrounded by vast areas on these granitic formations, despite the fact that all the geological maps indicate the basic intrusives to be older than the granitic formations. If the granites are truly later than the basic intrusives, what did the basic rocks intrude? Perhaps many of the granitized sediments are actually older than the Early Precambrian volcanics and quite possibly were granitized already in pre-Keewatin time.

If abundant sedimentary and perhaps volcanic formations did, in fact, exist before Keewatin time, what happened to any syngenetic ore deposits that these formations once may have harboured? It is suggested that the Early Precambrian "granites" be thoroughly researched since all the radiometric clocks seem to have stopped at 2,500 m.y. and no reliable datings of greater vintage can be obtained.

PUERTO RICAN ISLAND ARC GEOLOGY: A COMPARISON WITH AN ARCHEAN VOLCANIC-SEDIMENTARY BELT

Richard W. Ojakangas, Department of Geology, University of Minnesota,
Duluth, Minnesota 55812

ABSTRACT

Puerto Rico was part of an active volcanic island arc in Cretaceous-early Cenozoic time. Several workers (e.g., Malfait and Dinkelman, 1972) relate the volcanism to a subducting plate boundary. A comparison of Puerto Rican geology with that of the Archean Vermilion district of northeastern Minnesota (a volcanic-sedimentary belt representative of many "greenstone" belts of the Canadian Shield) shows numerous similarities. The scale is of the same magnitude in both total size and in distribution and thickness of individual rock units. The volcanic, sedimentary, and intrusive lithologies are generally similar. The volcanism and plutonism (partly coeval) presumably occurred over similar time spans -- about 75 m.y. in Puerto Rico (Monroe, 1968) and 50 m.y. in the Vermilion district (e.g., Goldich, 1972).

A detailed study of the Eocene Rio Culebrinas Formation in northwestern Puerto Rico, a 3000 m thick volcanogenic sedimentary unit comprised of sandstone, siltstone, mudstone, conglomerate, and breccia, reveals many similarities with volcanogenic sedimentary Archean units such as the Knife Lake Group. There are parallels in petrography and sedimentary structures. Both units apparently are the result of the erosion of volcanic piles of variable, but dominantly intermediate-felsic compositions. Turbidity currents were an important mechanism of transportation and deposition. All Rio Culebrinas sandstones ("graywackes" in the field) contain abundant volcanic rock fragments and plagioclase (commonly zoned); some contain hornblende, others pyroxene, and others volcanic quartz. A paleocurrent study, together with the lithologic variations, indicates multiple sources.

Two copper sulfide ore bodies (Lutjen, 1971) associated with the plutons have been fully drilled out and are awaiting development.

REFERENCES

- Goldich, S.S., 1972, Geochronology in Minnesota: In *Geology of Minnesota: A Centennial Volume*, P.K. Sims and G.B. Morey, Editors, Minnesota Geological Survey, St. Paul, Minnesota, p. 27-37.
- Lutjen, G.P., 1971, The curious case of the Puerto Rican copper mines: *Engineering and Mining Journal*, February.
- Malfait, B.T. and Dinkelman, M.G., 1972, Circum-Caribbean tectonic and igneous activity and the evolution of the Caribbean plate: *Geol. Soc. America Bull.*, V. 83, p. 251 - 272.
- Monroe, W.H., 1968, The age of the Puerto Rican trench: *Geol. Soc. America Bull.*, V. 79, p. 487-493.

MAJOR AND MINOR ELEMENT GEOCHEMISTRY OF SOME LATE
PRECAMBRIAN DIKES, KEWEENAW COUNTY, MICHIGAN

James M. Robertson, Department of Geology & Geological Engineering,
Michigan Technological University, Houghton, Michigan 49931.

ABSTRACT

A number of late Precambrian dikes have been identified in diamond drill cores from the Portage Lake Lava Series just north of the Keweenaw Fault toward the eastern end of Michigan's Keweenaw Peninsula.

Fifteen chemical analyses were obtained from selected dike samples, and two new analyses from the intrusive diorite and granophyre body at Mount Bohemia.

The dikes range in composition from basalt to dacite, although the majority are andesitic. Chemically, the dikes are sub-alkaline and straddle the dividing line proposed by Irvine and Baragar (1971) to distinguish between typical tholeiitic and calc-alkali petrogenetic suites. The more mafic rocks fall within the tholeiitic field; the more felsic, well inside the calc-alkali. When combined with other chemical data from the Portage Lake Lava Series, the dike analyses suggest an intermediate to more calc-alkali line of descent for Michigan's Keweenawan igneous rocks than has been previously proposed (Jolly and Smith, 1972).

Both the diorite and granophyre in a small intrusive plug at Mount Bohemia display chemical affinities with the dikes, and all may be genetically related.

COMPOSITION AND TECTONIC SETTING OF MIDDLE
PRECAMBRIAN LAVAS, CRYSTAL FALLS AREA, MICHIGAN

A. P. Ruotsala, Department of Geology and Geological Engineering,
Michigan Technological University, Houghton, Michigan 49931

ABSTRACT

Twenty-seven samples of metavolcanic rocks from the Crystal Falls-Iron River area, Michigan, and Florence County, Wisconsin, were chemically analyzed. The rocks analyzed include the Hemlock and Badwater Formations (Middle Precambrian) and Quinnesec Formation (Archean?).

AFM diagrams show that the Hemlock and Badwater Formations are tholeiitic while the Quinnesec is distinctly more alkaline. On the basis of these limited analyses the Quinnesec does not correlate with either Hemlock or Badwater Formations.

The Hemlock and Badwater Formations have higher contents of total Fe, TiO_2 and K_2O and lower contents of CaO and Al_2O_3 than reported analyses of Canadian Archean greenstones. The Hemlock Formation shows typical upward gradations noted in Archean greenstone belts. On the basis of a limited number of analyses, the Badwater greenstone appears to be homogeneous.

The Hemlock volcanic rocks ring the Amasa Oval and show considerable thickening on the western flank, where the sequence also contains the Kiernan Sill. This thickening and the sill suggests a volcanic center to the west. The Badwater greenstone resembles more a flood basalt in its distribution.

The rock association represented by the pillowed and massive basalts of the Hemlock Formation and the graywackes of the Michigamme Formation above has been compared to a eugeosynclinal sequence by previous workers. Chemically, the Hemlock resembles continental tholeiites more closely than oceanic types.

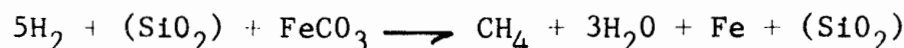
THE ECONOMIC POTENTIAL OF SIDERITIC CHERTS
AS A SOURCE OF ELEMENTAL IRON AND SILICA

C.A. Salotti and D. Weirauch, Department of Geological Sciences, University of Wisconsin-Milwaukee; Milwaukee, Wisconsin.

ABSTRACT

One of the most critical needs from the long-range point of view is a process that can utilize the entire iron-rich parts of major iron-formations.

Laboratory-scale experiments indicate that sideritic-cherts afford a unique opportunity to accomplish this goal. Sideritic chert reacts with hydrogen according to the following simplified equation:



The reaction proceeds rapidly above 400°C under a maximum operating pressure of 500 psi.

A large volume reduction in the solid results from the siderite to iron conversion, and relatively little energy is required for further comminution before the particles can be magnetically separated.

The entire process is discussed in terms of the following: 1) the availability of suitable ores; 2) the process parameters including reaction kinetics and product separation technologies; 3) the economics of the process including the present market demand and price for silica, hydrocarbons, and pre-reduced iron ore, as well as present hydrogen costs, sources, and future trends; and 4) the desirable ecological consequences of utilizing most of the material that is mined, as well as the reduced environmental insult at the steel mill because of the significant reduction in coke and flux requirements.

RE-INTERPRETATION OF STRUCTURE, WHITE PINE MINE, WHITE PINE, MICHIGAN

By The Geological Staff, White Pine Copper Company, Presented by R. W. Season, Resident Geologist, White Pine Copper Company, White Pine, Michigan 49971

ABSTRACT

Previous theories pertaining to the structure of the White Pine Mine and the surrounding area relate to a relatively simple system of faults and folds formed by a compressive force acting from the northwest. The general sequence of events which produced the structure was thought to be:

1. The oval-shaped upwarp of the Porcupine Mountains
2. Formation of the primary and secondary "mine" faults
3. Formation of the White Pine Fault - A reverse fault, steeply dipping to the northeast with 1,500 to 2,000 feet of vertical displacement and horizontal component of movement of 3,000 feet (right handed).
4. Drag on the northeast side of the White Pine Fault created the asymmetric White Pine Anticline, with an axis nearly parallel to the White Pine Fault and plunging 9° to the southeast.
5. Curved fault planes were developed within 1,000 feet of the White Pine Fault by the drag related to the horizontal movement of this major fault.

The extremely complex structure presently being encountered in the southeastern and southwestern portions of the White Pine Mine indicate a tectonic system inconsistent with all previous explanations. The most recent hypothesis relating to the tectonics that formed the structure as it is presently viewed incorporates distinct changes and departures from the sequence indicated above. The variations in thought are basically due to information added in the past few years. This new data has been derived from mining activity in the area thought to be occupied by the White Pine Fault, recent mapping in the Porcupine Mountain area*, new drilling data at the White Pine Mine, and results from computerization of geologic data.

The sequence of events incorporated in the re-interpretation, to be consistent with recent observations, would be:

1. Compressional forces acting from the northwest.
 - 1.1 Overthrust and gentle folding of the Porcupine Mountain area
 - 1.2 Formation or accentuation of the Iron River Syncline

2. Compressional forces acting from the northeast

2.1 Formation of the White Pine Anticline

2.2 Formation of the primary and secondary mine faults

(Steps 2.1 and 2.2 probably occurred contemporaneously)

3. Development of the White Pine Fault as a result of the steeper southwest limb of the White Pine Anticline failing as a shear-slip movement, vertically offset from 0 to 2,000 feet due to scissored effect.

The significance of this new interpretation is the northeast compressional force required to produce the structures exposed during recent mining and mapping. It is our hope that information gained in the future mining projected for the Southwest Orebody will substantiate this interpretation.

*Open file copy of map entitled, "The Bedrock Geology of The Porcupine Mountains, Michigan", J. A. Hubbard, U.S.G.S., 1970, 1971.

THE SHAWMERE ANORTHOSITE COMPLEX:
GENERAL GEOLOGY AND REGIONAL SETTING

P.C. Thurston, Geological Branch, Ministry of Natural Resources, Queen's Park, Toronto, Ontario.

ABSTRACT

The Shawmere Anorthosite Complex lies along the east side of the Kapuskasing Structural Zone, about 30 miles northeast of Chapleau and 120 miles north northeast of Sault Ste. Marie, Ontario. The complex has an areal extent, including associated rock types of about 300 square miles, and extends from west of Foleyet on the CNR track southwest for about 52 miles, attaining a maximum width of 15 miles.

Primary mineralogical layering in the complex roughly parallels structural trends in the high-grade metasediments and metavolcanics of the Kapuskasing Structural Zone to the north and west. The complex is fault bounded to the south and east and cut by post-Kenoran diabase and post mid-Devonian? lamprophyre dikes. This, coupled with a K/Ar age date on hornblende from the anorthosite of 2519 m.y. (Watkinson, Thurston and Shafiquallah, 1972) suggest that uplift of the Structural Zone was a post-folding Kenoran event. The anorthosite was intrusive into the rocks of the Structural Zone at some unknown time previous.

The center of the main anorthosite mass consists of anorthosite with megacrysts of plagioclase up to 18 x 3" and minor amounts of interstitial pargasitic hornblende, normal hornblende, augitic pyroxene and minor garnet. Toward the eastern margin, gabbroic phases are more common and the interstitial texture is less apparent, as grain size decreases and granulation is more common. Primary igneous layering is common in less disturbed portions of the mass but granular textures, pale purple anorthosite with trace amounts of magnetite and/or hornblende is common. The tonalitic rocks are commonly sheared. Several intrusive episodes are present and will be documented.

The plagioclase varies from An₅₃ to 74 with no systematic variation apparent through the mass. Whitney and McLelland (1973) suggest that the coronitic relations occasionally displayed between pyroxene, hornblende and garnet, indicate movement of Ca and that primary plagioclase

compositions are not necessarily maintained.

Chemical data (ferric to ferrous iron ratio, ferrous iron to magnesium, CaO content, total Fe and MgO) suggest that the rocks are of the anorthosite kindred.

The complex is tentatively compared to the stratiform calcic, primitive Archean anorthosite massifs of Greenland (Windley et al) and those of the Limpopo Mobile Belt (Mason, 1973) rather than later massif type anorthosites such as the Adirondack mass.

References

- Mason, R.
1973: The Limpopo Mobile Belt - Southern Africa; in Phil. Trans. R. Soc. Lond., A, Vol. 273, pp. 463-485.
- Watkinson, D.F., Thurston, P.C., and Shafiquallah, M.
1972: The Shawmere Anorthosite of Archean Age; Journ. of Geology, Vol. 80, no. 6, pp. 736-740.
- Windley, B.F., Herd, R.K., and Bowden, A.A.
The Fiskenaesset complex, West Greenland, Pt. 1: A preliminary study of the stratigraphy, petrology and whole-rock chemistry; Bull. Gronlands Geol. Undes. in press.

AN UNUSUAL CARBONATE BRECCIA UNIT AT STURGEON LAKE,
NORTHWESTERN ONTARIO

N.F. Trowell, Ontario Division of Mines, Toronto, Ontario.

ABSTRACT

A carbonate breccia unit is exposed on several islands along the Northeast Arm of Sturgeon Lake. Its strike length is close to three miles while its width reaches a maximum of 800 feet but averages closer to 200 feet. It is located between a lower intermediate to felsic, predominantly pyroclastic, metavolcanic sequence, and an upper mafic metavolcanic sequence comprising massive and pillowed flows, with local hyaloclastic-pillow breccia-zones. Stratigraphic relationships are obscured by tight folding and intense shearing along lithological contacts.

This unit has been subdivided into several subzones on the basis of possible initial composition; size, shape, and packing of clasts; presence of foreign fragments; and primary and secondary planar structures. The presence of amygdules and possible devitrified glass textures in some clasts indicate a volcanic origin for this unit. The subzones of this unit, therefore, have been tentatively classified as mafic and felsic pyroclastic, hyaloclastic, and locally as volcanoclastic in origin. Local small pods of this unit that occur within the lower metavolcanic sequence are probably clasts though an intrusive origin has not been ruled out.

The carbonatization of this unit takes the form of extensive replacement of the fragments by iron-rich dolomite, the fragments themselves are set in a calcite matrix. Locally the matrix is incompletely replaced and fine-grained equigranular-polygonal aggregates of quartz separate the fragments.

This unit has a trace element content characteristic of ultramafic rocks, high Ti, Cr, Ni, and moderately high Co and V. The mineralogical assemblage comprises carbonate, chlorite and stilpnomelane, quartz (chert), minor plagioclase, titaniferous magnetite, with local tourmaline, fuchsite, and disseminated sulphides. The mineral assemblage is consistent with greenschist facies metamorphism.

This unit lies along a major structural zone evidenced by tight complex folding, and intense shearing. Despite this, the unit appears to be an integral part of the metavolcanic sequence. The carbonatization process envisioned is one whereby iron-rich carbonate solutions replaced fragmental units within the volcanic pile; that is, this unit is of exhalative origin, akin to carbonate facies iron formation. The presence of hyaloclastic subunits suggest a possible source of carbonate, as the breakdown of palagonite glass can both give rise to substantial quantities of carbonate as well as to a segregation of such elements as Fe, Cr, Ni, and possibly Ti. Of interest is that quartz veins which cut this unit carry high Au and Cu values.

INTERGROWTH TEXTURES IN NORITE AT STRATHCONA
AND THEIR INTERPRETATION*

M.A. Vos, Ministry of Natural Resources, Division of Mines,
Geological Branch, Toronto M7A 1X3

ABSTRACT

Textural variations in heterogeneous norite of the Sudbury Nickel Irruptive are relevant to an understanding of genetic relationships between ore, host rock and overlying norite. Heterogeneous norite on the north range at the Strathcona Mine, which forms part of the sulphide-rich sublayer of the irruptive, is characterized by abrupt changes in grain size and by juxtaposition of ophitic and diabasic textured components, distinguishing it from overlying homogeneous norite.

Examples of intergrowth texture discussed are: 1) oval shaped mosaics of plagioclase surrounded by hypersthene, 2) cross-cutting concentric and linear patterns of distribution of plagioclase grains, 3) patterned distribution of pyroxene grains enclosing patches of plagioclase and 4) coincidence of the trace of plagioclase twin planes or twin lamellae in thin section with a semicircular outline which is interpreted as the location of a potential tension crack at the time of crystallization.

The intergrowth textures are part of a regular three dimensional distribution pattern of leucocratic and melanocratic minerals and are consistent with an interpretation of crystallization of a highly viscous melt.

*Published by permission of the Director, Geological Branch,
Ontario Division of Mines.

A STUDY OF STRAIN VARIATION IN SUPRACRUSTAL ROCKS AT
UPPER MANITOU LAKE, N.W. ONTARIO

P.I. Wallace, Department of Geology, McMaster University, Hamilton, Ontario, L8S 4M1; J.W. Cosgrove, Department of Geology, Imperial College, London, England; P.M. Clifford, Department of Geology, McMaster University, Hamilton, Ontario, L8S 4M1.

ABSTRACT

The Archaean volcanic-sedimentary assemblage which outcrops at Upper Manitou Lake is segmented by a northeast-southwest trending zone of disruption into a large, solely volcanic sequence occupying the central and northwest portions of the area and a sedimentary-plus-volcanic sequence in the southeast portion of the area.

The northwestern volcanic sequence has a major anticline within it, but the overwhelming pattern of deformation is an intense flattening. Cleavage density varies across the area. Some of the variation is a function of lithologic variations; but much represents changes in the intensity of deformation. Analyses of lapilli shapes by the methods devised by Ramsay and others tend to confirm the variations in the intensity of strain as expressed in the axial ratios of the tectonic strain ellipsoids. Attitudes of these ellipsoids show the parallelism of their [XY] planes to the local cleavage. Bombs and blocks are usually too large to give satisfactory data, because of the lack of good exposure in the third dimension, but a two-dimensional comparison with lapilli suggests that blocks are somewhat less flattened than lapilli.

Across the zone of disruption which coincides in some of the highest values of $[X/Y]$ and $[Y/Z]$, pebbles and boulders in the conglomerates of the southeast volcanic-sedimentary sequence, are curiously devoid of signs of significant flattening. Instead, deformation is confined to a turbidite unit at the top of the sequence. Double folds abound, though their detection demands the closest attention to graded bedding to confirm the local sense of younging. These double folds are such that the flattening of the northwest segment is here compatible with the second phase of folding. The first phase of folding can best be explained by a shortening parallel to bedding, and within the turbidite unit alone. There is no evidence for such a shortening elsewhere. A lack of strain indicators within the turbidite prohibits any stipulation of the axial ratios of the finite strain ellipsoid.

THE SPANISH RIVER ALKALIC ROCK - CARBONATITE COMPLEX,
TWPS. 107 and 108, ONTARIO

David H. Watkinson and John H. Grimes

Department of Geology, Carleton University, Ottawa, Canada.

Rocks of the ijolite series and carbonatite in the Spanish R. complex, intruded into Archean granite and gneiss, produced an extensive fenite aureole with numerous thin carbonatitic, biotitic and feldspathic dike rocks. Fenitization produced granulation and recrystallization of quartz, followed by precipitation of calcite, aegirine (Wo18 En14 Fs0 Ac68) and sodic amphibole in veins and by successive replacement of quartz, plagioclase and K-feldspar. Rocks of the ijolite series at the margin of the intrusion are vertically banded; they consist of pyroxene (Wo42 En28 Fs12 Ac18) and nepheline with variable amounts of biotite and calcite as well as minor cancrinite, sphene, apatite and pyrrhotite. These rocks are intercalated with and intruded by carbonatite with biotite and pyroxene (Wo41 En27 Fs10 Ac22) as major accessories. Vermiculite-rich rocks are interbanded with ijolite and carbonatite. Towards the interior of the complex carbonatite is the predominant rock type and the accessory minerals are magnetite, phlogopite and partially serpentinized and carbonated olivine. Minor amounts of pyroxene-rich syenitic and nepheline syenitic rocks often contain cancrinite and hackmanite; some pegmatitic varieties have primary cancrinite. Paleomagnetic studies (Robertson and Watkinson, 1974) have shown that the ijolite and carbonatite are normally magnetized and have a pole at 37°N. , 96°W. , while altered dikes and fenite near the intrusion are reversely magnetized and give a pole at 10°S. , 136°W. Because of the coarse grain size and extensive weathering the rocks give poles with large ovals of confidence. K-Ar mica ages from fresh diamond drill-core range from 1400-1800 million years; the values vary as a function of depth, and distance from the intrusive contact in the -45° drill hole. A whole-rock Rb-Sr isochron gives an age of 1790 ± 90 million years (Bell, Blenkinsop and Watkinson, 1974).

Robertson, W.A. and Watkinson, D.H. (1974) Paleomagnetism of the Spanish River alkaline rock-carbonatite complex, Twps. 107 and 108, Ontario. (Manuscript submitted for publication).

Bell, K., Blenkinsop, J., and Watkinson (1974) Geochronology of the Spanish River alkaline rock-carbonatite complex, Townships 107 and 108, Ontario. (Manuscript).

TRIP 1

LEADERS: J. F. GIGUERE, E. J. LEAHY, G. BENNETT, P. E. GIBLIN

MIDDLE KEWEENAWAN ROCKS OF THE
BATCHAWANA-MAMAINSE POINT AREA

BY

P. E. GIBLIN

GENERAL GEOLOGY

The Batchawana-Mamainse Point area, 40 miles northwest of Sault Ste. Marie, is underlain by Middle Keweenawan basaltic flows and intercalated sedimentary rocks, which have been intruded by felsic and mafic rocks.

Although much of the east half of Lake Superior appears to be underlain by Keweenawan rocks, exposures are generally limited to small isolated patches of volcanic and sedimentary rocks fringing the lake at intervals from Sault Ste. Marie to Cape Gargantua, 85 miles north. The area underlain by Keweenawan rocks at Mamainse Point, 11 miles long by 6 miles wide, constitutes the principal occurrence of these rocks on the east shore of the lake.

The Keweenawan rocks lie unconformably on a basement consisting of Archean metavolcanic and granitic

rocks. They strike northwest and dip west at 20° - 60° , commonly forming cuestas with gentle western slopes and east-facing escarpments. Elevations increase across strike to the northeast, reaching elevations of 1,500 feet.

The general geology is illustrated in Figure 1, accompanying this field guide, and on Map 2251 of the Ontario Division of Mines, Ministry of Natural Resources. Copies of the latter map will be provided to field trip participants.

Thickness of the Mamainse Point succession has been estimated by various writers as from 14,300 to 19,900 feet. The estimates do not take into account the unknown and indeterminate affects of faulting and are to be considered as first approximations.

Basalt flows comprise approximately 70% of the section, with the balance consisting of about equal amounts of conglomerate and felsite. Thickness of individual flows most commonly ranges from about 5 feet to 30 feet, with some flows being about 100 feet thick. There is little variation in lithology or chemistry of the basalts throughout the section. Distinctive flows are rare, a notable exception being the glomeroporphyritic "Daisy Stone" of Stop 8, and the lateral extent of individual flows is difficult to determine. Chemical analyses (Annells, 1973, and unpublished data by the writer) show most basalts to be tholeiitic, with a few being calc-alkaline.

FIGURE 1 GENERAL GEOLOGY OF BATCHAWANA - MAMAINSE POINT AREA

SCALE 1 INCH = 2 MILES

② FIELD TRIP STOP

LEGEND

CAMBRIAN (OR UPPER KEWEENAWAN)

 Jacobsville Formation: sandstone

UPPER KEWEENAWAN (OR CAMBRIAN)

 Mica Bay Formation: siltstone, arkose, conglomerate, breccia

MIDDLE KEWEENAWAN

 Diabase, gabbro, quartz gabbro

 Felsite

 Sedimentary Rocks: conglomerate, sandstone, siltstone

 Volcanic Rocks: basalt

ARCHEAN

 Granitic Rocks

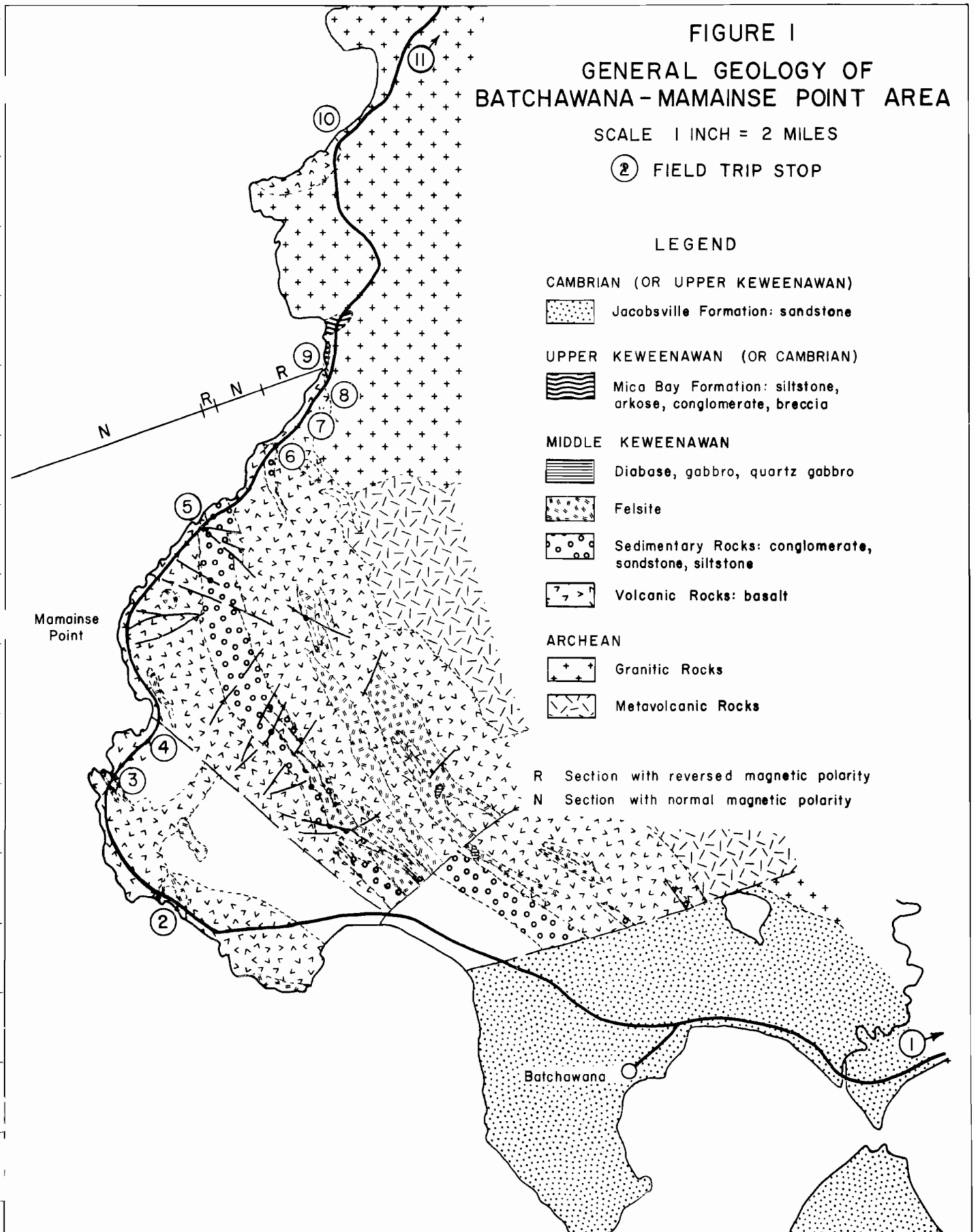
 Metavolcanic Rocks

R Section with reversed magnetic polarity

N Section with normal magnetic polarity

Mamainse Point

Batchawana



The intercalated sedimentary rocks are predominantly polymictic boulder conglomerates, which commonly contain thin lenses of red to grey sandstone, siltstone, and shale. The conglomerates are poorly sorted rocks with indistinct bedding. Clasts are well rounded to sub-rounded, and range in size from sand-sized particles to large boulders. They consist largely of granitic rocks and basalt, with minor amounts of mafic metavolcanics, diabase, felsite, and vein quartz.

The felsites are commonly pink to grey-white rocks, with small quartz and/or feldspar phenocrysts set in an aphanitic matrix consisting largely of quartz, feldspar, mica, chlorite, and epidote. Chemical analyses (Annells, 1973, and unpublished data by the writer) show that these rocks are predominantly rhyolites, with a few being dacitic in composition. Most display flow-lamination, particularly near their margins, and many have auto-brecciated border zones.

Small dikes and plugs of felsite cross-cut Keweenawan basalt, conglomerate, and Archean rocks and are clearly intrusive in origin. Small plugs near the coast at Cottrell Cove and Pancake Point probably formed rhyolite domes. The origin of many of the stratiform felsite bodies is uncertain, and although they are all tentatively classed as intrusives, some may well be extrusives.

Quartz-feldspar porphyries and breccia pipes which carry copper and molybdenum mineralization are found in the Archean terrain to the east. Radiometric dating and geological relationships indicate that these rocks are of Keweenawan age and that they are probably genetically related to the felsites.

A few narrow diabase and trap dikes cut the above-noted rocks. Two small quartz gabbro-gabbro plutons intrude basalt and felsite in Ryan Township, about 1 1/2 - 2 miles north of Pancake Bay.

The Mica Bay Formation, a thin sequence of grey clastic sedimentary rocks, unconformably overlies Middle Keweenawan basalt at Mica Bay and Alona Bay, and appears to underlie the Jacobsville Formation. The Mica Bay Formation is believed to be either Upper Keweenawan or Cambrian in age, more probably the former, and may be correlative with the Freda Formation.

The Jacobsville Formation (of Cambrian or Upper Keweenawan age) forms the floor of much of the east part of Lake Superior. Sandstones displaying the typical red and white mottling of the Jacobsville underlie the northwest shore of Batchawana Bay and appear to be in fault contact with the Middle Keweenawan rocks.

Glaciolacustrine deposits, in the form of raised beaches and spits, are common in the southern part of the area.

STRUCTURAL GEOLOGY

The Middle Keweenawan section forms a broad anticline which plunges gently west. In the north part of the area the rocks strike N 30° W; southwards the strike gradually changes to N 55° W. There is a gradual decrease in dip upwards in the section, from 60° W at the base to 20° W near the top. Anomalous attitudes of the basalts near felsite bodies at Cottrell Cove and Pancake Point probably reflect local doming produced by forceful intrusion of the felsites.

Rocks of the Mica Bay Formation strike east, are gently folded, and dip to the north or south at 15° to 30°. Jacobsville strata strike N 25° W to N 40° W and dip west at 15° to 25°.

The Middle Keweenawan rocks are cut by numerous steeply-dipping faults, which most commonly strike northeast and northwest. The fault zones are commonly filled by carbonate veins.

ECONOMIC GEOLOGY

Copper deposits of Keweenawan age are of economic importance in the area and consist of 3 types: (i) fissure-filling carbonate vein breccias which carry chalcocite, bornite, chalcopyrite, specularite, and very minor amounts of native copper, (ii) porphyry copper type deposits, in which chalcopyrite, chalcocite, molybdenite and pyrite are disseminated in quartz-feldspar porphyry, (iii) breccia pipe

deposits, in which wallrock fragments are set in a matrix of quartz, carbonate, and minor fluorite. Chalcopyrite and pyrite, with minor molybdenite, sphalerite, galena, tetrahedrite, stibnite and scheelite occur in the matrix of the breccia.

The Coppercorp Mine, 1 mile east of Hibbard (Sand) Bay operated from 1965 until 1972 on a deposit of the first type. The Tribag Mine, 10 miles north of Batchawana Bay, has produced copper from breccia pipe deposits from 1967 to the present. Milling rate at these mines averaged 400 to 500 tons per day of ore grading approximately 2% copper with minor values in gold and silver.

Two porphyry copper type deposits are known and have been explored by diamond-drilling.

RADIOMETRIC AGE DETERMINATIONS

The basalt exposed at Chippewa Falls (Stop 1, south of the Batchawana-Mamainse Point area) has been dated by the K/Ar method at 915 ± 140 m.y. Minerals and rocks from the Tribag Mine breccia pipe have K/Ar ages ranging from 785 ± 103 m.y. to $1,055 \pm 35$ m.y. (Wanless et al, 1966, 1967, 1968). These ages should be regarded as minimum ages because of the probability of argon loss. Felsites in the Mamainse Point section yield a Rb/Sr isochron age of $1,070 \pm 50$ m.y. (Van Schmus, 1971).

PALEOMAGNETISM

Studies of the paleomagnetism of Keweenawan rocks around Lake Superior (the Portage Lake lavas in Michigan; North Shore lavas and intrusive rocks in Minnesota; Thunder Bay dikes and Logan sills, Osler and Cape Gargantua lavas in Ontario) have consistently shown that the older rocks exhibit reverse magnetic polarity while the younger rocks exhibit normal polarity. The Mamainse Point section is different in that it contains 2 zones of reversed polarity, each underlying a zone of normal polarity (Figure 1).

In the earliest study of the paleomagnetism of the Mamainse Point lavas, DuBois (1962) investigated rocks from the upper part of the Mamainse Point section and from Keweenawan lavas at Alona Bay, 3 miles north of the Mamainse Point section, which had long been assumed to be correlative with the Mamainse Point flows. The Mamainse Point rocks were found to be of normal polarity, the Alona Bay rocks to be of reversed polarity. DuBois suggested that the two groups of flows were of different age, that the Alona Bay rocks were older and were of Lower Keweenawan age.

Palmer (1970) carried out detailed work on the Mamainse Point section and found that the lowermost part

of the section was of reverse polarity. This zone was succeeded by a zone of normally magnetized rocks, a second zone of reversely magnetized rocks, and by a second zone of normally magnetized rocks. He found that the changes from reverse to normal polarity occur at the base of conglomerate units. To explain the unusual relationships in the Mamainse Point section, Palmer suggested that the original sequence was reverse, normal, and that part of the section had been repeated by a strike fault located at the boundary between the lower normal and upper reverse zones.

This interpretation implies that the two conglomerates of Figure 1 (near Stop 5 and at Stop 6) once were parts of the same bed. The very different lithological characteristics of the conglomerates make this interpretation improbable.

More recently, work by Robertson (1973) confirmed the polarity succession in the Mamainse Point flows. He suggested that the succession might be explained by three reversals in the earth's magnetic field occurring at the times represented by the boundaries between the zones of differing polarity, or alternatively, that the succession could be explained by a single polarity change which has been repeated by faulting. Robertson concludes that although the magnetic evidence is not entirely conclusive, it strongly favours the hypothesis of repetition by faulting of a single reversal of the earth's field.

SELECTED REFERENCES

Annells, R. N.

- 1973: Proterozoic Flood Basalts of Eastern Lake Superior: the Keweenawan Volcanic Rocks of the Mamainse Point Area, Ontario. Geol. Surv. Can. Paper 72-10. 51 p.

DuBois, P. M.

- 1962: Palaeomagnetism and Correlation of Keweenawan Rocks. Geol. Surv. Canada, Bull. 71. 75 p.

Ermanovics, I. F., Helmstaedt, H., and Plant, A. G.

- 1972: An Occurrence of Archean Pseudotachylite from Southeastern Manitoba. Canadian J. Earth Sci., v. 9, p. 257-265.

Giblin, P. E.

- 1966: Recent Exploration and Mining Developments in the Batchawana Area of Ontario. Canadian Mining J., v. 87, no. 4, p.77-80.
- 1969a: Kincaid Township, District of Algoma. Ontario Dept. Mines, Prelim. Geol. Map P. 553. Scale 1 inch to 1/4 mile.
- 1969b: Mamainse Point Area, District of Algoma. Ontario Dept. Mines, Prelim. Geol. Map P. 554. Scale 1 inch to 1/4 mile.
- 1969c: Herrick Township, District of Algoma. Ontario Dept. Mines, Prelim. Geol. Map P. 556. Scale 1 inch to 1/4 mile.

Giblin, P. E., and Armbrust, G. A.

- 1973: Batchawana, Algoma District. Ontario Div. Mines, Ministry of Natural Resources, Map 2251. Scale 1 inch to 1 mile.

Giblin, P. E., and Leahy, E. J.

- 1967: Sault Ste. Marie - Elliot Lake Sheet, Districts of Algoma, Manitoulin, and Sudbury. Ontario Dept. Mines, Geological Compilation Series, Map 2108. Scale 1 inch to 4 miles. Geological compilation 1964-65.

Moore, E. S.

- 1926: Batchawana Area, District of Algoma,
Ontario Dept. Mines, v. 35, pt. 2, p. 53-85.
Accompanied by Map 35b. Scale 1 inch to 2 miles.

Nuffield, E. W.

- 1955: Geology of the Montreal River Area.
Ontario Dept. Mines, v. 64, pt. 3. 32p.
Accompanied by Map 1955-1. Scale 1 inch
to 1/2 mile.

Palmer, H. C.

- 1970: Paleomagnetism and Correlation of some
Middle Keweenawan Rocks, Lake Superior.
Canadian J. Earth Sci., v. 7, p. 1410-1436.

Philpotts, A. R.

- 1964: Origin of Pseudotachylites. American J.
Sci., v. 262, p. 1008-1035.

Reynolds, Doris L.

- 1954: Fluidization as a Geological Process, and
its Bearing on the Problem of Intrusive
Granites. American J. Sci., v. 252, p. 577-614.

Robertson, W. A.

- 1973: Pole Positions from the Mamainse Point Lavas
and their Bearing on a Keweenawan Pole Path
and Polarity Sequence. Canadian J. Earth
Sci., v. 10, p. 1541-1555.

Thomson, J. E.

- 1953: Geology of the Mamainse Point Copper Area.
Ontario Dept. Mines, v. 62, pt. 4 25p.
Accompanied by Map 1953-1. Scale 1 inch to
1,000 feet.

Tovell, Walter M., and Deane, Roger E.

- 1966: Ancestral Lake Superior Shorelines, Montreal
River Harbour Area, Ontario. Proc., Geol.
Assoc. Canada, v. 17, p. 53-63.

Van Schmus, W. R.

- 1971: Rb-Sr Age of Middle Keweenawan Rocks, Mamainse
Point and Vicinity, Ontario, Canada. Geol.
Soc. America Bull., v. 82, p. 3221-3226.

Wanless, R. K., Stevens, R. D., Lachance, G. R., and
Rimsaite, J. Y. H.

1966: Age Determinations and Geological Studies,
K-Ar Isotopic Ages, Report 6. Geol. Surv.
Canada, Paper 65-17, p. 58.

Wanless, R. K., Stevens, R. D., Lachance, G. R. and
Edmonds, C. M.

1967: Age Determinations and Geological Studies,
K-Ar Isotopic Ages, Report 7. Geol. Surv.,
Canada, Paper 66-17, p. 84-85.

1968: Age Determinations and Geological Studies,
K-Ar Isotopic Ages, Report 8. Geol. Surv.
Canada, Paper 67-2, Pt. A, p. 95-96.

Wilshire, H. G.

1971: Pseudotachylite from the Vredefort Ring,
South Africa. J. Geol., v. 79, p. 195-206.

ITINERARY

Leave Sault College of Applied Arts and Technology, proceed approximately 1/2 mile to the intersection of Highway 17 (Great Northern Road) and Highway 550 (Second Line).

Mileage

0.0 Intersection of Highways 17 and 550.
Proceed north on Highway 17.

From the northern outskirts of the city for a distance of about 12 miles the highway crosses Archean granitic gneisses and migmatites which are cut by diabase and lamprophyre dikes.

Approximately 12 miles north of Sault Ste. Marie the highway descends into the valley of the Goulais River. A fleeting glimpse can be had of high rugged hills to the northeast which are underlain by Huronian sedimentary rocks of the Gowganda and Lorrain Formations and by Nipissing Diabase.

The Goulais River valley is underlain by sandstones and a basal conglomerate of the Jacobsville Formation. There is a high correlation of population centres in this region with areas underlain by the gently-dipping, relatively easily

eroded rocks of the Jacobsville Formation. Such areas are characterized by modest elevation and low relief, and are relatively good building sites. Sault Ste. Marie, villages in the Goulais River valley, and the village of Batchawana Bay are all underlain by the Jacobsville Formation.

- 14.9 Goulais River. From about 1 mile north of the river to Havilland Bay (a small bay forming the southeast part of Batchawana Bay) the highway crosses Archean metabasalt and sedimentary rocks of the Gowganda Formation. North of Havilland Bay roadcuts expose Archean granitic rocks. From mile 25.0 to 25.5 roadcuts expose Middle Keweenawan basalts.

32.2 Stop 1 Chippewa Falls

A monument in the small roadside park marks the approximate mid-point of the Trans-Canada Highway.

Follow the trails for approximately 100 yards to the top of the lower falls, where there is an excellent exposure of Middle Keweenawan basalt unconformably overlying Archean trondhjemite.

The best exposure of the contact is on the small island, which although readily accessible during periods of low water, will probably not be accessible early in the summer. If the island is

not accessible, the contact can be viewed from the trail, and then by following the trail to the foot of the falls, the contact can be inspected on the east shore of the river.

The unconformity on the island generally dips 10° - 30° southwest, but is nearly vertical on the east bank of the river. The basalt is chilled near the contact, which in detail is quite irregular, with narrow tongues of basalt extending downwards for several inches along fractures in the trondhjemite, sometimes isolating and completely enclosing blocks of trondhjemite in the basalt.

Rare pipe amygdules occur near the base of the flow. On the island, near its east side, a few pillows ranging in length from 1 to 4 feet, occur in the lowermost 10 feet of the flow. These are the only pillows found to date in the Keweenawan lavas of the east shore of Lake Superior. Also on the island, inclusions of grey and red siltstone up to 3 feet long occur in the basalt.

For the most part the surface of the trondhjemite at the time of burial by the basalt appears to have been as clean and free of weathered material as are the outcrops on the river bank to-day. On the island, near its eastern side, a few small rounded pebbles and cobbles of trondhjemite beneath the basalt may represent a pre-flow regolith. At some

places along the contact the trondhjemite is very red in colour and is noticeably pitted, features which may reflect pre-flow weathering.

Several large potholes, up to 5 feet in diameter and 3 feet in depth, occur in basalt on the southwest corner of the island.

- 37.5 Batchawana River
- 37.9 Road to Tribag Mine
- 44.1 Pancake River
- 45.4 Pancake Bay Provincial Park
- 49.2 Stop 2 Cottrell Cove Felsite

A small rhyolite pluton, which outcrops as a crescent-shaped body intrudes basalt at this locality. The first part of this stop is at the eastern contact of the south arm.

The felsite displays prominent flow banding which in detail is much contorted, but which in general trends parallel to the contacts of the body. Although the rock is predominantly pink to red in colour it is mottled by grey-green-white alteration lenses and irregular patches.

Alteration of some of the felsite bodies in the area has resulted in extensive development of kaolin, and some bodies have been explored as possible sources of this mineral.

The outermost part of the felsite body consists of a breccia in which angular to rounded fragments of felsite, basalt, and granite occur in a matrix of felsite. The breccia envelope ranges in thickness from a few inches to several feet. Dikes of felsite breccia intrude the wallrock basalts.

On the southwest side of the highway near the north end of the roadcut there is a funnel-shaped mass of grey, intensely altered, felsite breccia, which appears to be intrusive into the main body of felsite. Please do not remove samples of this grey breccia as there is very little remaining in place.

Throughout the upper part of the Middle Keweenawan stratigraphic sequence the flows generally strike northwest and dip west at 20° - 25° . Anomalous attitudes in the vicinity of the felsite body suggest that the lavas have been domed by forceful intrusion of the felsite. The presence of numerous slickensided surfaces in the wallrock flows,

a feature that is rare elsewhere in the area, support this concept of forceful intrusion.

The presence of slickensided surfaces in the felsite suggest that intrusion of material may have continued after consolidation of much of the body.

Narrow branching pseudotachylitic veins, ranging in thickness from a few inches to paper-thin films, also cut the wallrock basalts. They may be best seen in the outcrops on either side of the highway about 200 yards northwest, where the western contact of the south arm is exposed. Please do not collect samples or deface these outcrops. This is the only occurrence of pseudotachylitic material found in the area to date, and it occurs in limited amount. Field trip participants who wish specimens for serious examination should consult one of the guides who will make suitable arrangements.

The pseudotachylitic vein material is dark grey to black to dark brown in colour, aphanitic, hard, and often breaks with a sub-conchoidal fracture. Fragments of quartz, felsite, and basalt are visible with the naked eye in the dark matrix.

Thin-sections show the vein material to be a microbreccia. It consists of angular fragments of quartz (free of strain shadows), feldspar, devitrified glass, quartz-feldspar porphyry with a matrix of devitrified glass, opaque minerals, feldspar, and basalt, set in a matrix of finely comminuted fragments of the above-noted materials and larger, irregular grains of carbonate and chlorite. Small carbonate veinlets cut the rock. An overall pinkish colour suggests the presence of finely disseminated hematite. Limited studies to date have disclosed the presence of one amygdale, filled by chlorite, within the matrix of the rock. No glass, nor devitrified glass, other than that contained in fragments, has been identified.

The origin of pseudotachylites is not well understood, and definitions of the term vary. Reynolds (1964) attributed the origin of pseudotachylites to the erosive power of fluidized gas-solid systems streaming through brecciated material. Philpotts (1964) concluded that pseudotachylite is formed by fusion along fault zones due to frictional heat and hot gases. Shock deformation has been postulated as the origin of some of these rocks by Wilshire (1971).

Ermanovics et al (1972) suggest that crushed rock veins can be part of a continuum of mechanical deformation related to regional mylonitization. They suggest that the presence or absence of water might be an important factor in the production of glass, with melting in the rock-paste veins occurring before melting of the host rock due to minuteness of the fragments and perhaps mainly due to the presence of water. They state that all crushed rock veins would not produce melt, simply because water was not always available to them.

The pseudotachylitic veins are tentatively interpreted as phenomena associated with the early stages of intrusion of the felsite. It is envisaged that gas escaping from the underlying felsic magma streamed upwards, under high pressure, through fractures in the overlying rocks. Fragments of the wallrocks, detached by erosive power of the gas and structural dislocation, were transported in a fluidized gas-solid system, which further eroded the wallrocks and the entrained particles. The fluidized material filled the fractures, and upon the eventual decrease in gas pressure, remained as veins of very fine-grained rock powder.

A late diabase dike cuts basalt in the roadcut on the west side of the highway.

After leaving Stop 2 the highway runs approximately parallel to the strike of the flows for 1 1/2 miles. One quarter mile west of the highway the highest flows in the Mamainse Point section are exposed between Whiskey and Coppermine Points and on the small islands nearby.

From the small bay at the foot of Coppermine Point the highway crosses successively lower flows in the section.

52.0 Stop 3 Interbedded Basalt and Conglomerate

Two polymictic conglomerates are separated by basalt at this locality.

The base of the thick flow has been the locus of minor faulting. The fault zone ranges from a few inches to one foot in thickness and has been filled by carbonate.

The base of the flow has a narrow amygdaloidal zone, with a few pipe amygdules. Intermittent outcrops towards the top of the flow reveal an amygdaloidal zone thicker than that at the base and reddish-purple in colour. The grain size rapidly coarsens upwards.

Clasts in the conglomerates consist predominantly of Archean granitic rocks, with

minor amounts of Archean mafic metavolcanic rocks, iron formation, and Keweenawan basalt. The clasts are generally sub-rounded and range in size up to about 2 feet in diameter. Carbonate is common in the matrix. Small lenses of sandstone occur in the conglomerates.

53.8 Stop 4 Felsite

Follow a bush road east of the highway for approximately 1/4 mile to a small outcrop of felsite. The rock is quite different from the felsite of Stop 2: it is hard, splintery, relatively fresh and unaltered, and is without the fine banding seen at Stop 2. It is part of a stratiform body which is tentatively interpreted as being intrusive in origin.

Lunch at Hibbard (Sand) Bay

56.7 Scenic Stop, optional

Time and weather permitting a brief stop will be made. On a clear day one can see the high granitic hills which form the coast north of Agawa Bay, some 20 miles away.

57.2 Stop 5 Composite Dike

A narrow composite dike cuts basalt, and is exposed on the shore of the lake. The

dike strikes east and dips north at 45° - 50° . The basal mafic part is about 2 feet thick and displays a chilled contact with the wallrock basalt flows. The remaining, much thicker, part of the dike consists of grey-white to red felsite. Near the mafic-felsic interface the felsite exhibits flow lamination and is, in places, a breccia. The northern contact of the dike is not exposed.

Rubble used in road construction in this area is from the thick conglomerate unit which outcrops a few hundred feet east of this stop.

59.0 Stop 6 Conglomerate

Most conglomerates in the Mamainse Point sequence are similar to those seen at Stop 3 and in the rubble near Stop 5. The conglomerate at this stop is unusual in that the clasts consist almost entirely of Keweenawan basalts. The clasts are generally well-rounded to sub-rounded, range in size up to about 1 foot in diameter and are set in a matrix of fine basaltic debris. Lenses of red-brown silt, some of which show cross-bedding and ripple marks, occur in the conglomerate. The conglomerate is cut by carbonate veins which carry minor amounts of quartz and laumontite.

higher in the sequence at previous stops.

Follow the guides across the highway and down a trail to the shore of the lake.

60.7 Stop 9 Mica Bay Formation

Clastic sedimentary rocks of this formation unconformably overly Keweenawan basalt at this locality.

The Keweenawan basalts strike N 30° W and dip 45° to 50° W. The overlying sedimentary rocks strike N 65° E, and in the section examined, dip 15° N.

The sedimentary section is approximately 200 feet thick, of which the lower 60 feet are exposed at this stop. The rocks are predominantly grey-brown in colour.

A thin basal conglomerate, about 1 foot thick, is succeeded by siltstones, arkoses, and minor pebble conglomerate units. Since very little of the basal conglomerate remains, please do not collect samples or deface the exposures. Siltstones predominate, and comprise approximately 70% of the section.

Sedimentary structures include ripple marks, graded bedding, cross-lamination, flame structures, and ball-and-pillow structures. In other exposures, north of the section examined,

flute casts and clastic dikes are found.

The structures are indicative of shallow-water deposition. The flute casts indicate a northerly direction of current flow.

Steeply-dipping faults with dip separations of up to about 6 feet cut the sedimentary rocks.

The section examined lies on the south limb of a syncline. The axis of the fold and the north limb are exposed between the creek at the end of the section examined and the small granite headland at the north end of the beach. The north limb of the fold is in fault contact with the granite. North of the fault a thin basal breccia occurs on the granite, and similar basal breccias are found at the base of the sediments, overlying the granite, at several points along the shore of Mica Bay.

A thinner section of similar clastic sedimentary rocks occurs in Alona Bay, 4 miles north.

The age and correlation of these rocks are uncertain. The unconformity observed at this stop indicates that they are post-Middle Keweenawan. Lithologically and structurally they are unlike rocks of the Jacobsville Formation.

They appear to underlie the Jacobsville, which forms nearby islands in Lake Superior and which comprises much of the floor of the eastern part of the lake.

The Mica Bay Formation is post-Middle Keweenawan and is probably pre-Jacobsville in age. Age of the Jacobsville is itself uncertain; it is variously assigned to the Lower and Middle Cambrian and to the Upper Keweenawan. The Mica Bay Formation is considered to be either Upper Keweenawan or Lower Cambrian, with the former age the more probable. It may be correlative with the Freda Formation of Michigan and Wisconsin.

65.7 Stop 10 Alona Bay Scenic Lookout

Theano Point, consisting of Archean granitic rocks cut by diabase dikes, lies on the north side of the bay. The south side is formed by Point Aux Mines, which consists of Archean granitic rocks overlain by Middle Keweenawan basalts. Sedimentary rocks similar to those of the Mica Bay Formation outcrop on the south-east shore of the bay.

An historical plaque commemorates the first discovery of uranium in Canada, made nearby in the 1840's. A sample of pitchblende

from a collection made by lake-boat Captain B. A. Stannard was described by J. L. Le Conte in the American Journal of Science in 1847. Le Conte noted that the sample was from a vein 2 inches wide, located about 70 miles north of Sault Ste. Marie. Subsequent papers by other writers gave the location as between 40 and 90 miles north of the Soo.

At the end of the Second World War, when uranium became sought after, prospectors researched the old descriptions and attempted to find the occurrence. Vagueness of the location and the small size of the deposit made the search difficult. In 1948 Robert Campbell of Toronto found pitchblende at the north-west end of Theano Point. The occurrence may well be the site of Stannard's original specimen. Subsequently prospectors found several other pitchblende deposits inland, to the north and east.

Although not commemorated in any way, Point Aux Mines on the south side of Alona Bay is also of historical significance to those interested in early Canadian mining operations. It was the site of the earliest organized mining venture in Ontario. In 1772-73, a mining company

formed by Alexander Henry, the noted fur-trader, worked a copper deposit and shipped a small amount of ore to England.

From Alona Bay to Montreal River the highway crosses Archean granitic rocks which are cut by diabase dikes.

70.6 Stop 11 Cobble Beaches

Cobble beaches are exposed in a clearing on the west side of the highway. The area is a Provincial Nature Reserve Park and walking on this fragile site is prohibited. Follow the guides along a trail which crosses the beaches at the north end of the clearing.

These magnificent raised or perched beaches are some 200 feet higher than the present level of Lake Superior. They consist of well rounded cobbles and boulders of granitic rock now covered with a growth of lichens. The beaches are gently curved, and occur in the form of "waves", with the distances between crests varying generally between 50 and 100 feet. The "wave height" varies but is of the order of 10'. The area, with minor exceptions, slopes toward the lake. Tovell and Deane (1966, p. 61) interpret the "waves" of cobbles as representing submerged off-shore bars.

Correlation of these features with ancestral lakes has not been made.

The south part of the east shore of Lake Superior abounds with glacial lake shoreline features. Apart from the work of Tovell and Deane, which was restricted to a study of the cobble beaches near Montreal River, these features have been little studied. They appear to offer a fruitful field for research.

TRIP 3

LEADERS: K. D. CARD, M. J. FRAREY, D. G. INNES,
E. F. PATTISON

PRECAMBRIAN IGNEOUS ROCKS OF
THE NORTH SHORE OF LAKE HURON REGION

BY

K. D. CARD

INTRODUCTION

The geology of the eastern part of the Southern Province along the North Shore of Lake Huron will be examined, with emphasis on the intrusive and extrusive igneous rock units and their relationships to the tectonic history of this part of the Canadian Shield.

This guide is to be used in conjunction with Ontario Division of Mines Guidebook No. 4, "Geology and Scenery of the North Shore of Lake Huron Region", which will be supplied. Maps, photographs, and additional information are available there, as well as in the publications listed in this guide.

GENERAL GEOLOGY

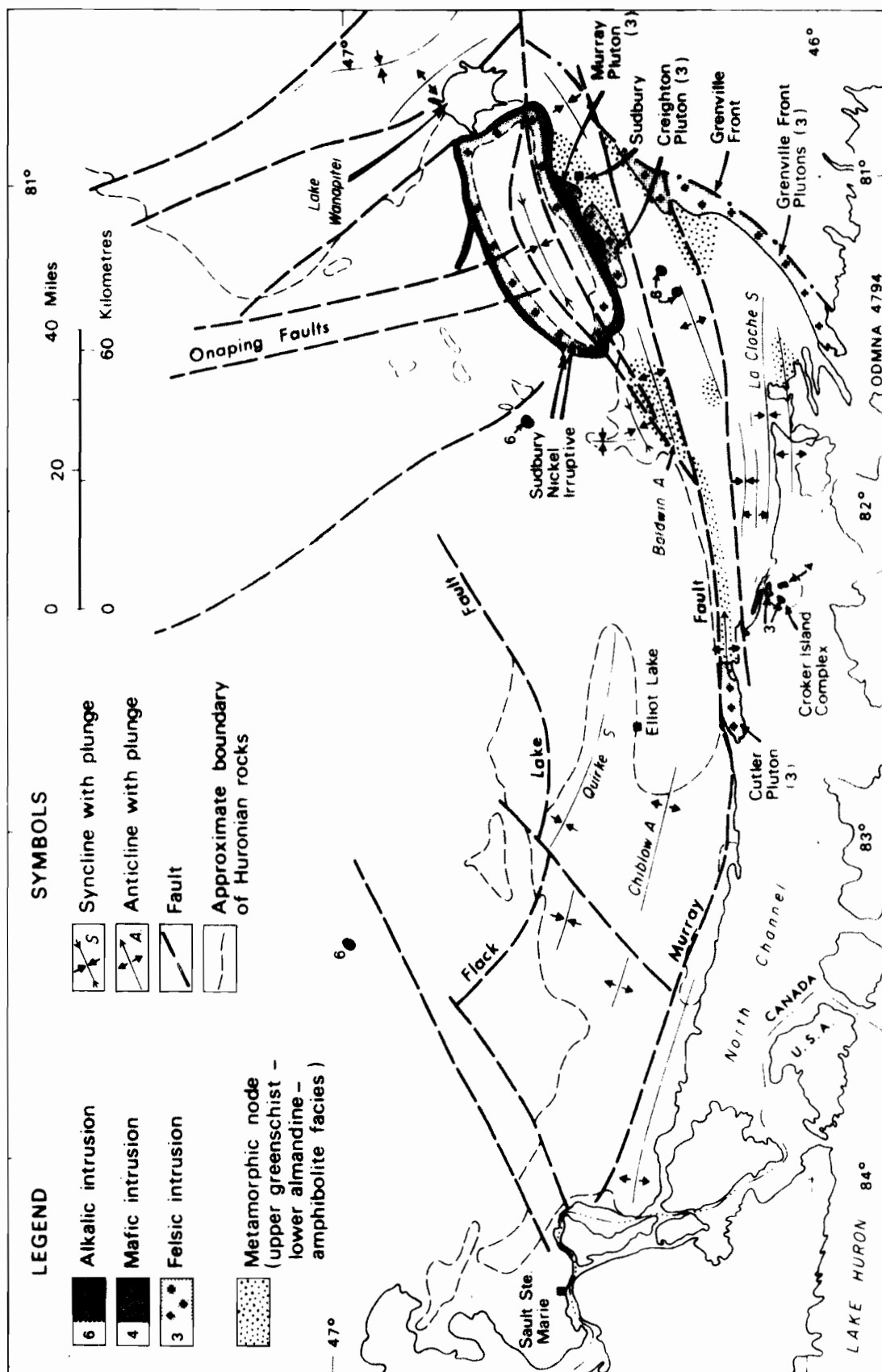
The Southern Province adjoins the Superior Province on the north and west and the Grenville Province on the east. To the south, Precambrian rocks of the

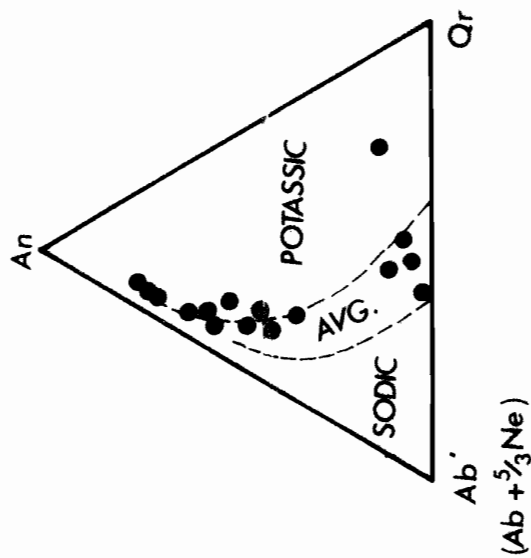
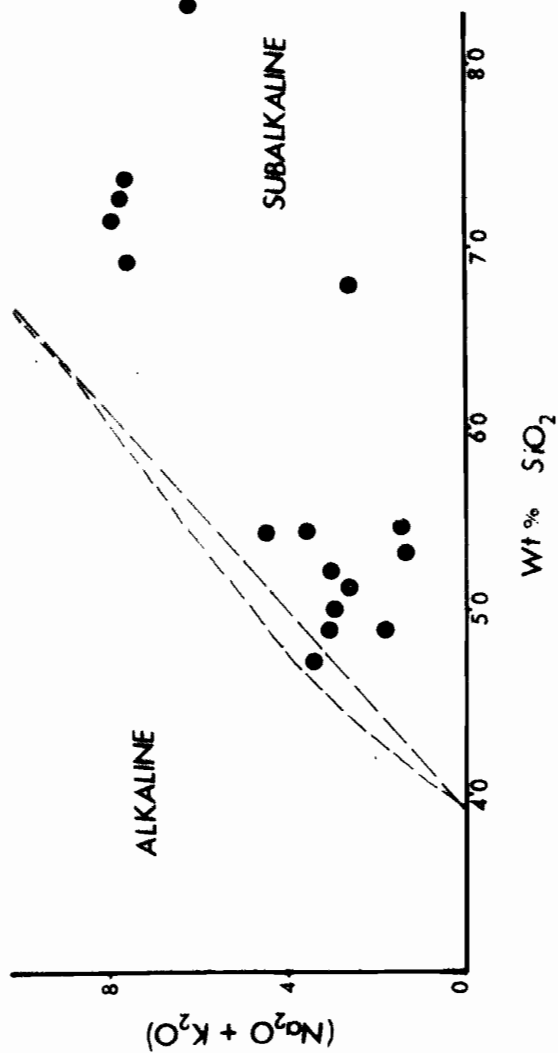
Published with the permission of the Director, Geological Branch, Ontario Division of Mines, Ministry of Natural Resources.

Southern Province are unconformably overlain by undeformed Paleozoic strata (see Map 2, page 24, Guidebook 4).

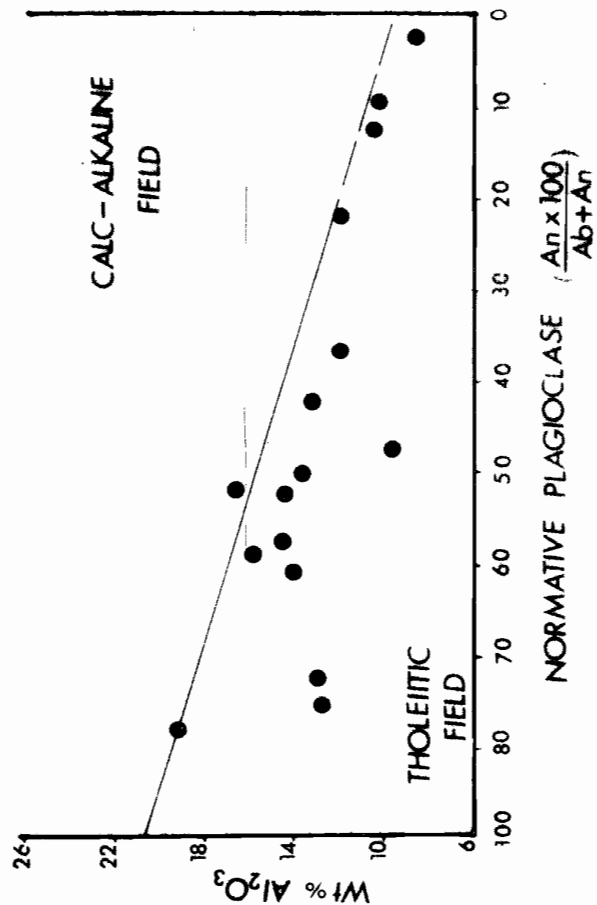
The Southern Province is comprised mainly of folded, metamorphosed Middle Precambrian (Aphebian) rocks of the Huronian Supergroup, a thick (up to 35,000 feet or more) wedge of coarse, craton-derived clastic metasediments deposited some 2,150 to 2,500 million years ago (see page 35, Guidebook No. 4 for details on Huronian stratigraphy and lithology). These rocks rest unconformably upon Early Precambrian granitic basement (see photo 4, page 10, Guidebook 4) and were deposited under shallow-water conditions for the most part, probably in a fault-initiated basin superimposed on downdropped Early Precambrian blocks. The basin and hinterlands were tectonically active during sedimentation; volcanism is recorded by accumulations of mafic and felsic flows and related intrusions near the base of the sequence around Sudbury and westward to Spragge, near Elliot Lake, at Thessalon, north of Bruce Mines and Sault Ste. Marie.

The Middle Precambrian volcanic accumulations consist mainly of tholeiitic basalts with lesser amounts of felsic volcanic rocks, both flows and pyroclastics, and metasedimentary intercalations. The metavolcanic accumulations probably represent fissure eruptions controlled by early, graben-style fault structures along





An-Ab-Or projections for Proterozoic meta-volcanic rocks of the Elsie Mnt., Stobie, and Copper Cliff Fms. The dashed lines are provisional boundaries for distinguishing K-poor, "common", and K-rich variants. Plots in % cation equivalents.



Normative plagioclase composition against Al_2O_3 in wt. %. The dividing line after Irvine and Barager (1971).

the margin of the developing Southern Province basin. Volcanism and sedimentation occurred contemporaneously. Associated mafic dikes and layered gabbro-anorthosite plutons are probably also related to this early tectonic activity.

Middle Precambrian metavolcanic and associated metasedimentary rocks of the Sudbury area occur in an east-to northeast-trending belt, south of and in contact with rocks of the Nickel Irruptive in the east and granitic rocks of the Superior Province in the west. The volcano-sedimentary sequence is part of the Elliot Lake Group of the Huronian Supergroup and consists of several thousand feet of mafic metavolcanics and intercalated metasediments of the Elsie Mountain and Stobie Formations, overlain by up to 2,400 feet of felsic metavolcanics of the Copper Cliff Formation. Thick accumulations (up to 6,000 feet) of pelitic metasedimentary rocks of the McKim Formation conformably overlie the metavolcanic sequence. Associated mafic and felsic intrusions occur within the volcanic-sediment pile.

Chemical data (see diagrams) indicate that the metavolcanic rocks are a subalkaline-tholeiitic sequence of slightly potassic metabasalts, dacites, rhyolites and associated pyroclastics. Tholeiitic andesites appear to be absent from the section. A genetic relationship between metavolcanic rocks and intercalated metasedimentary and tuffaceous rocks is supported by their close spatial association and by similarities in

their chemical trends.

Petrographic studies of mineral assemblages of metavolcanic and metasedimentary rocks of the Sudbury area indicate conditions corresponding to the greenschist and amphibolite facies of low pressure-intermediate type regional metamorphism, although retrograde metamorphic effects are prevalent.

The Sudbury-Sault Ste. Marie region is situated in the "Penokean Fold Belt" portion of the Southern Province and is characterized by deformation and metamorphism which occurred during Middle Precambrian (Penokean-Hudsonian) orogenic events. Major folds are open to subisoclinal concentric buckles with upright to slightly overturned (northward), commonly curved axial surfaces. In the east, the folds are mainly tight, fold axes display abrupt culminations, and the resulting fold pattern is one of doubly plunging, en echelon synclines and anticlines (photo 62, page 102, Guidebook 4). In the west, the folds are mainly open, fold axes plunge gently, and axial traces of individual folds extend many miles.

Fault sets striking generally east, northeast, and northwest are present. Major east-west faults of the Murray System were probably initiated as graben-style structures prior to Huronian sedimentation but were periodically reactivated as steep thrusts and strike-slip faults during subsequent deformational events. Foliations

of several ages are present, including early east-west penetrative cleavage, later approximately east-west crenulation cleavages, and late strain-slip cleavages and kink bands (see photo 24, page 39). In the area surrounding Sudbury, shatter cones and breccias of possible meteorite impact origin (Dietz, 1964) are abundant (see photo 41, page 71, and photo 44, page 79, Guidebook 4).

The structural elements were formed during several deformational events which varied in intensity from place to place. Early major folding was accompanied by, in its later stages, emplacement of Nipissing Diabase, tholeiitic gabbro intrusions approximately 2,150 million years old (see Photos 25 and 26, page 39, Guidebook 4). Concordant to discordant Nipissing Diabase intrusions, some of large dimensions, are prominent throughout the sedimentary pile of the Huronian Supergroup and are the dominant igneous component of the eastern Penokean Fold Belt. The Creighton and Murray granitic plutons near Sudbury, with a Rb-Sr isochron age of about 2,200 million years (Gibbins et al, in Guy-Bray, 1972) may be approximately syntectonic with this early deformation, or may represent part of a volcanic-plutonic cycle to which the Huronian volcanics also belong.

Later deformation and regional metamorphism were approximately accompanied by the Cutler and Grenville

Front granitic plutons whose Rb-Sr isochron ages are 1,750 million years and 1,600 to 1,730 million years respectively. Regional metamorphism of the low pressure-intermediate type that affected the Huronian rocks and Nipissing Diabase was approximately coincident in time with secondary deformation.

The Sudbury Nickel Irruptive, famous for its rich nickel-copper ores, is a differentiated tholeiitic intrusion notably enriched in silica and alkalies. It forms a northeast-northwest trending elliptical ring approximately 36 miles (58 km.) long and 17 miles (26 km.) wide.

Recent studies (Naldrett et al, 1970) have shown that the Sudbury Nickel Irruptive consists of concentric rings of granophyre (micropegmatite), quartz gabbro, quartz-hypersthene gabbro, and quartz-augite norite, and a discontinuous basal unit, the sub-layer, which is a complex assemblage of noritic and gabbroic intrusions and leucocratic igneous and non-igneous breccias. The sub-layer is the host for most of the ore in the Sudbury area.

It has been shown that cryptic variations in the compositions of pyroxenes and plagioclase occur which, together with observed modal variations, support the concept that the main Irruptive is gravity differentiated and shows phase layering. It appears, however, that whereas the south limb of the intrusion, the South Range, shows a complete section through the Irruptive, the bulk

of the norite member is missing on both the North and East Ranges. It is suggested that the main Irruptive started to crystallize as a funnel shaped body under a thin cover of breccias (Onaping) and sediments (Onwatin and Chelmsford). After a portion of the magma had crystallized as the South Range norite, some of the remaining norite was further squeezed out (during deformation of the basin during the Penokean Orogeny?) beneath the cover to crystallize as a thinner peripheral sill of felsic norite, quartz gabbro and micropegmatite. The difference between the lopolith, or the South Range, and the northern sill-like limb, the North Range, is supported by observations on the internal structure on the two sections of the Irruptive. The quartz-rich marginal phase of the South Range norite, interpreted as a border group facies of the Irruptive, has its counterpart in the much more pyroxene-rich mafic norite of the North Range.

The mafic sub-layer rocks can be divided into three groups; the North Range sub-layer, the South Range sub-layer, and the rocks making up the offset dikes. All are rich in inclusions which are either of country rocks or, very commonly, belong to a suite of ultramafic and mafic rocks differing from any exposed portion of the main Irruptive or footwall rocks. North Range sub-layer ranges from augite norite to hypersthene gabbro. Texturally and modally these rocks are quite distinct from the mafic and felsic norites forming the lower

part of the main Irruptive along the North Range.

On the South Range the sub-layer in part closely resembles the overlying main mass norite texturally and mineralogically, but some variants are distinctly different. The offsets are dike-like, generally steeply dipping bodies which project as much as 10 miles (16 km) beyond the outer contact of the Nickel Irruptive. Although noritic rocks occur within the dikes, the dominant rock type is hornblende-biotite quartz diorite.

Nearly all of the mafic sub-layer rocks are exceptionally rich in sulphides in comparison with the main body of the Irruptive. The proportion of sulphide, which is generally restricted to the matrix, ranges from a few per cent up to almost one hundred per cent; some variants of the sub-layer consist of exotic silicate inclusions in a matrix of almost massive sulphides. Most Sudbury geologists believe that emplacement of the ores was in conjunction with the sub-layer, rather than with the main body of the Irruptive. The relative ages of the mafic sub-layer and the main Irruptive are, however, uncertain. On the North Range, contacts between these units are sharp, but no chilling is evident, and clear evidence of one type cross-cutting the other has not been observed. It is difficult to recognize the exact contact between sub-layer and main norite on the South Range.

A variety of leucocratic breccias occurs between the North Range of the Nickel Irruptive and the Early Precambrian gneisses. A group of these breccias, referred to locally by such terms as "granite breccia" "late granite breccia", "grey breccia" and "footwall breccia" are classed as the leucocratic sub-layer. They are characterized by abundant footwall rock inclusions and, in places, by abundant inclusions of ultramafic and mafic rocks in a granoblastic matrix composed largely of quartz and plagioclase. They are host to much of the ore in the large deposits occurring along the North Range.

Some controversy exists over the origin of the breccias and whether they are pre- or post-Irruptive. It is very likely that a pre-Irruptive breccia with many of the characteristics of this group was formed at the time of origin of the Sudbury structure, and that this breccia served to localize intrusion of the main Irruptive and sub-layer. Subsequent explosion and fluidization due to heating of water in the breccia zone by overlying Irruptive rocks may have caused further brecciation along the contact, affecting the Irruptive rocks and giving rise to the ore-bearing breccias.

The Irruptive is situated near the common junction of the Superior, Southern and Grenville Provinces along the juncture of major regional faults of the east-west Murray and north-south Onaping Systems. The Irruptive

was emplaced along the contact between the Whitewater Group of the Sudbury Basin and the underlying Early Precambrian and Huronian rocks. Both inner and outer contacts of the Irruptive dip inward, defining a funnel-shaped structure. It was emplaced approximately 1,700 million years (Fairbairn et al, 1969) to 2,000 million years (Gibbins, pers. comm., 1973) ago after an explosive event of great magnitude which resulted in the formation of a basin, deposition of the Onaping Formation of the Whitewater Group, brecciation (see Photo 44, page 79, Guidebook No. 4) and the formation of shatter cones in the surrounding rocks (see Photo 41, page 71, Guidebook No. 4). Stevenson (in Guy-Bray, 1972) and others have attributed this event to explosive volcanism whereas Dietz (1964) and others attribute it to meteorite impact.

Emplacement of the Nickel Irruptive was followed by deformation, including faulting, development of cleavage, and folding of the Whitewater Group. Tectonic and intrusive activity occurred within the Grenville Province and Grenville Front Tectonic Zone during the Middle and Late Precambrian. Mafic and felsic intrusions along the Grenville Front Zone and intrusions within the Southern Province such as the Croker Island granite-gabbro complex (1,475 million years) (see Photo 2, page 3 and see Photo 31, page 49, Guidebook 4), fenitic breccias (Photo 58, page 100, Guidebook 4), and lamprophyre

dikes may be connected with this activity. Northwest-trending olivine diabase dikes (1,250 or 1,460 m.y.) are clearly post-tectonic, post-metamorphic with respect to Middle Precambrian orogenic events, and may have been emplaced under tensional conditions associated with broad arching of the Shield (Photo 72, page 117, Guidebook 4).

Geological relationships and radiometric age determinations indicate that the eastern part of the Southern Province was affected by a series of deformational events, accompanied by emplacement of a variety of igneous rock units, which began in the early Middle Precambrian some 2,400 m.y. or more ago and continued sporadically until some 1,000 m.y. with uplift of the adjacent Grenville Province. There is evidence for early deformation, predating or broadly synchronous with emplacement of Nipissing Diabase, and for later, post-Nipissing, post-Nickel Irruptive deformation and regional metamorphism. The latter event, which may be correlative with the Penokean or Hudsonian Orogenies, occurred approximately $1,750 \pm 100$ m. y. ago judging from radiometric ages of metamorphosed Middle Precambrian rocks. (See page 5, Guidebook No. 4 for a summary of rocks, units and events).

SELECTED REFERENCES

Card, K. D., Church, W. R., Franklin, J. M., Frarey, M. J., Robertson, J. A., West, G. F., and Young, G.M.

1973: The Southern Province, in Price, R.A., and Douglas, R. J. W. : Variations in Tectonic Styles in Canada. Geol. Assoc. Canada, Spec. Paper no. 11, p. 335-380.

Card, K. D., and Robertson, J. A.

1972: Geology and Scenery, North Shore of Lake Huron Region. Ontario Div. Mines, Geol. Guidebook No. 4. 224p.

Dietz, R. S.

1964: Sudbury Structure as an Astrobleme. J. Geol., v. 72, p. 412-434.

Fairbairn, H. W., Hurley, P. M., Card, K. D., and Knight, C. J.

1969: Correlation of Radiometric Ages of Nipissing Diabase and Huronian Metasediments with Proterozoic Orogenic Events in Ontario. Canadian J. Earth Sci., v. 6, p. 489-497.

Frarey, M. J.

1961: Wakwekobi Lake, District of Algoma. Geol. Surv. Canada, Prelim. Series Map 6-1961. Scale 1 inch to 1 mile.

In press: The Geology of the Huronian Belt Between Sault Ste. Marie and Blind River, Ontario. Geol. Surv. Canada.

Guy-Bray, J. V. (ed.)

1972: New Developments in Sudbury Geology. (A collection of 12 papers on various aspects of Sudbury geology). Geol. Assoc. Canada, Spec. Paper no. 10. 124 p.

Innes, D. G.

1972: Proterozoic Volcanism and Associated Sulphide-Bearing Metasediments in the Sudbury Area, Ontario. Unpub. B. Sc. thesis, Laurentian University. 60 p.

Irvine, T. N., and Baragar, W. R. A.

1971: A Guide to the Chemical Classification of
the Common Volcanic Rocks. Canadian
J. Earth Sci., v. 8, p. 523-546.

Naldrett, A. J., Bray, J. G., Gasparrini, E. L.,
Podolsky, T., and Rucklidge, J. C.

1970: Cryptic Variation and the Petrology of
the Sudbury Nickel Irruptive. Econ. Geol.,
v. 65, p. 122-155.

ITINERARYMay 4

Proceed via Highway 144 from Laurentian University directly to the first stop located approximately 5 miles north of the town of Levack which is situated on North Range of the Sudbury Nickel Irruptive.

Stop 1 Pseudotachylite Breccia (Map 3, page 72,
Guidebook No. 4)

Early Precambrian granitic and gneissic migmatitic rocks of the Superior Province north of the Sudbury structure are shattered and brecciated over an area of unknown dimensions. At this locality the Sudbury-type or "pseudotachylite" breccia consists of rounded to angular, disoriented fragments of granitic country rock in a dark-coloured matrix of finely comminuted rock flour. The breccia has apparently been formed by attrition in place without melting or significant addition of elements other than water and carbon. Some fragments display microscopic features of shock metamorphism.

Proceed south on Highway 144 to the Levack turn.

Stop 2 Quartz gabbro and transition into
micropegmatite, Sudbury Nickel Irruptive

We will stop at an outcrop on Highway 144 showing most of the quartz gabbro. The most northerly outcrop is oxide-rich gabbro with a south-dipping igneous lamination. On walking south, up the hill, on the east side of Highway 144, we cross the transitional contact between quartz gabbro and micropegmatite which is arbitrarily placed at the point where granophyre content exceeds that of plagioclase. The basal micropegmatite here is a rather dark pink rock, richer in mafic minerals and plagioclase than the micropegmatite higher in the sequence. The section is cut by several small dykes of dark red granophyre.

Stop 3 Onaping Formation, Onaping Falls
(point 19, map 3, Guidebook 4)

This is the type area for the Onaping Formation, the basal unit of the Whitewater Group of the Sudbury Basin. The rock is massive, apparently unstratified, and consists of angular rock fragments in a fine-grained matrix composed of rock and mineral fragments and numerous devitrified glass shards. The matrix is characterized by the presence of carbon, accounting for its dark colour, and of disseminated

sulphides, including pyrohotite and chalcopyrite. Many of the rock fragments are representative of rock units of the Superior Province to the north; others may represent volcanic fragments or fused country-rock fragments. Many of the rock fragments display microscopic evidence of shock metamorphism including planar features in quartz and plastic deformation of feldspar. The Onaping has been interpreted as an ignimbrite or ash-flow sheet (Stevenson, in Guy-Bray, 1972) and as a fall back breccia produced by meteorite impact (French, in Guy-Bray, 1972).

Stop 4 Chelmsford Formation
(Point 18, map 3, Guidebook 4)

The Chelmsford Formation at the top of the Whitewater Group is a thick-bedded (0.5 to 3 m.) sequence of greywacke with numerous features indicative of turbidite origin including the presence of graded bedding, Bouma layering, ripple-drift cross-lamination, and sole markings (Cantin and Walker; Rousell, in Guy-Bray, 1972). Several of these features are evident at this locality, as are elliptical, replacement-type concretions (see Photo 46, page 80, Guidebook 4).

Stop 5 . Discovery Site
(Point 14, Map 3, Guidebook 4)

At the base of the norite is the sub-layer, the heterogeneous marginal facies of the Irruptive, which contains all the orebodies. Its outcrop is delineated by a line of gossans, old pits and mine buildings. The discovery gossan is high grade nickel-copper ore, comprising rounded inclusions of exotic mafic and ultramafic rocks in a copious matrix of nearly massive pyrrhotite, chalcopyrite and pentlandite, with little if any Irruptive silicate matrix. Similar material is being mined from the open pit across the road.

The sub-layer, which dips northward beneath the norite, in places is several hundred feet thick. The adjacent outcrop of basal quartz-rich norite presents a striking contrast, being homogeneous, free of inclusions, and virtually devoid of sulphide.

The footwall hills southeast of the discovery site are of Murray granite; the hill on the southwest consists of mafic metavolcanics.

Stop 5 . Discovery Site
(Point 14, Map 3, Guidebook 4)

At the base of the norite is the sub-layer, the heterogeneous marginal facies of the Irruptive, which contains all the orebodies. Its outcrop is delineated by a line of gossans, old pits and mine buildings. The discovery gossan is high grade nickel-copper ore, comprising rounded inclusions of exotic mafic and ultramafic rocks in a copious matrix of nearly massive pyrrhotite, chalcopyrite and pentlandite, with little if any Irruptive silicate matrix. Similar material is being mined from the open pit across the road.

The sub-layer, which dips northward beneath the norite, in places is several hundred feet thick. The adjacent outcrop of basal quartz-rich norite presents a striking contrast, being homogeneous, free of inclusions, and virtually devoid of sulphide.

The footwall hills southeast of the discovery site are of Murray granite; the hill on the southwest consists of mafic metavolcanics.

A quarter mile south on the east side of the highway, a small outcrop displays an agmatitic contact between granite and metavolcanics. On the west side is the Irruptive's contact aureole, a hypersthene-plagioclase-magnetite hornfels.

Stop 6 Elsie Mountain Formation
(Point 1, map 3, Guidebook 4)

Turn right off Highway 144 onto the Murray Mine Road, and proceed along this road for about 1 1/4 mile. Turn left and park in front of a long row of garages and proceed up the hill.

Rocks of the Elsie Mountain Formation comprise the basal unit of the Huronian strata in the Sudbury area and are represented by up to 3,300 feet of mafic metavolcanic flows with minor interflow pelitic metasedimentary and mafic tuffaceous rocks. Mafic flows are generally massive, coarse to medium grained, structureless, and vary in thickness from 75 to 300 feet. Flow thicknesses decrease westward and upward in the formation. Amygaloidal and pillowed metabasalt flows as seen here are most common in the middle and upper parts of the formation.

In thin section, the rocks consist mainly of amphiboles (hornblende, actinolite-tremolite), plagioclase (An₂₀ to An₄₀), quartz

and chlorite with lesser amounts of mica, epidote, carbonate, apatite, sphene, sericite, iron sulphides and oxides. At Stop 6, local hornfels metamorphism related to the emplacement of the Nickel Irruptive can be observed by the intense "fish-net" type alteration veining, and by large hornblende porphyroblasts.

Stop 7 Stobie Formation (Map 3, Guidebook 4)

Rocks of the Stobie Formation, including mafic metavolcanic flows with appreciable amounts of sulphide-bearing metasedimentary and tuffaceous rocks, conformably and gradationally overlie the Elsie Mountain Formation. The Stobie Formation has an average thickness of about 2,800 feet and a maximum thickness of some 5,000 feet. The proportion of metavolcanic flows to interflow metasediments decreases upward from about 90% flows in the lower Stobie to about 50% flows in the upper part of the formation. Repetitions of a sequence characterized by a thin metabasalt flow overlain by a 1 to 2 foot section of "stirred top" through a thin well-bedded sequence of sulphide-bearing greywacke, grit, argillite-siltstone and sulphide-free arkose, constitute the Stobie Formation and result in an overall cyclical nature. Stauroilite-biotite metapelites are common and can be seen at Stop 7. These rocks consist primarily

of quartz, sericite, plagioclase (albite-oligoclase) and chlorite with lesser amounts of amphibole (mostly hornblende), opaques and sericite, chlorite and quartz pseudomorphically replacing staurolite or andalusite porphyroblasts. Metamorphism has resulted in reversed graded bedding as evidenced by staurolite metacrysts occurring in what was probably once fine-grained aluminous clay-rich tops.

Stop 8a. Copper Cliff Formation

The Copper Cliff Formation represents the felsic end member of the Middle Precambrian metavolcanic succession of the Sudbury area and occurs stratigraphically above the Stobie Formation and is overlain conformably by pelitic metasediments of the McKim Formation. The Copper Cliff is up to 2,400 feet thick and is exposed over a strike length of approximately 15 miles. The main rock-types present include crystal tuff, quartz-feldspar porphyry, porphyritic flows, flow-banded rhyolite, coarse fragmental units termed "ghost fragmental" rhyolite, massive rhyolite, dacite, and sulphide-bearing crystal tuff. These units form interfingering lensoid bodies. In thin-section, the rhyolitic rocks consist of a fine-grained intergrowth of perthite, orthoclase, plagioclase, and quartz with lesser sericite, biotite, chlorite, epidote, carbonate and opaques. Phenocrysts of quartz, plagioclase,

and microperthite in the crystal tuff and porphyritic flow units are commonly deformed, reflecting a well-developed tectonic foliation. At Stop 8a, porphyritic flows, and ghost fragmental units of the Copper Cliff Formation can be seen.

Stop 8b. McKim Formation

Proceed to the rear of the school and examine the outcrops belonging to the McKim Formation.

In the Sudbury area, metasedimentary rocks of the McKim Formation comprise the upper part of a conformable interfingering basal sequence, the Elliot Lake Group. At Stop 8b the McKim consists of interbedded, fine- to coarse-grained greywacke and siltstone, with lesser laminated siltstone and argillite. Sedimentary structures, including graded beds, ripples, rippled drift crossbedding, cross laminations, Bouma layering and slump structures, together with bedding thickness which averages several feet and ranges up to 15 feet, suggest a proximal turbidite.

As the formation is traced westward, a significant facies change occurs and laminated argillites constitute the dominant facies, with lesser amounts of greywacke and feldspathic sandstone.

The laminated argillites are thin-bedded (1 to 6 inches thick) and characteristically display thin varve-like parallel laminations. Ripples, graded beds, cross laminations and incomplete Bouma layering are common structures and together with the relatively thin bedding suggest a distal turbidite.

Stop 9 Copper Cliff Offset
(point 9, map 3, Guidebook 4)

The offset is a quartz diorite dike projecting south from the main Irruptive west of Murray Mine, and by definition is part of the sub-layer. It is less than 200 feet (60 m) wide here and remains narrow over the rest of its 3 mile (5 km) length to Kelley Lake. Ore-grade mineralization is confined to zones within the dike, as here, or at one margin, which have great longitudinal and vertical extent.

MAY 5

Stop 10 Mississagi Formation with Sudbury-
type breccia and shatter cones,
Laurentian University campus (point 8,
map 3, Guidebook 4)

Outcrops of metamorphosed feldspathic sandstone of the Mississagi Formation display well-preserved sedimentary structures such as

bedding and crossbedding. Locally these rocks are brecciated and exhibit shatter cones. The breccias consist of rounded fragments of sandstone in a comminuted quartz-rich, dark coloured matrix. The shatter cones are cone-shaped parting surfaces on which numerous lineations radiate outward from the apices. Breccias and shatter cones are indicative of passage of a high energy shock wave through these rocks, possibly the result of meteorite impact or volcanic explosive activity.

Stop 11 Espanola Road-cut
(point 1, map 5, page 104, Guidebook 4)

Folded pelitic metasediments of the McKim Formation and dikes of Nipissing-type metagabbro are well-exposed and display a number of features of interest including:

a) thin, regular bedding and ripple-drift cross lamination (climbing ripples).

b) a dike-like body of Sudbury breccia which crosscuts the bedding and fold structures in the McKim. The breccia consists of rounded fragments of country rock in a pelitic crush matrix. Note the alteration haloes about some of the mafic (Nipissing-type metagabbro) fragments and flow-lines in the matrix.

c) relationships between folds, minor structures and metamorphic porphyroblasts of

chloritoid (altered).

Stop 12 Clear Lake
(point 5, map 5, Guidebook 4)

Thin-bedded calcareous siltstone and impure sandstone of the Espanola Formation are cut by several conglomeratic dikes which are lithologically similar to the underlying Bruce Formation. (see Photo 67, page 109, Guidebook 4). The Espanola rocks display ripples, flame structures, ball-and-pillow structures and porphyroblasts of scapolite.

Across Highway 68, a Late Precambrian olivine diabase dike of the Sudbury Swarm is exposed. This northwest-trending, vertical dike is approximately 300 feet thick and is at least 50 miles long.

Stop 13 Cutler Batholith and Spragge Group
(Point 18, map 5, Guidebook 4)

Schistose metavolcanic, metasedimentary, and mafic intrusive rocks of the "Spragge Group" of probable Middle Precambrian (Huronian Supergroup) age form an anticlinal structure, the north limb of which is truncated by the Murray Fault.

In the core of the fold, the "Spragge Group" rocks are intruded by granitic rocks of general quartz monzonite composition, the Cutler Batholith which has a Rb-Sr radiometric age of about 1,750 m.y. (see Photo 28, page 42, Guidebook 4). The granite and associated deformational structures are possibly correlative with the Hudsonian orogeny.

Stop 14 Nipissing Diabase, Iron Bridge
(Point 24, map 7, page 152, Guidebook 4)

A sill-like body of Nipissing Diabase intruding rocks of the Gowganda Formation forms a series of hills north of the village of Iron Bridge. The intrusion is notably differentiated and from bottom to top consists of gabbro, granophyric gabbro, and granophyre. These rock-types are completely intergradational. In addition, there are several copper (chalcopyrite) occurrences in quartz-carbonate (ankeritic) veins in the granophyre which have been explored by pits, trenches, and an adit. Good specimens of iridescent-weathering chalcopyrite are available.

Stop 15 Thessalon Formation
(map 10, page 188, Guidebook 4)

Mafic metavolcanics in the Thessalon area which in the past were variously classed as Keewatin (Early Precambrian), Huronian (Middle Precambrian), or Keweenawan (Late Precambrian) have been recognized by Frarey (1961; in press) as part

of the Huronian Supergroup. The Elliot Lake Group around Thessalon comprises some 300 feet of sandstone and conglomerate, the Livingstone Creek Formation, which are conformably overlain by more than 2,000 feet of metavolcanics, the Thessalon Formation. The Livingstone Creek Formation, which is probably stratigraphically equivalent to the Matinenda Formation, nonconformably overlies Early Precambrian granitic and metavolcanic basement rocks.

The Thessalon Formation consists mainly of metabasalt flows with intercalations of rhyolite, minor sandstone and argillite, and rare quartz pebble conglomerate. The massive, generally structureless metabasalt flows are apparently thick; amygdules are common, and pillows are rare. The rhyolite is fine-grained, locally porphyritic, and amygdules, flow layering, and breccia are present.

Examples of metavolcanics of the Thessalon Formation, metasediments of the Livingstone Creek Formation, and Early Precambrian basement rocks will be examined at several localities in the Thessalon area.

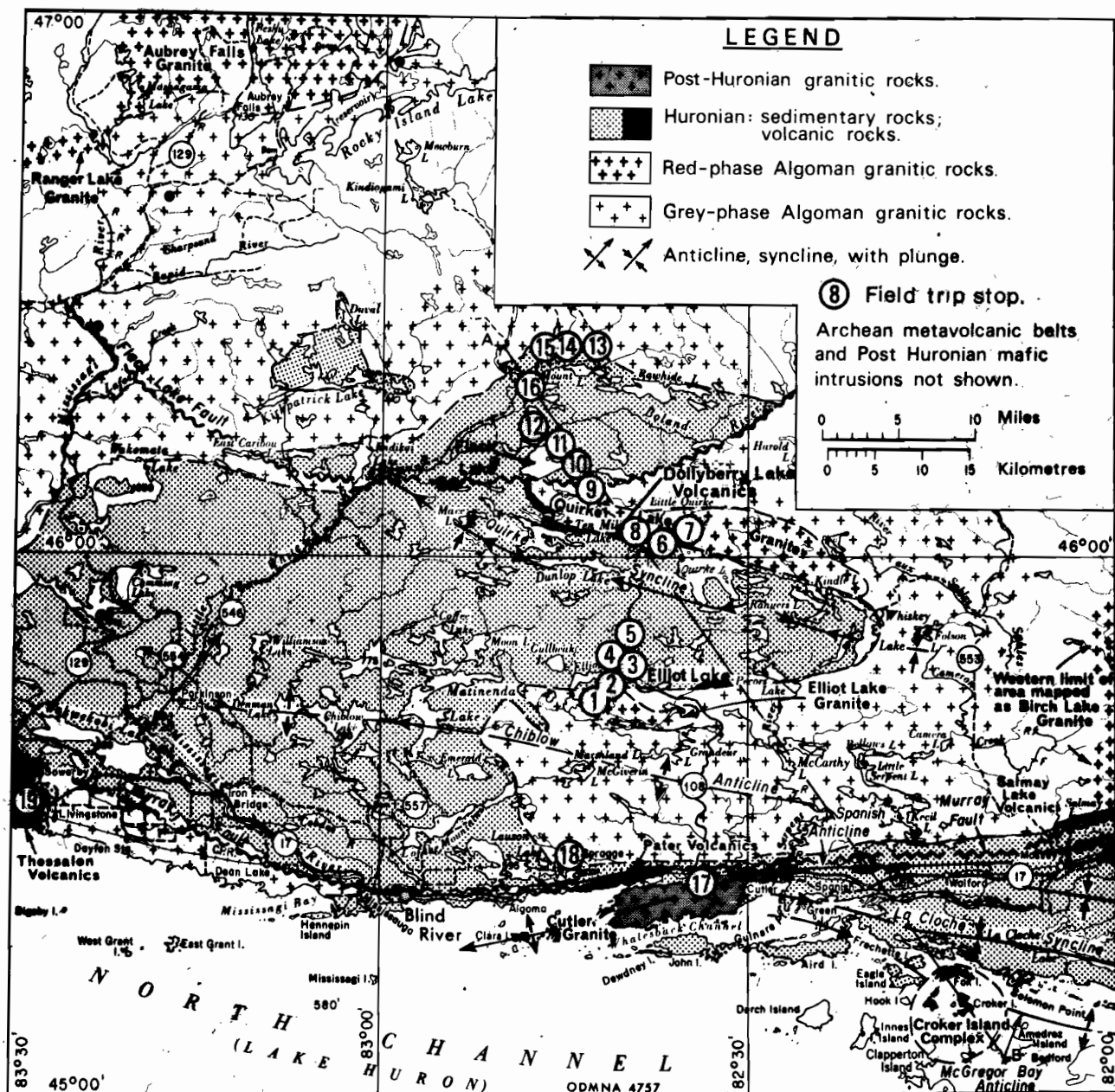
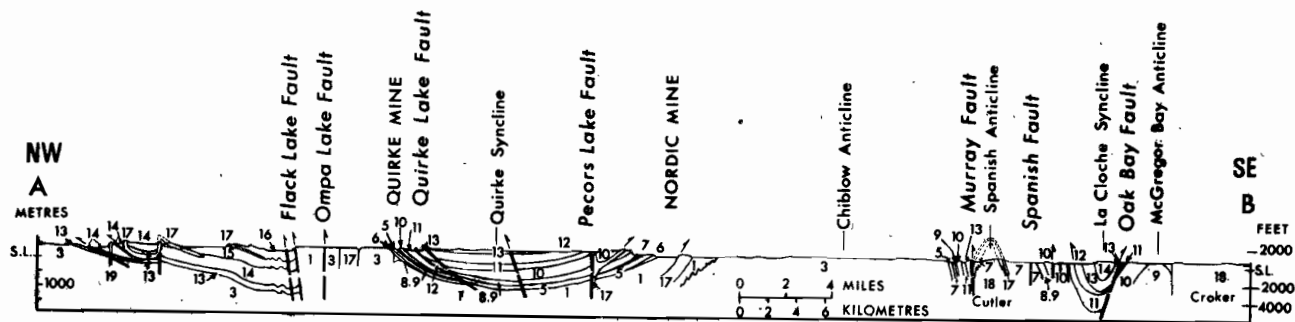


Figure 1 - Generalized geological map of the Blind River-Elliot Lake area
-Cross-section; units keyed to Table of Formations

TRIP 4

LEADERS: J. A. ROBERTSON, D. A. B. PEARSON

STRATIGRAPHY AND SEDIMENTATION OF THE

HURONIAN SUPERGROUP

BY

J. A. ROBERTSON

INTRODUCTION

The field trip will permit examination of outcrops on or near Highways 17, 108, 639, and 546 between Blind River and Mount Lake. These highways provide a traverse across the Southern Province of the Canadian Shield and are in the vicinity of the Principal Reference Section for the Huronian Supergroup (Robertson, et al 1969).

The trip will concentrate on the Huronian Supergroup stratigraphy, sedimentation, facies changes (from north to south, i.e. from the Archean craton of the Superior Province towards the Penokean fold belt). It will also include a study of the relationship of uranium deposits to stratigraphy, and the changes in structural style and metamorphism from the foreland area to the Penokean fold belt.

Throughout the trip nomenclature recommended by the Federal-Provincial Committee on Huronian Stratigraphy (Robertson et al 1969) will be used.

Recent significant publications are the paper by Card et al on the Southern Province in the G.A.C., Special Paper #11, "Variations in Tectonic Styles in Canada" and G.A.C. Special Paper #12, "Huronian Stratigraphy and Sedimentation".

GENERAL GEOLOGY

The bedrock of the area has been assigned to three broad units, the distribution of which is shown on the map (Figure 1). They are 1) the Archean basement consisting of Keewatin-type greenstone, Algoman granite which was emplaced during the Kenoran orogeny at least 2,500 million years ago, and minor mafic intrusive rocks; 2) the Huronian sedimentary and metasedimentary rocks with local mafic volcanic assemblages deposited on the north flank an easterly-trending basin by water and ice bringing rock debris from the Superior Province (sedimentation was markedly influenced by basement topography and southeasterly flowing currents, facies change away from the transgressive shore line is well displayed); and 3) the post-Huronian intrusive rocks comprising the Nipissing Diabase sills, NW diabase dikes, the Cutler granite, the Croker Island complex, a NE trending tholeiite dike system, and the NW trending Sudbury Swarm of olivine diabase dikes (of these intrusives only the Cutler granite and the Croker Island complex are shown on the map, however, they do not fall into the context of this field trip).

The structure is also shown on Figure 1. In the north lies the Quirke syncline, the north limb of which is cut by the Flack Lake Fault; in the centre lies the Chiblow anticline, the south limb of which is repeated by the Murray Fault; in the south lie the metamorphosed and complexly folded rocks of the Penokean Fold belt.

The post-Archean tectonic events increased in intensity from north to south. The sequence is as follows:

The Kenoran orogeny terminated about 2,500 million years ago. Huronian sedimentation, including the deposition of uraniferous quartz pebble conglomerates and local mafic volcanic rocks began at least 2,400 million years ago. During sedimentation there was a change from reducing conditions and from a cold climate to a hot climate, with occasional interruptions marked by unconformities or disconformities best developed in the north, until the Penokean disturbance at about 2,100 million years ago. The Nipissing Diabase was intruded during the Penokean disturbance and in the south is metamorphosed and foliated. The next major tectonic event was the Hudsonian orogeny. The Cutler granite (1750 million years) is a post-orogenic granite. The northeast trending differentiated tholeiite occurrence north of Mount Lake (which may be part of the Abitibi swarm or part of an earlier unnamed swarm) has not been dated and dikes of the Sudbury Swarm comprising olivine diabase were intruded 1,255 million years ago (Van Schmus, 1965).

ECONOMIC GEOLOGY

Uranium bearing pyritic quartz pebble conglomerates were deposited in the Lower Huronian (Matinenda Formation) close to the strand line. The uranium deposits are generally regarded as syngenetic (transported either in the solid or solution state) and the host rocks were probably deposited in a reducing environment. Recent work has shown that mafic volcanic rocks are widely distributed in the Lower Huronian sequence and volcanic piles had considerable effect on the distribution of conglomerates and possibly on the deposition of uranium in those conglomerates. In the Upper Huronian (Lorrain Formation) radioactive conglomerates comprise quartz pebble conglomerate with thorium-bearing and iron oxide (hematite or maghemite, T. Bottrill personal communications) heavy minerals. This and the presence in other members of the Lorrain Formation of clay minerals (Chandler et al 1969) indicates the onset of oxidizing conditions and a hot climate.

Copper occurrences are associated with the Huronian volcanic rocks and with the Nipissing Diabase. Bruce Mines is one of the earliest mining towns in Ontario. The Pater Mine at Spragge was opened on a silicified shear zone transecting metavolcanics. The Bi-Ore Mine at Cobre Lake near Flack Lake developed quartz-carbonate-specularite-chalcopryrite veins close to a thick Nipissing sill. Elsewhere granophyric segregations and associated quartz-carbonate veins carry minor pitchblende and chalcopryrite mineralization.

More detailed information on the individual rock units, structural geology, and economic geology can be obtained in the reports listed in the selected references.

SELECTED REFERENCES

Brown, L.C.

- 1967: Elliot Lake, The World's Uranium Capital, Canadian Geographical Journal, October 1967. (Reprints from Ontario Division of Mines).

Cannon, W.F.

- 1970: Plutonic Evolution of the Cutler Area, Ontario; Bull. Geol. Soc. Am., Vol. 81, p.81-94.

Card, K.D., and Robertson, J.A.

- 1972: General Geology of the Sudbury-Elliot Lake Region, 24 Int. Geol. Cong., Field Excursion, C.38.

Card, K.D., Church, W.R., Franklin, J.M., Frarey, M.J., Robertson, J.A., West, G.F., and Young, G.M.

- 1973: The Southern Province in Price, R.A. and Douglas, R.J.W.; Variations in Tectonic Styles in Canada, Geol. Assoc. Can. Special Paper No. 11, p.335-380.

Chandler, F.W., Young, G.M., and Wood, J.

- 1969: Diaspore in Early Proterozoic Quartzites (Lorrain Formation) of Ontario; Canadian J. Earth Sci., Vol. 6, p.337-340.

Collins, W.H.

- 1925: The North Shore of Lake Huron, Geol. Surv. Canada, Mem. 143. 160 p.

Donaldson, J.A.

- 1967: Precambrian Vermiform Structures: A New Interpretation. Canadian J. Earth Sci., Vol. 4, p.1273-1276.

Giblin, P.E., and Leahy, E.J.

- 1967: Sault Ste. Marie - Elliot Lake Sheet, Districts of Algoma, Manitoulin, and Sudbury. Ontario Dept. Mines, Geological Compilation Series, Map 2108. Scale 1 inch to 4 miles. Geological compilation 1964-65.

Hoffman, H.J.

- 1967: Precambrian Fossils(?) near Elliot Lake, Ontario. Science, Vol. 156, p.500-504.

McDowell, J.P.

- 1957: The Sedimentary Petrology of the Mississagi Quartzite in the Blind River Area, Ont. Dept. Mines G.C. No. 6, 31p.

Robertson, J.A.

- 1968: Geology of Township 149 and Township 150, District of Algoma. Ont. Dept. Mines GR57, 162 p. Accompanied by Map 2113, 2114, scale 1 inch to $\frac{1}{2}$ mile.
- 1969a: Geology and Uranium Deposits of the Blind River Area, Ontario. Bull. C.I.M. Vol. 62, June 1969, p.619-634.
- 1969b: Township 157, District of Algoma. Ont. Dept. Mines, Prelim. Geol. Map P.561, scale 1 inch to $\frac{1}{2}$ mile.
- 1970a: Geology of the Spragge Area, District of Algoma. Ont. Dept. Mines GR76, 109p. Accompanied by Maps 2185, 2186, scale 1 inch to $\frac{1}{2}$ mile.
- 1970b: Township 1A, District of Algoma. Ont. Dept. Mines, Prelim. Geol. Map P.610, scale 1 inch to $\frac{1}{2}$ mile.
- 1971: Blind River-Elliot Lake Sheet, Ont. Dept. Mines and Northern Affairs, Geological Compilation Series Map P.304 (1971 revision). Scale 1 inch to 2 miles. Original compilation by P.E. Giblin and E.J. Leahy, Map P.304, 1965.

Robertson, J.A., Card, K.D., and Frarey, M.J.

- 1969: The Federal-Provincial Committee on Huronian Stratigraphy Progress Report, Ont. Dept. Mines MP 31, 26p.

Robertson, J.A., and Card, K.D.

- 1972: Geology and Scenery, North Shore of Lake Huron Region. Ont. Div. Mines, Ministry of Natural Resources, 224p.

Roscoe, S.M.

- 1969: Huronian Rocks and Uraniferous Conglomerates in the Canadian Shield, Geol. Surv. Canada, Paper 68-40, 205p.

Van Schmus, W.R.

- 1965: The Geochronology of the Blind River-Bruce Mines Area, Ontario, Canada. J. Geol. Vol. 73, p.775-780.

Young, G.M.

- 1969: Inorganic Origin of Corrugated Vermiform Structures in the Huronian Gordon Lake Formation near Flack Lake, Ontario. Can. J. Earth Sci., Vol. 6, p.795-799.
- 1973: (Editor) Huronian Stratigraphy and Sedimentation. Geol. Assoc. Can. Spec. Paper No. 12, 271 p.

TABLE 1

TABLE OF FORMATIONS, BLIND RIVER-ELLIOT LAKE

<u>UNIT</u>	<u>CODE</u>	<u>LITHOLOGY</u>	<u>AGE</u>
PHANEROZOIC			
CENOZOIC			
RECENT AND PLEISTOCENE		Sand, gravel, till	
	Unconformity		
PALEOZOIC			
ORDOVICIAN	(20)	Limestone	
PRECAMBRIAN			
PROTEROZOIC			
KEWEENAWAN SUPERGROUP			
SUDBURY DIKES	(19)	Olivine diabase	1,225 m.y.
	Intrusive Contact		
MOUNT LAKE DIKE		Quartz diabase	
	Intrusive Contact with Nipissing Diabase		**
HUDSONIAN			
CROKER ISLAND COMPLEX	(18)	Gabbro, granite	1,445 m.y.
CUTLER BATHOLITH	(18)	Granite	1,750 m.y.
	Intrusive Contact		
PENOKEAN			
NIPISSING	(17)	Quartz diabase, diorite	2,155 m.y.
	Intrusive Contact		
HURONIAN SUPERGROUP			
COBALT GROUP			
BAR RIVER	(16)	Quartzite	
GORDON LAKE	(15)	Siltstone	
LORRAIN	(14)	Quartzite, conglomerate	
GOWGANDA	(13)	Conglomerate, greywacke	
	Unconformity-Disconformity		
QUIRKE LAKE GROUP			
SERPENT	(12)	Quartzite	
ESPANOLA	(11)	Limestone, greywacke	
BRUCE		Conglomerate	
	Local Disconformity		
HOUGH LAKE GROUP			
MISSISSAGI	(10)	Quartzite	
PECORS	(9)	Argillite	
RAMSAY LAKE	(8)	Conglomerate	

** Mount Lake Dike may be 1,795 m.y.

		Local Disconformity	
ELLIOT LAKE GROUP*			
McKIM	(7)	Argillite	
MATINENDA	(5)	Quartzite, + U-conglomerate	
		Conglomerate	
		Arkose+ U-conglomerate	
		Unconformity	

ARCHEAN

LATE ARCHEAN INTRUSIVES		Diabase	2,500 m.y.
		Intrusive Contact	
KENORAN (ALGOMAN)	(3)	Granite	2,500+m.y.
		Intrusive Contact	
EARLY ARCHEAN INTRUSIVES		Gabbro	
		Intrusive Contact	
KEEWATIN	(1)	Volcanic and sedimentary rocks	

* Volcanic rocks are found locally in the Elliot Lake Group (6), each occurrence has been given its own name.

ITINERARY

May 3

Depart from Sault Ste. Marie and travel to Elliot Lake.

Road Logs

- Notes
1. Care must be taken on highway stops. Do not loiter on pavement.
 2. Quick loading and unloading of vehicles is essential.
 3. Leaders reserve right to eliminate stops in order to maintain schedule.
 4. Sample taking should not deface main portions of outcrops.

First Day (May 4, 1974)

Mileage0.0 Stop 1 Elliot Lake (Matinenda Formation)

Outcrops on Highway 108 and in the vicinity of the Elliot Lake shopping centre are of Matinenda Formation. The outcrops show bedding and cross-bedding and interbedding of brownish weathering feldspathic quartzite and green-weathering sericite-rich bands.

0.0 Stop 2 Balsam Place (McKim Formation)

The outcrop shows interbedded protoquartzite and argillite. A cleavage is diffracted when passing from protoquartzite layers to argillite layers. A diabase dike cuts the northeast tip of the outcrop.

- 0.0 South Entrance to Elliot Lake.
- 0.20 Elliot Lake Municipal Offices and Nuclear Museum.
- 0.5 Horne Lake.

Cliff on the east side of lake shows Mississagi Formation (white, thick-bedded) overlying Pecors Formation (grey, thin-bedded). Horne Lake overlies a fault - the Horne Lake Fault. Outcrop of the Pecors Formation is displaced north on the west side of the fault and underlies Elliot Lake.

- 1.5 Elliot Lake.

- 2.3 Stop 3 Mississagi Formation

Grey to white well-bedded feldspathic quartzite, note cross-bedding from west, and bedding plane lineations.

- 2.5 Stop 4 A sill of Nipissing Diabase which forms a prominent ridge running east from the road can be seen at road level. Over the next few hundred feet the following units can be seen (1) Diabase, (2) Mississagi Formation showing albite (pink) and chlorite (green) introduced from the diabase, (3) contact with Bruce Formation, (the Mississagi Formation was still unconsolidated when the Bruce Formation was deposited), (4) a second part of the diabase intrusion, (5) Bruce Formation, (6) transition zone to Bruce Limestone member of the Espanola Formation. The Bruce Limestone is

converted to a skarn. Grossularite (garnet) idocrase, diopside, and minor wollastonite are found. These do not show their crystal form. Drag-folding, caused by differential movement of different layers during the formation of the Quirke syncline, etched weathering and a thin diabase sill exposed on the west side of the highway are other points of interest. The limestone outcrop is bounded on the north by a gully, north of which is the Gowganda Formation: the actual contact of the Bruce Limestone and the Gowganda Formation is not exposed.

2.8 Over the next mile the highway climbs through a series of road cuts which show Gowganda conglomerate of tillite type. Some people use this as an ornamental stone.

4.0 Stop 5 At the top of the hill is a spectacular road cut in bedded boulder conglomerate with conglomeratic quartzite interbeds. The conglomerate makes a good ornamental stone. The relay tower for the Elliot Lake T.V. satellite station is located on this ridge. The highway then runs through interbedded sparse pebble conglomerate (tillite), pink feldspathic quartzite, and greywacke.

7.9 Serpent River, west of the highway, is the access to Dunlop Lake. From the east end of Dunlop Lake an esker follows Highway 108 northwards past the access road to Denison Mine.

- 8.7 Denison Mine Access Road.
- 9.4 Panel Mine, Quirke #2 mine access road.
- 9.7 End of Highway 108. Start of Highway 639,
Quirke #1 mine and Quirke mill.
- 0.0 Panel Mine Access Road

Outcrops along Panel Road to the end of pavement at Quirke #2 mine are in the Espanola Limestone Member of the Espanola Formation. Over much of this distance the road is close to a fault and near vertical dips can be seen in several of the outcrops adjacent to the road.

Stop 6 The first outcrop east of the side road to Quirke #2 mine shows most features of the Espanola Limestone - interbedded brown weathering dolomitic siltstone and siltstone. Sedimentary features, such as ripple marks, small scale cross-bedding, dessication breccias, and slumpage structures such as slumpage pillows, convolute bedding, flame casts, and siltstone dikes can be seen (Eisbacher 1970 has recently discussed the clastic dikes at this locality). The road swings northeast crossing the automatic railway which transports ore from the Quirke No. 2 shaft to the Quirke Mill. A roadside cut (private property) shows the thin bedded white Bruce Limestone overlain by Espanola Greywacke. The next outcrop on the road shows Bruce Conglomerate: this is more

densely packed than that seen on Highway 108 indicating greater proximity to the source area. The road then swings eastward along the valley of the Serpent River. Outcrops on the south side of the road show green arkose (feldspathic sandstone) of the Mississagi Formation. Pebbly horizons are moderately radioactive.

This should be contrasted with the rocks seen at Stop 3.

The Serpent River valley has resulted from the erosion of the soft argillites of the Pecors Formation and the high ground to the north of the valley consists of red Archean granite.

Serpent River Crossing

East of the Serpent River crossing to the Panel Mine gate the road runs along the contact between rocks of Archean and Proterozoic age just north of Quirke Lake.

Stop 7 Outcrops at the northwest corner of Quirke Lake show the boulder conglomerate of the Ramsay Lake Formation against weathered basement rocks. An outcrop just north of the road shows banded rhyolite but most outcrops are of red granite. The boulder conglomerate is overlain by greywacke showing graded bedding transitional to argillite of the Pecors Formation. This sequence

shows a number of pebbles and pebbles dropped from floating ice. A cleavage intersects the bedding. Outcrops in the river bed at the entrance to Quirke Lake show shattered argillite with numerous quartz stringers.

9.7 Return to junction of Highway 108 and 639 and proceed northwest on Highway 639, mileage measured from south entrance to Elliot Lake along Highway 108 and 639.

10.2 Stop 8 At the foot of the hill west of the Quirke #1 mine there are exposures of Bruce Formation similar to that on the Panel Road. The cuts on the hill are in brownish-green arkosic Mississagi Formation and pebble bands showing weak radioactivity. The road then crosses the valley over the Pecors Formation and the Ramsay Lake Formation. Outcrops at the roadside north of the valley are of red Algoman quartz monzonite. On the south fringe of the outcrop west of the road massive to amygdaloidal and/or porphyritic mafic volcanic rocks can be seen resting on a regolith on granitic basement. Locally quartz-pebble conglomerate can be seen between the volcanic rocks and the Archean rocks and elsewhere granite inclusions can be seen in flow rocks or granite cobbles in interflow sedimentary rocks.

The recognition of the extent and relationship of Huronian mafic volcanic rocks has been an important result of recent mapping and exploration.

- 14.8 Brick red granitic rocks cut by diabase dikes are exposed to Ompa Lake where the road is crossed by a fault--the Ompa Lake Fault, which is not exposed. North of this the highway cuts and shoulders expose volcanic and sedimentary rocks of Keewatin-type.
- 15.2 Stop 9 There are good exposures of pillow lavas. At the north end of this series of outcrops metasediments are strongly fractured and intruded by quartz veins. The road drops sharply into a valley at the bottom of which is an outcrop
- 15.6 of shattered quartzite of the Bar River Formation. The Flack Lake Fault lies between these two outcrops. Bar River Formation is exposed over the next few miles. It is essentially well-bedded cream coloured quartzite showing cross bedding, ripple marks, mudcracks, and other dessication features characteristic of deposition in shallow to intermittent water.
- 16.5 Access road to Semiwhite Camp site, Mississagi Provincial Park.
- 17.3 Stop 10 Christman (Jimchrist) Lake and Flack Creek. Ripple marked flaggy quartzites and iron bearing quartzites are exposed on the highway and along the creek.

Both on the highway and on the shores of Flack Lake ripple marked bedding planes have sinuous structures believed to be fossils, possibly worm casts (Hoffman 1967) or infilled dessicated algal mats (Donaldson 1967). Dessication structures are also common and comparison with dessication structures in the Gordon Lake Formation has led to the suggestion that the structures are consolidated dessication fracture fillings transported and redeposited by later current action (Young 1969).

18.0 Small scale anticline in Bar River quartzite (best exposure east side of road).

19.3 A thin sill of Nipissing Diabase crosses the road: columnar jointing is well developed on east side of road. Immediately south of this lies bedded fine-grained pinkish quartzite marking the transitional zone between the Bar River and Gordon Lake Formations. The road descends to the Boland River crossing through intermittent exposures of the interbedded siltstones, cherts, and fine-grained sandstones of the Gordon Lake Formation. The best outcrop is at the junction with the Laurentian Lodge road $\frac{1}{4}$ mile south of the Boland River.

20.4 Stop 11 Here ripple marks, mudcracks, cross bedding slumpage structure and a late cleavage are well displayed.

20.7 Boland River.

The prominent ridge north of the Boland River is a large body of Nipissing Diabase dated at $2,130 \pm 215$ million years (Hoffman 1967). Cuts show that the body is differentiated, the rock varying from diabase (black) through diorite (grey-green) to granophyre (pink) with hornblende crystals. Epidote veins are associated with the granophyre.

21.9 Stop 12 From the top of the hill an excellent view of the Boland valley and Flack Lake is obtained.

22.1 The next outcrop on the west side of the road shows altered quartzites of the Gordon Lake Formation with spots of chlorite and biotite developed as a result of alteration or metamorphism. To the north and northwest lies the Little White River valley. The hills beyond are Lorrain Formation and Archean granite.

22.8 Gravel road leads east to Cobre Lake. Here is an old copper mine, the Bi-Ore Mine. Specimens of banded chert, chalcopyrite, pyrite, specular hematite, quartz, and carbonate minerals, including malachite and azurite, can be obtained in the vicinity of the workings.

- 23.1 Stop 16 (see later) About a quarter mile northwest of the junction of the Cobre Lake road and Highway 108 there are several small outcrops of white quartzite of the uppermost member of the Lorrain Formation. Cross bedding is poorly developed.

Highway 639 then runs over Pleistocene sands and gravels filling the Little White River valley.

- 24.2 River-cut terraces are seen at the junction with Highway 546. Proceed north on Highway 546.

- 24.6 Little White River crossing.

- 25.6 Junction with Kendiogami access road, turn right.

- 28.3 (Stop 15) West end of Mount Lake.

Lorrain quartz-chert-jasper pebble conglomerate and buff quartzite with clay minerals.

- 28.8 (Stop 14) Lorrain radioactive quartzite and quartzite and pebble conglomerate.

- 31.1 (Stop 13) Lorrain Arkose

- 31.2 Junction with Portelance Road, turn and retrace route. Location of stops 13-16 has been indicated above. Outcrops along the road north of Mount Lake show the Lorrain Formation. The

- Stop 13 Lorrain is divided into three units: 1) a lower arkose grading upwards to coarse quartzite

with interbeds of quartz pebble conglomerate with iron oxides, zircons and monzonite. The

Stop 14 heavy minerals are also found defining the bottoms of beds and crossbeds in the quartzite.

Stop 15 2) interbedded quartz-chert-jasper pebble conglomerate (normally non-radioactive) and white weathering, buff quartzite carrying clay minerals indicative of warm weathering conditions (Chandler et al 1969) and

Stop 16 3) massive, white, generally crossbedded ortho-quartzite. Further detailed subdivision is possible (see Robertson 1970b).

Return to Elliot Lake

Second Day May 4, a.m.

Stop 17 Proceed south on Highway 108 to Highway 17. At the junction of Highway 108 and 17, the outcrops north of Highway 17 comprise Mississagi arkose (green weathering) resting on granitic rocks of the Chiblow-Lewis basement high. South of the road are schistose quartzite, garnet-staurolite-mica schist, and amphibolite. Chlorite schist marking the Murray Fault can be seen a mile east of Spragge. Follow Highway 17 west to the Pronto Mine Service Road.

Figure 3 - Geological Section - Pronto Mine (after company drawing)

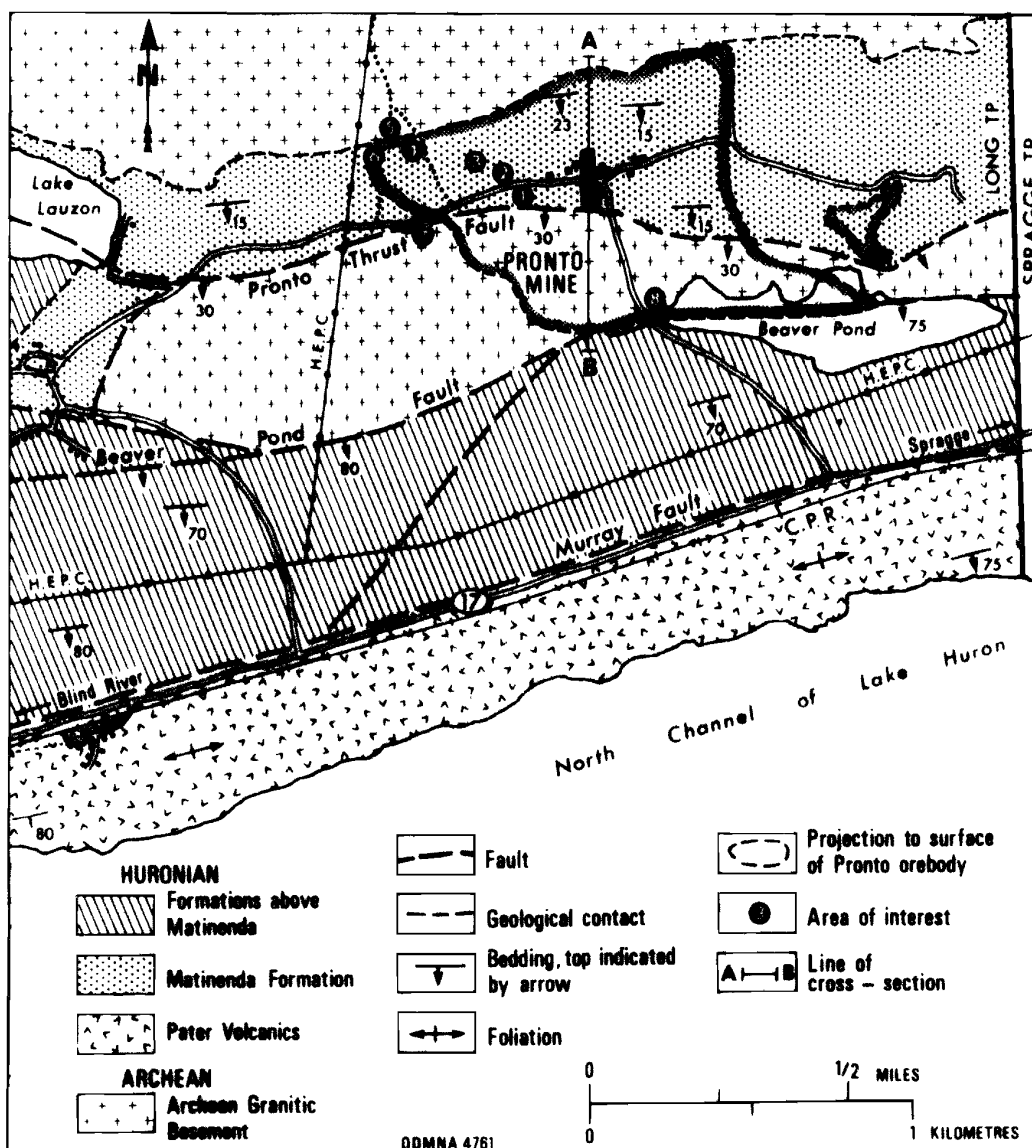
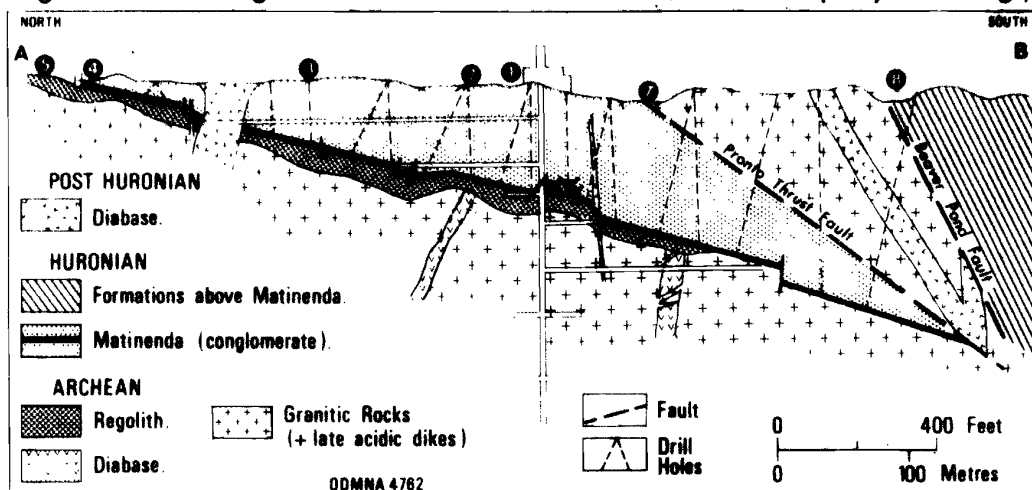


Figure 2 - Surface geology of Pronto Mine, Long Township

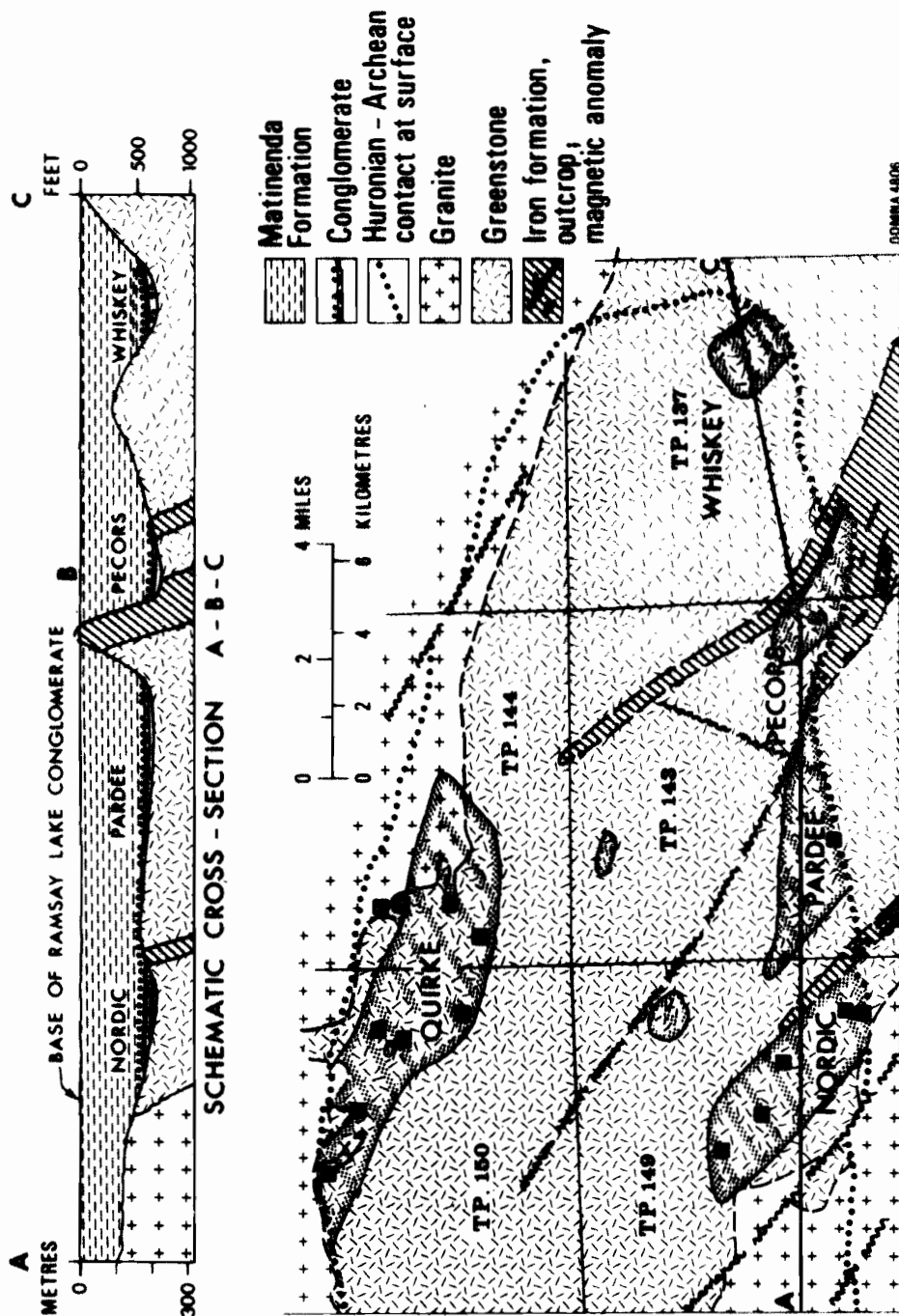


FIGURE 4 - URANIUM DEPOSITS IN QUIRKE SYNCLINE

Stop 18 Pronto Mine

Figure 2 shows the general geology in the vicinity of Pronto Mine and Figure 3 is a typical vertical cross section through the mine. Numbers on the map and section are areas of interest described below:

- Locality (1) Trough crossbedding in Matinenda Formation, weak radioactivity: south of road a gully marks the location of the Pronto Thrust Fault, beyond which is a ridge of Archean granitic rocks.
- (2) Matinenda arkose cut by albite veins.
- (3) Going north, arkose becomes coarser-grained and more radioactive. Thin pebble bands show moderate radioactivity.
- (4) Glory Holes. At the old mine workings the ore conglomerate is exposed on Archean granitic basement. The hangingwall shows pebble bands and crossbedding. The arkose is weakly to moderately radioactive and the ore bed strongly so.
- (5) Archean surface showing transition to fossil soil overlain by scattered patches of pebble conglomerate. The front slope is essentially the pre-Huronian surface. The Archean rocks are cut by diabase dikes.

(6) The discovery locality - a number of shallow pits and trenches (some post-date the discovery). The original radioactive sample that resulted in the discovery of the mine came from one of these pits.

Note Gossan (oxide stained rock) due to weathering of pyrite.

(7) Pronto Thrust Fault, repeats Archean basement to south.

(8) Beaver Pond Fault.

Second Day, p.m.

Stop 19 Return to Highway 17 and return to Sault Ste. Marie. Should time and transportation schedules permit, a brief stop will be made at Thessalon to examine lower Huronian volcanics.

These comprise massive basaltic andesite with occasional phenocrysts and amygdules.

Bruce Mines Bruce Mines $8\frac{1}{2}$ miles west of Iron Bridge is the oldest community on the north shore of Lake Huron dating back to discovery of copper in 1847. Quartz veins were mined at intervals over a strike length of 1-5 miles. The war-memorial is built from Lorrain jasper pebble conglomerate.

Desbarats

About 1.5 miles west of the village of Desbarats a roadside cut in thinly-bedded arkosic sandstone of the Lorrain Formation gives excellent exposures of asymmetrical ripple marks. Orientations on successive bedding planes may vary by 90° , indicating rapidly varying currents. This outcrop is a designated historical site and should not be defaced.

TRIP 5

LEADERS: R. J. RUPERT, G. BENNETT

THE MICHIPICOTEN GREENSTONE BELT

BY

G. BENNETT AND R. J. RUPERT

GENERAL GEOLOGY

The Michipicoten greenstone belt forms part of the Superior Province of the Canadian Shield, and contains many of the rocks, structures and relationships which make these Early Precambrian supracrustal assemblages unique and enigmatic.

The Michipicoten belt has the gross form of an irregular east-west trough with a large southward projecting salient extending under Lake Superior. The supracrustal rocks of the belts consist mainly of mafic and felsic metavolcanics with subordinate metasediments including iron formation. The metavolcanic-metasedimentary assemblage is intruded by a variety of minor intrusions ranging from gabbros to felsic porphyries. As with (almost?) all Archean greenstone belts the metavolcanics have no recognizable basement. Field relationships clearly indicate that the surrounding granitic terrain is intrusive into the belt.

Published with the permission of the Director, Geological Branch, Ontario Division of Mines, Ministry of Natural Resources.

STRATIGRAPHY

The most recent subdivision of the Michipicoten rocks is that of Goodwin (1962) as shown below:

<u>Unit</u>	<u>Rock Type</u>
Precambrian	Diabase dikes
Intrusive rocks	Granite, granodiorite, syenite Diorite, gabbro, peridotite
	Upper volcanic rocks - basalt, andesite, minor rhyolite
	Dore sedimentary rocks - conglomerate, greywacke, shale
Michipicoten group	Middle volcanic rocks - andesite, dacite, minor rhyolite
	Helen iron formation - chert, siderite, pyrite, magnetite, hematite
	Lower volcanic rocks - andesite, dacite, rhyodacite, rhyolite, iron formation

Cooke (1937), Moore (1948) and Bruce (1940) concluded that the Dore metasedimentary rocks unconformably overlies the entire metavolcanic group and have later been infolded with the metavolcanics.

METAVOLCANICS

The oldest rocks of the Michipicoten greenstone belt are predominantly mafic to intermediate lavas which lie at the stratigraphic base of the belt. These were referred to by Coleman and Wilmott (1902) as the Gros Cap greenstone, and by Goodwin (1962) as the lower portion of the lower volcanic division. The lavas are predominantly metamorphosed mafic flows, commonly displaying well developed pillow structures.

Goodwin (1962) reports that individual flows display thicknesses up to 200 feet and thicknesses of about 60 feet are average.

The stratigraphically higher portions of the mafic metavolcanic sequence contain an increasingly larger proportion of felsic metavolcanics and eventually pass into a sequence of predominantly dacitic to rhyolitic pyroclastic breccias, tuffs and flows. Goodwin (1962) interpreted thick pyroclastic sections of the Michipicoten belts as consisting of "large, irregular coalescing, domical masses" which he referred to as "breccia domes". For the most part these are relatively thick deposits of volcanic breccias, largely devoid of internal stratification.

The volcanic rocks of the Michipicoten area have locally undergone pervasive carbonatization resulting in the development of fine-grained, disseminated ankerite. Narrow veinlets and irregular masses of ankerite several feet across are also developed. Ankeritized rocks are generally recognizable by their reddish to orange mottled surface. In some localities the alteration may be controlled by steeply dipping shear zones up to several hundred feet wide.

A feature which appears to be most common in the felsic metavolcanics of the Wawa area is the local development of ottrelite (chloritoid). The chloritoid occurs mainly as disseminated crystals a few millimeters across in the felsic metavolcanics, but it has also been reported in many of the older intrusive rocks (Moore and Armstrong, 1948). The development of chloritoid appears to be associated with the ankeritization and it may therefore be of hydrothermal rather than of metamorphic origin.

IRON FORMATION

Goodwin (1962) considered Michipicoten iron formation to be divisible into two main types, namely iron formation of sedimentary association and iron formation of volcanic association. The former consists essentially of alternating layers of chert and silicious magnetite or hematite; while the latter, where fully developed, consists of three distinct members (Collins and Quirke 1926, Goodwin 1962). These members tend to occur in a definite stratigraphic succession beginning with a basal deposit of massive siderite up to 350 feet thick resting upon a thick sequence of highly ankeritized felsic pyroclastics. The carbonate member passes upward into a pyrite member, up to 120 feet thick, which consists essentially of pyrite with variable amounts of pyrrhotite, siderite, magnetite and silica. The pyrite member is in turn overlain by a banded silica member, which at the Helen Mine is about 600 feet thick, but is generally less than 200 feet thick. The banded silica member generally consists of alternating layers of metachert and siderite, with minor magnetite, pyrite and chlorite. The entire iron formation sequence is generally overlain by a thick unit of mafic metavolcanics (Goodwin, 1962).

Collins and Quirke (1926) concluded that the siderite ore body of the Helen Mine and the immediately overlying pyrite deposit are replacement deposits formed by the action of hot springs during the main period of vulcanism. The banded silica deposits on the other hand were considered to be due to chemical precipitation from surface waters.

Moore and Armstrong (1946), Grout (1926) and others favoured a hydrothermal origin for the carbonate, stating that it resulted from the replacement of felsic metavolcanic at depth long after the deposition of the metavolcanics.

Goodwin (1962) returned to an hypothesis similar to that originally put forward by Coleman and Wilmott (1902) and stated that the evidence favoured a syngenetic, (i.e. chemical precipitate) origin for the carbonate, pyrite and banded silica members of the Michipicoten iron formations.

METASEDIMENTS

The Dore metasediments represent the main clastic member of the Michipicoten greenstone belt. The dominant lithologies are greywacke, siltstone and argillite. Polymictic conglomerate is locally abundant; quartzite is present but rare.

Goodwin (1962) reports that the thickness of the Dore metasediments near Michipicoten Harbour is about 8,500 feet. At Iron Lake the thickness of conglomerate alone may reach up to 2,000 feet (Bennett and Thurston, 1972).

Conglomerate generally consists of subrounded to well rounded pebbles, cobbles and boulders set in a sand-sized arkosic matrix. Megaclast populations consist mainly of felsic porphyries, equigranular metafelsite (metavolcanics) and, locally, equigranular granitic rocks. A common feature of the Dore conglomerate is the marked deformation of the porphyritic and fine-grained metafelsite clasts, in contrast to the relatively undeformed state of the co-existing granitic clasts. This apparent difference in rigidity

of the clasts is probably a reflection of the former presence of a glassy groundmass in the felsites in contrast to the holocrystalline state of the plutonites.

Cooke (1937), Moore and Armstrong (1946) and Bruce (1940) interpreted the Dore as forming an infolded trough resting unconformably upon the metavolcanics. Collins and Quirke (1926) and Goodwin (1962) considered the Dore metasediments as forming an integral part of the volcanic succession. The latter interpretation appears to have gained acceptance with most geologists to-day.

EARLY INTRUSIVE ROCKS

The metavolcanic assemblage has been intruded by a number of minor intrusions which pre-date the emplacement of the main granitic batholiths. Among these pre-granite intrusions are thick sills, plugs and dikes of medium-to-coarse-grained, altered or metamorphosed gabbro which in many places is indistinguishable from coarse-grained portions of mafic flows. The essential constituents are albite, epidote, actinolite, chlorite, leucoxene with minor quartz. Locally these mafic intrusions have been extensively ankeritized. Moore and Armstrong (1946) report that ottrelite and cordierite are present in some of these bodies.

Sills and dikes of quartz feldspar porphyry, generally a few tens of feet thick, are common in many parts of the Michipicoten belt. For the most part these are older than the main granitic intrusions but a few similar dikes intrude the granitic batholiths.

The intrusive relationships between the mafic intrusions and the felsic porphyries vary in different parts of the belt. It is likely that more than one age of these mafic and felsic intrusions are present; some coeval with the metavolcanics while others may represent younger igneous events.

Early ultramafic intrusions of serpentinite and serpentinitized peridotite appear to be rare in the Michipicoten belt.

LATE MAFIC AND ULTRAMAFIC INTRUSIONS

Northeast trending and northwest trending diabase dikes are common throughout the Michipicoten area. K/Ar age determinations by the Geological Survey of Canada indicate that at least two ages of diabase are present, one corresponding to that of the Abitibi Swarm (ca. 1,200 m.y.) and the other corresponding to the age of the Matachewan Swarm (ca. 2,400 m.y.).

Locally some of the diabase magma has undergone differentiation to serpentinite and peridotite.

Minor dikes and irregular bodies of lamprophyre are widespread in the central and eastern parts of the Michipicoten belt. Narrow, ultramafic lamprophyres are among the youngest intrusions of the region and intrude all of the diabase dikes. Mafic kersantitic lamprophyres appear to be more common than the ultramafic types. They post-date the granitic intrusions but are (at least in part) older than the diabase.

The Firesand Carbonatite, two miles south of Wawa Lake, is a roughly circular body of calcite and dolomitic carbonatite about two miles in diameter. Local concentrations of pyrochlore have been found in the body. A K/Ar determination indicates an absolute age of 1,048 m.y. (Gittins et al, 1967).

METAMORPHISM

The supracrustal rocks of the Michipicoten greenstone belt have undergone regional metamorphism of the greenschist facies. Detailed metamorphic studies are generally lacking but it appears that for the most part the quartz-albite-epidote-biotite subfacies has been reached. Superimposed upon this regional metamorphism is the contact metamorphism resulting from the intrusion of the major granitic plutons. These younger metamorphic events have resulted in the formation of a zone of amphibolitic rocks from a few hundred feet to several thousand feet thick at the borders of the greenstone belt. Locally the amphibolites of this hornfels zone display a remarkably continuous layering from less than one quarter of an inch to three inches thick. Such layered or gneissic amphibolites are readily mistaken for metasediments.

STRUCTURAL GEOLOGY

The only attempt to interpret the overall structure of the Michipicoten belt is that of Goodwin (1962). He proposes that the major structures of the belt consist of a central east-trending anticline flanked by parallel synclines. These folds are in turn deformed about northwest trending axes to produce a

central cross-syncline flanked by parallel cross-anticlines. Goodwin's interpretation, although reasonable in the light of present data, should be considered provisional since many critical areas of the Michipicoten belt have yet to be mapped in detail.

A series of north to northwest trending faults in the central portion of the belt have resulted in mainly left-lateral displacements of up to 2 miles. Pronounced northeast trending lineaments such as defined by Missinaibi Lake, Manitowik Lake and Wawa Lake reveal regional fractures but the lateral displacement appears to be minor. In the eastern portion of the belt these lineaments may be related to the uplift of the Kapuskasing Structure.

In spite of their great age and complex history the supracrustal rocks of the Michipicoten belt are, on the whole, surprisingly undeformed. In many areas pillow structures, breccia fragments, amygdules, etc. appear to have retained their original proportions. The foliation generally parallels the bedding and penetrative deformation is generally restricted to zones of shearing.

ECONOMIC GEOLOGY

Iron: Between 1900 and 1918 about 2,700,000 tons of hematite iron ore averaging 53% Fe were extracted from the "Old Helen" Mine at Wawa. The hematite is believed to have formed as an oxidized capping over an extensive deposit of siderite. Following the depletion of the hematite deposit a sintering process was

developed which allowed the profitable extraction of the siderite. This deposit, "the new Helen Mine" continued production until 1962. Present production is from the George W. McLeod Mine of the Algoma Steel Corporation at Wawa, at the rate of about 3,000,000 tons per year.

Between 1957 and 1967, 7,646,269 tons of siderite were mined at the Sir James Mine of the Algoma Steel Corporation Limited at the east end of Wawa Lake.

Other iron producers of the Michipicoten belt are the Magpie Mine which produced about 1.2 million tons of siderite between 1913 and 1921, and the Josephine Mine, about 12 miles northeast of Wawa, where a small tonnage of high-grade hematite ore was mined in 1945-56 before flooding of the mine forced an end to mining (Shklanka, 1968).

Gold: The major gold producer of the Michipicoten area is the Renabie Mine at the extreme eastern end of the belt. Production from the Renabie amounted to a total of 3,633, 386 ounces of gold between 1939 and 1969. Operations ceased in 1971 but recent increases in the price of gold have brought renewed interest in the area. The entire production has come from steeply dipping thick lenses and pipes of quartz within plutonic granodiorite and trondhjemite. The ore zones occurred in the granitic rocks 350 to 1,000 feet from the contact of these rocks with the metabasalts of the Michipicoten greenstone belt.

Several gold occurrences south of Wawa Lake have been mined intermittently since 1903. One of these is currently being redeveloped. In the 1920's and 1930's several mines, all producing less than 100 tons per day operated on small, high-grade deposits. The present exploratory development operation by Pursides Mines Limited at the Surluga Mine contemplates mining at a rate of several hundred tons to a thousand tons per day.

The gold deposits occur both in discrete quartz veins, and in silicified and carbonatized sections of shear zones which contain stringers and lenses of quartz. Tourmaline, arsenopyrite, pyrite and traces of base metal sulphides occur with erratically distributed gold.

The gold occurrences south of Wawa Lake are all found near or within intermediate to felsic intrusive bodies.

A FEW PROBLEMS REGARDING THE ORIGIN OF ARCHEAN GREENSTONE BELTS

Archean greenstone belts such as the Michipicoten belt present many fundamental problems, some of which are not posed by younger rock assemblages. Among the foremost of these are:

1. What was the nature of the crust upon which the first volcanic units were laid down? Was it basaltic or essentially sialic? In other words does the surrounding granitic terrain represent an intrusive event (or events) much younger than the volcanics or has it in part been remobilized to produce the observed intrusive relationships?

2. What were the nature and origin of the forces which produced the main period of deformation of the belt? Were they primarily horizontal stresses or essentially the result of the collapse of the basement?

3. K/Ar determinations on rocks from the Superior Province indicate that the argon clocks of the granitic rocks and the greenstones were set, or re-set, about 2,500 m.y.b.p. as the result of an event referred to as the Kenoran Orogeny (Stockwell, in Leech et al, 1963). What was the Kenoran Orogeny? Windley (1973) has recently suggested that K/Ar dates of Archean rocks may reflect the time of uplift of the shield areas and may bear no relationship to the period of crystallization or metamorphism of the rocks.

4. What is the provenance of the granitic boulders in the Archean conglomerates such as the Dore? Bass (1961) proposes that they are merely the result of the erosion of sub-volcanic stocks. Not all geologists agree. Pettijohn (1970, 1972) has reviewed the subject and suggested that there is evidence of a major granitic source area for some Archean rocks.

The writer has examined several thin sections of granitic clasts from the Dore conglomerate in the western end of the Michipicoten greenstone belt. It was found that the granitic rocks displayed textures of plutonic and not epizonal granitic rocks. In fact, they differed in no significant respect from granitic rocks intruding the belt.

5. Goodwin (1962) pointed out that the sequence mafic volcanism followed by felsic volcanism, which is in turn succeeded by the development of iron formation constitutes a volcanic cycle

which may be repeated during the development of a metavolcanic assemblage. What is the "driving force" of this cycle?

6. What is the origin of the mineral deposits of the Archean greenstone belts? Those who consider the gold deposits to be related to Archean volcanism should consider the occurrence of the Renabie Mine within the surrounding granitic terrain. A small but high grade gold deposit at the east end of the Michipicoten greenstone belt occurs within a diabase dike (Burwash, 1937). These deposits are clearly much older than the volcanic events.

7. Can the recently developed concepts of plate tectonics be applied to Archean greenstone belts?

SELECTED REFERENCES

Bass, N. M.

- 1961: Regional Tectonics of the Canadian Shield.
J. Geol., v. 69, p. 668-702.

Bell, J. M.

- 1905: Iron Ranges of Michipicoten West.
Ontario Bur. Mines, v. 14, pt. 1, p. 278-355.

Bennett, Gerald

- In Prep: Geology of the Lang-Stover Area,
District of Sudbury. Ontario Div.
Mines, Ministry of Natural Resources.

Bennett, Gerald, and Thurston, P. C.

- 1972: Operation Pukaskwa. Ontario Dept.
Mines and Northern Affairs, Open File Rept. 5073,
pt. 1. 92 p.

Brooks, C., and Hart, S.

- 1972: An Extrusive Basaltic Komatiite from a
Canadian Archean Metavolcanic Belt.
Canadian J. Earth Sci., v. 9, p. 1250-1253.

Bruce, E. L.

- 1940: Geology of the Goudreau-Localsh Area.
Ontario Dept. Mines, v. 49, pt. 3. 47 p.
- 1945: Geology of Township 47, Missinaibi Area.
Ontario Dept. Mines, v. 54, pt. 4. 24 p.

Burwash, E. M.

- 1935a: The Michipicoten-Missinaibi Area. Ontario
Dept. Mines, v. 44, pt. 8, p. 1-26.
- 1935b: Geology of the Localsh-Missinaibi Area.
Ontario Dept. Mines, v. 44, pt. 8, p. 27-38.

Coleman, A. P., and Willmott, A. B.

- 1902: The Michipicoten Iron Region. Ontario
Bur. Mines, v. 11, p. 152-185.

Collins, W. H., and Quirke, T. T.

- 1926: Michipicoten Iron Ranges. Geol. Surv. Canada, Mem. 147. 170 p.

Cooke, H. C.

- 1937: Structure of the Dore Series, Michipicoten District, Ontario. Royal Soc. Canada, Trans., 3rd ser., v. 31, p. 69-80.

Deer, W. A., Howie, R. A., and Zussman, J.

- 1966: An Introduction to the Rock Forming Minerals. John Wiley and Sons, Inc., New York. 528 p.

Frohberg, M. H.

- 1935: The Ore Deposits of the Michipicoten Area. Ontario Dept. Mines, v. 44, pt. 8, p. 39-83.

Gates, T. M., and Hurley, P. M.

- 1973: Evaluation of Rb-Sr Dating Methods Applied to the Matachewan, Abitibi, Mackenzie, and Sudbury Dike Swarms in Canada. Canadian J. Earth Sci., v. 10, p. 900-919.

Gittins, J., MacIntyre, R. M., and York, D.

- 1967: The Ages of Carbonatite Complexes in Eastern Canada. Canadian J. Earth Sci., v. 4, p. 651-655.

Goodwin, A. M.

- 1962: Structure, Stratigraphy, and Origin of Iron Formations, Michipicoten Area, Algoma District, Ontario, Canada. Geol. Soc. America, Bull., v. 73, p. 561-586.

- 1973: Archean Iron Formations and Tectonic Basins of the Canadian Shield. Econ. Geol., v. 68, p. 915-933.

Grout, F. F.

- 1926: Michipicoten Iron Ranges. Econ. Geol., v. 21, p. 813.

Leech, G. B., Lowden, J. A., Stockwell, C. H., and Wanless, R. K.

- 1963: Age Determinations and Geological Studies (Including Isotopic Ages - Report 4). Geol. Surv. Canada, Paper 63-17. 140 p.

Moore, E. S.

- 1931: Goudreau and Michipicoten Gold Areas, District of Algoma. Ontario Dept. Mines, v. 40, pt. 4, p. 1-54.

Moore, E. S., and Armstrong, H. S.

- 1946: Iron Deposits in the District of Algoma. Ontario Dept. Mines, v. 60, pt. 4, p. 1-118.

Parsons, G. E.

- 1961: Niobium-Bearing Complexes East of Lake Superior. Ontario Dept. Mines, GR 3. 73 p.

Pettijohn, F. J.

- 1970: The Canadian Shield - A Status Report 1970; in Basins and Geosynclines of the Canadian Shield, edited by Baer, A. J. Geol. Surv. Canada, Paper 70-40, p. 239-265.
- 1972: The Archean of the Canadian Shield: A Resume. Geol. Soc. America, Mem. 135, p. 131-149.

Robertson, W. A., and Fahrig, W. F.

- 1971: The Great Logan Paleomagnetic Loop - the Polar Wandering Path from Canadian Shield Rocks During The Neohelikian Era. Canadian J. Earth Sci., v. 8, p. 1355-1372.

Shklanka, R.

- 1968: Iron Deposits of Ontario. Ontario Dept. Mines, MRC 11. 489 p.

Windley, B. F.

- 1973: Crustal Development in the Precambrian. Phil. Trans. Royal Soc. London, v. 273, p. 231-241.

By
R. J. Rupert and G. Bennett
May 4, 1974

Mileage

The first outcrop west of the highway and north of the causeway across the east arm of Kabenung Lake, consists of red granitic rock of variable composition with occasional small mafic inclusions. The contact of the greenstone belt underlies Kabenung Lake.

The mafic composition of the rock and vague deformed structures resembling selvages in mafic volcanic flows indicate a volcanic origin for these rocks. A small intrusion of granitic rock is present in the north part of the outcrop.

3.2 Stop 3 Deformed Pebbly Greywacke Conglomerate

An outcrop west of the road displays deformation and folding characteristics common in clastic sedimentary units of the belt. Small scale fold structures and elongation of pebbles and cobbles may be noted here.

3.8 Stop 4 Lean Iron Formation

The outcrop consists of banded quartzite (metachert) with minor quantities of magnetite, pyrite, and carbonate.

Notwithstanding the low iron content, these banded silica zones have been mapped as iron formation. Several miles to the east and west of this point, parts of this unit are richer in iron and have been investigated as possible sources of iron.

4.0 Stop 5 Pillow Lavas

The large outcrop exposed along the highway at this location shows well developed pillow structures, which are common in mafic metavolcanic flows of the Michipicoten belt.

5.5 Stop 6 Lamprophyre

Irregularly shaped intrusive bodies of kersantitic lamprophyre are common in the central portion of the Michipicoten greenstone belt. At

least some of them post-date the granitic rocks but are intruded by the diabase dikes.

At this locality an outcrop of lamprophyre contains numerous subangular to well rounded xenoliths up to two feet in diameter. Recrystallization of the xenoliths has resulted in a well developed radial arrangement of prismatic amphibole crystals. The occurrence of inclusions of country rock in lamprophyre is not uncommon.

⁷
(approx) Stop 7 Basaltic Komatiite

Brooks and Hart (1972) report the occurrence of a pillowed basaltic komatiite flow from this area. An attempt to locate the rock in the fall of 1973 was unsuccessful. However, with the aid of a more precise description of the location, it is hoped that the outcrop can be located in time for this field trip.

The rock is described by Brooks and Hart as "a medium-grained, grey-green basic rock, distinguished from the adjacent metabasalts by its extreme toughness". The rock consists of "85 per cent tremolite-actinolite and 15 per cent epidote-clinozoisite, quartz, sodic plagioclase

and trace calcite."

Komatiites in general are characterized by high MgO contents, high CaO/Al₂O₃ ratios, and low alkali contents. The normative mineral content suggests that basaltic komatiite represents metamorphosed pyroxene-rich basalt.

7.1 Stop 8 Xenoliths of Felsic Tuff in Matadiorite

Large xenoliths or screens of felsic metatuff are included in a large intrusion of gabbro at this locality. The relationships between the two rock types are best observed on the weathered surface above the rock cut on the east side of the highway.

These relationships are also seen along the highway for 3/4 mile to the north and 1 1/2 miles to the south.

Mafic intrusions such as this one are present throughout the Michipicoten greenstone belt. In areas of poor exposure they are difficult to distinguish from mafic flows.

The steeply dipping diabase dike on the west side of the highway is an extension of a larger northeasterly trending diabase dike.

8.1 Stop 9 Diabase Dike of the Abitibi Swarm

The northeast striking diabase dike

exposed in the roadcut is a member of the Abitibi Swarm. Leech et al (1963) obtained a K/Ar radiometric age of 1,120 m. y. for this dike.

Robertson and Fahrig (1971) considered 1,150 m.y. to be the best estimate of the age of the Abitibi intrusions based on K/Ar determinations. Gates and Hurley (1973), using Rb/Sr whole rock data, have proposed that the absolute age of the Abitibi Swarm is $2,147 \pm 68$ m. y.

Adjacent to the dike the felsic meta-volcanic breccias and tuffs have undergone varying degrees of alteration (albitization) characterized by a pink to red colouration. Such alteration is not uncommon along the margins of diabase dikes of the area, but is particularly intense at this locality.

9.0

Stop 10 Felsic Pyroclastics

This outcrop of lapilli tuff illustrates the massive character of the felsic pyroclastic beds of the area. Similar pyroclastic units form thick sequences in the Michipicoten greenstone belt.

Stop 11 Felsic Volcanic Breccia

A number of excellent exposures of felsic pyroclastic breccia, and tuff are present along highway 17 north of Wawa. Conditions at the time will determine which of these outcrops will be examined.

23.2

Stop 12 Dore Conglomerate

At this locality the conglomerate and interbedded greywacke contains pebble to boulder sized clasts of intermediate to felsic metavolcanics, quartz porphyry, granitic rocks and vein quartz. The finer grained clasts are highly deformed in comparison to the felsic plutonites. Gneissic granite, common in the surrounding granitic terrain, is not represented in the clast populations. The matrix of the conglomerate is a quartz biotite schist.

Proceed to the Helen Mine via Highway 101 and mine road leading from Broadway Street in Wawa.

Stop 13 View of the Helen Mine

The hill northwest of the mine office provides a vantage point from which the extent of the overturned ore zone and the enclosing rocks can be seen.

The siderite ore zone extends from Sayer Lake at the foot of the hill through the open pit, to a point about 1/2 mile beyond the east wall of the open pit. It is succeeded stratigraphically by a low grade banded silica iron formation about 600 feet thick with some pyrite zones near the base. The siliceous member forms the hill to the northeast. Mafic metavolcanic flows overlie the iron formation.

Pyroclastic breccias and tuffs, such as exposed at this locality stratigraphically underlie the orebody.

Stop 14 Ottrelite Schist

Outcrops along the mine access road near the director's lodge or "Eagles' Nest" consist of metamorphosed rhyolites containing small disseminated, euhedral, black crystals of ottrelite, a manganiferous variety of chloritoid. Chloritoid is a common constituent of aluminum and ferric-iron rich pelitic sediments which have undergone low grade regional metamorphism (Deer et al 1966). Its origin in ankeritized, sericitic felsic metavolcanics is less clear. It may be the result of low grade metamorphism of such lavas, or it may be of hydrothermal origin.

Stop 15 Metadiorite Intrusions

Outcrops along the mine access road south of the road junction at the G. W. McLeod mine provide an example of the gabbroic intrusions locally described as metadiorite.

These intrusions comprise up to 25 per cent of the sequence in the footwall of the ore zones. They intrude the rhyolites and the ore zones but appear to be less common in the overlying meta-volcanics.

Iron carbonate alteration is commonly developed near the contacts of these intrusions.

Stop 16 Spherulitic Rhyolite

The outcrops immediately north of the offices and sea-plane base of the Ministry of Natural Resources consist of rhyolite containing abundant spherical structures up to one inch or more in diameter.

These spherulites, or lithophysae, commonly have recessively weathered carbonate centers rimmed by resistant very fine-grained felsic material.

May 5, 1974

Stop 17 Lucy Mine

Access is via a private road leading north from Highway 101 at the east end of Wawa Lake.

The Lucy Mine northeast of Wawa Lake provides an opportunity to study the typical stratigraphic sequence of the iron formations of the Wawa-Goudreau area.

The stratigraphic foot-wall contact of the siderite ore zone and the rhyolite is exposed in the west end of the open pit. Selective replacement of rhyolite breccia fragments in the foot-wall by siderite may be observed.

Ore specimens comparable to the Helen Mine ore may be obtained here. The Lucy ore contains slightly higher sulphur and arsenic values. Specimens with well developed arsenopyrite crystals and spherical pyrite concentrations may be collected.

North of the open pit, brecciated siliceous iron formation may be examined.

Stop 18 Sir James Mine

The eastern extension of the Helen iron formation was formerly mined at this locality. A northwest-striking fault displaces the ore zone northwards to the Lucy Mine.

Mileages for the following stops are measured to the southwest from the junction of Highway 101 and the Lucy Mine access road at the east end of Wawa Lake. This point is 5.4 miles northeast of the intersection of Highway 101 and Broadway Street in Wawa.

1.9 Stop 19 Contact Zone Between Quartz
 Porphyry and Mafic Lava

An adit has been driven along the contact of a quartz porphyry intrusive and basalt flows at this locality. Quartz veinlets and minor shearing are developed along the contact.

The quartz porphyry is relatively uniform and free from inclusions, unlike the intermediate intrusions to be examined at Stop 20.

2.8 Stop 20 Contact Zone of Inclusion-Bearing
Diorite or Quartz Diorite

An intermediate intrusive of medium-grained hypidiomorphic-granular grey rock intrudes clastic rocks at this locality. Included fragments range in size from an inch or less to over 8 inches across and are angular to well rounded. They display a wide range of lithology and degrees of assimilation.

During regional mapping it has been noted that mafic inclusions tend to be smaller than felsic inclusions. The composition of the intermediate intrusive varies from diorite to quartz diorite or granodiorite. Where mafic inclusions predominate, the matrix is usually dioritic, and where felsic inclusions predominate, granodioritic compositions are noted.

3.0 Stop 21 Large Inclusion in Quartz Diorite

An inclusion of felsic metavolcanic rock 300 feet long is exposed on the surface of the outcrop and rockcut north of the road. The contact of this xenolith can be followed for about 3/4 of its circumference. Many smaller inclusions of other rock types can also be seen.

Across the road from the large inclusion is an adit driven on a shear zone containing auriferous quartz veins. Most of the gold mines south of Wawa Lake are in or very near intermediate to felsic intrusions.

3.8 Stop 22 Surluga Shear Zone and Mackey
 Point Shaft

The Surluga shear zone is a bifurcating group of zones, up to 400 feet wide, composed of several relatively intensely sheared zones surrounding horses of relatively unsheared inclusion-rich intermediate intrusive rocks. Most of the shear zone is located in the gully beneath the old road.

Pervasive alteration and cementing of the shear zone by carbonates (calcite, dolomite, and ankerite) and silica is evident in the shear zone. Red colouration is locally present. Parts of the shear zone are brecciated.

The inclined shaft is about 250 feet deep, and was sunk along a quartz vein in the shear zone. Most of the gold ore mined

in this area was obtained from similar lenses of carbonate-rich quartz.

Minerals associated with gold mineralization in the area (not visible here) include tourmaline, arsenopyrite, pyrite, and traces of chalcopyrite.

4.1 Stop 23 Beds of Welded Felsic Tuff

The outcrops southwest of the junction of the Surluga Mine road and Highway 101 consist of 3 to 10 feet thick beds of differentially weathering grey to dark grey quartz feldspar porphyry tuff. Lapilli of rhyolite and biotite-rich mafic rock are visible in some beds. At poorly exposed outcrops, these rocks have often been mapped as felsic intrusive porphyries.

A dike of rusty weathering carbonate is present in this roadcut. The dike and the fragments in it are almost entirely carbonate.

4.7 Stop 24 Hornblende Gabbro Intrusive

Outcrops of amphibolitic gabbro are present on the shoreline and road west of the William Teddy Trailer Park.

Some plugs of similar size and appearance in the area have been found

to contain peridotitic zones with nickel and copper sulphides.

Mileages for the succeeding stops are measured southwards along Highway 17 from the bridge across the Michipicoten River, 3.8 miles south of the junction of Highways 17 and 101.

3.2 Stop 25 Iron Formation and Felsic Porphyry

A flat lying to moderately folded unit of banded magnetite-chert iron formation 15 to 20 feet thick overlies a pale grey quartz feldspar porphyry, the base of which is not exposed. These two units are exposed almost continuously for about 800 feet in outcrops along the highway. For most of its exposed length, the contact between the rocks indicates that they are conformable, however at a few places, the porphyry appears to truncate layers of the iron formation.

3.8 Stop 26 Chaotic Breccia

An irregularly shaped body of breccia lying between intermediate to mafic meta-volcanics and quartz feldspar porphyry is well exposed on the east side of Highway 17

at this locality. The breccia is heavily stained as a result of the weathering of iron sulphides and contains blocks up to several feet across of a variety of meta-volcanic rocks. Blocks of granular quartz are prominent and resemble the metachert of local iron formations. The metavolcanics adjacent to the north side of the breccia display a distinct, steeply dipping, layering.

At least two interpretations are possible for this breccia complex. The breccia may be a pyroclastic deposit overlying a felsic flow (the porphyry) and which is, in turn, overlain by the intermediate to mafic metavolcanics. Alternatively, the breccia may be intrusive into the metavolcanics and may, in turn, be intruded by the porphyry.

