Institute on Lake Superior Geology
Thirty-Third Annual Meeting

WAWA, ONTARIO
1987

Field Trip Guidebook

Geology and Stratigraphy of the

Michipicoten Iron Formation

Sponsored by

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Volume 33, Part 3



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Lake Superior Geology

33rd Annual Meeting

Wawa, 1987

Fieldtrip Guidebook

Geology of the Michipicoten Iron Formation

by

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Organized by the Ontario Geological Survey, Toronto, Ontario and Resident Geologist's Office, Wawa, Ontario with the support of the Algoma Steel Corporation Limited

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Cover Photo: Alternating brecciated and unbrecciated chert layers in the upper part of the Michipicoten Iron Formation, Lucy Iron Range

Acknowledgements

Illustrations for the field guide were prepared by Ms. K. Gil and Mr. D. Walker and the manuscript was typed by Ms. A. Branicky and Ms. P. Arora. The guidebook has been edited by Mr. H. Wallace, and Mr. E. Berdusco. Most of the field trip is on the property of the Algoma Steel Corporation Limited whose support has made this field trip possible.

Lead model ages obtained on galena-bearing samples collected by the Ontario Geological Survey and analyzed by the Geological Survey of Canada are summarized by R. Thorpe.

Introduction

The Michipicoten greenstone belt lies within the Wawa Subprovince of the Canadian Shield (Ayres et al. 1970). The supracrustal rocks composing the Michipicoten greenstone belt extend east from the northeast corner of Lake Superior for a distance of approximately 141 km and have a maximum width of approximately 38 km. This package of supracrustal rocks is enclosed within Archean granitic rocks, which on the basis of U-Pb isotopic ages, are younger than the supracrustals. The supracrustal rocks of the Michipicoten belt have produced iron ore since 1900 and have both present and past gold production. The area is currently the scene of intense exploration activity in search of gold.

The Ontario Geological Survey has recently mapped 16 townships underlain by supracrustal rocks of the Michipicoten belt. The results of this work are given in Sage (1987a, 1987b, 1987c) and Massey (1985).

General Geology

The Michipicoten supracrustal rocks consist largely of metamorphosed intermediate to mafic and intermediate to felsic metavolcanics with metasediments derived from the metavolcanics. The metavolcanics represent two major mafic to felsic volcanic

cycles; a minor third mafic to felsic cycle is represented in the stratigraphic sequence east of Wawa Lake and is referred to as Subcycle I. Another incomplete volcanic cycle, represented only by intermediate to mafic metavolcanic rocks, caps the intermediate to felsic volcanism of Cycle II.

The term cycle is defined by AGI (1972) as follows:

> "A series of events or changes that are normally, but not inevitably, considered to be recurrent and to return to a starting point, that are repeated in the same order several or many times at more or less regular intervals and that operate under conditions which, at the end of the series, are the same as they were at the beginning."

In the context of Archean volcanism, cyclic volcanism pertains to the repetition of volcanic sequences consisting of lower mafic and upper felsic portions (Goodwin 1967). The Wawa supracrustals dominantly form cycles ranging in composition from tholeiitic basalt to calc-alkalic felsic volcanics (Thurston, 1986).

Metasediments are common within the Wawa supracrustals and consist of conglomerate, wacke, siltstone, and argillite. The metasediments interfinger with intermediate to felsic volcanics of Cycle II and are largely derived by erosion of the intermediate to felsic volcanics. The quantity of conglomerate decreases rapidly from west to east and in the west the conglomerate units commonly contain rounded trondhjemite boulders. The finer grained metasediments often display well preserved primary sedimentary structures. Facies analysis indicates a marine alluvial fan environment of deposition at the base of the metasedimentary section and a shallow braided stream

environment at the top. Shallow water structures in the upper part of the metasedimentary section imply that equivalent intermediate to felsic volcanism was subaerial.

Intermediate to mafic intrusions ranging in composition from peridotite to quartz diorite cut the metavolcanics and metasediments. These intermediate to mafic intrusions are most likely of several ages, and they vary from fine-to coarse-grained. The emplacement of the later mafic intrusions appears to have been fault controlled.

Granitic stocks ranging from tonalite and trondhjemite to granite in composition (Ayres 1972) cut the supracrustals. One Archean nepheline-cancrinite syenite stock intruded the supracrustal rocks in the Goudreau area. This alkalic rock complex has no known effusive equivalent. The tonalite-trondhjemite stocks are compositionally similar to the intermediate to felsic metavolcanics and could be feeders for these extrusive rocks. The granodiorite and granite plutons, however do not appear to have chemically equivalent extrusive phases.

The supracrustals and intrusive rocks are tentatively interpreted to represent an originally monoclinal stratigraphic sequence that has undergone considerable folding and faulting. One prominent regional fold, the Centre Anticline, has a recumbent south limb and vertically dipping north limb (Figure 1). Strike slip faulting or faulting that cuts the stratigraphy at a very low angle accompanied folding. Subsequent to the major folding event and associated strike slip faulting a prominent set of northwest, left-lateral transverse faults were established.

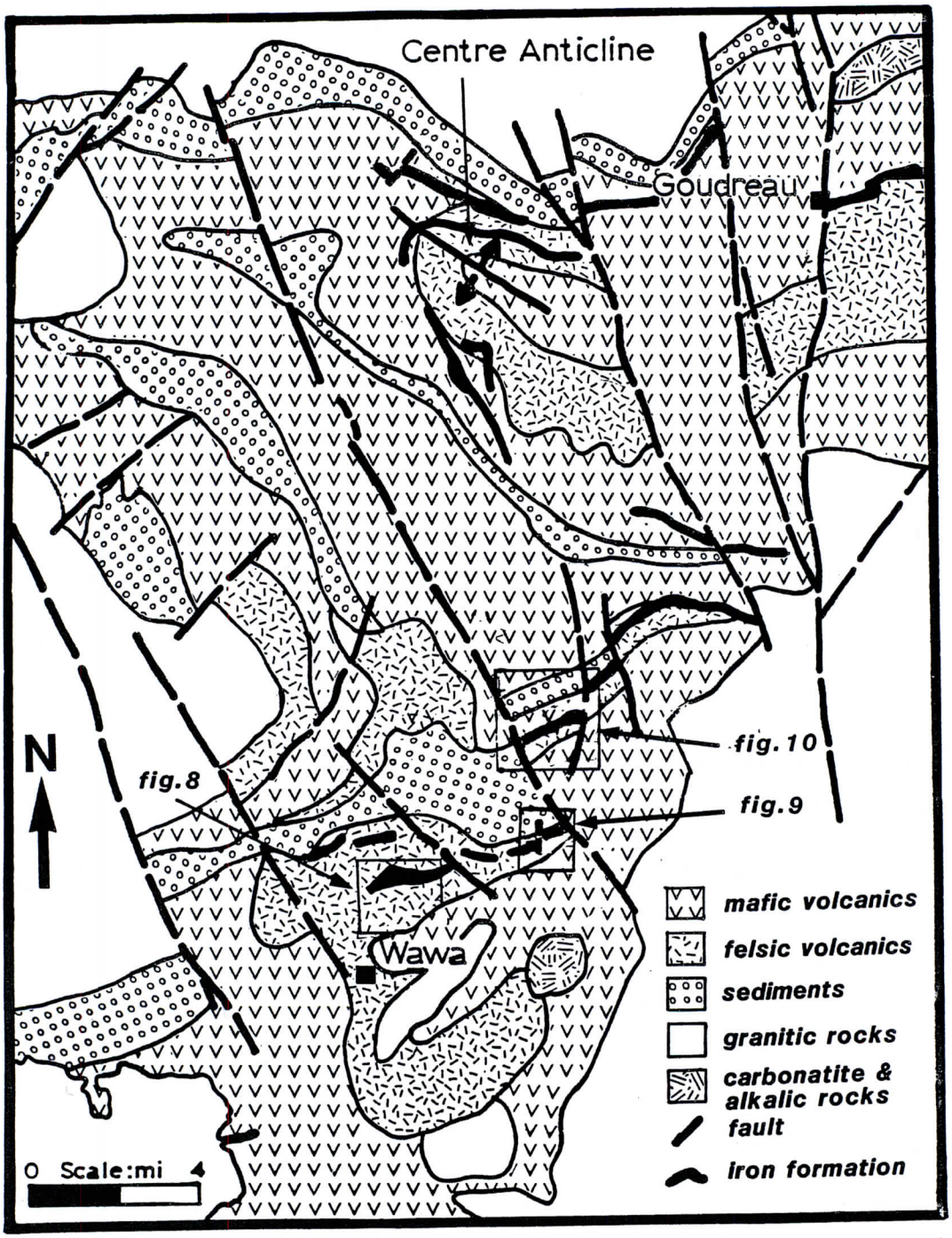


Figure 1 Schematic diagram of the Michipicoten supracrustal belt with tour sites indicated.

The later faults decrease in offset as one moves northward along the strike of the fault. It cannot be positively established on the basis of most field observations, but it is likely that the east side of these northwest-trending faults is the upthrown side. This is in keeping with the regional observation of Percival and Card (1983) that as one moves eastward towards the Kapuskasing Structural Zone one is viewing increasingly deep crustal levels.

The transverse faults are commonly occupied by diabase dikes. Northeast-trending diabase dikes are common in the northern portion of the Michipicoten greenstone belt. Northwest- and northeast-trending dikes may represent intrusion into a conjugate fracture set; the dikes are likely of several different ages.

Local reactivation of the strike slip faults has resulted in offsets of the transverse diabase dikes in some cases.

The core of the Michipicoten greenstone belt consists of highly carbonated greenschist facies rocks. As the margins of the belt are approached the metamorphic grade increases to amphibolite facies in response to contact metamorphism by the younger external granitic rocks (Ayres, 1978; Turek et al. 1982, 1984).

The Wawa supracrustals display a pronounced regional carbonate alteration and the widespread presence of chloritoid. Local areas of tourmaline alteration and sodium plus calcium metasomatism have also been identified. Table 1 gives the sequence of lithologic units within the Michipicoten greenstone belt.

Cenozoic	Quaternary		Pleistocene & Recent Till,sand,gravel,clay,organic soils **unconformity**
Precambrian	Proterozoic		Firesand River Carbonatite **intrusive contact** Diabase dike **intrusive contact**
	Archean	cycle III	Trondhjemite,granodiorite,quartz monzonite **intrusive & fault contact** Mafic to intermediate volcanics **conformable contact**
		cycle II	Gutcher Lake Stock **intrusive contact** Intermediate to felsic volcanics & associated metasediments **conformable contact** Tholeiite & high iron tholeiite **conformable & intrusive contact** Diorite,gabbro, & quartz diorite intrusions **intrusive contact**
		cycle I	Iron formation **conformable & intrusive contact** Jubilee Stock Quartz - feldspar Porphyry **intrusive contact** Intermediate to felsic volcanics (Wawa tuffs) **? conformable contact ?** Jubilee tuffs,minor iron formation **? conformable contact ?** Tholeiite & high iron tholeiite **conformable contact**
		subcycle I	Iron formation **conformable contact** Hawk Lake Granite Complex **intrusive contact** Intermediate to felsic volcanics **conformable & intrusive contact** Diorite,gabbro,peridotite(?) **intrusive contact** High iron tholeiites & basaltic komatiites

Table 1 Table of lithologic units, Michipicoten supracrustal rocks.

Stratigraphy

The first modern interpretation of the stratigraphy of the Michipicoten greenstone belt was by Goodwin (1962). Additional stratigraphic data was given by Goodwin (1964, 1973) and Goodwin and Shklanka (1967) and the reader should refer to these articles. The author (Sage, 1986) prepared a stratigraphic summary based on mapping in the supracrustals up to 1983.

Mapping within the Wawa supracrustals has indicated a systematic repetition of rock types in vertical succession throughout the belt. Faulting and folding have locally modified the distribution of lithologies and the various stratigraphic units vary in thickness along strike. Figure 2 is an idealized schematic diagram of lithologic relations.

Early in mapping the exposed section in the Lucy Iron Range appeared to be the least deformed and most continuous in the area, and was therefore used as a type section for comparative purposes throughout the belt. The Lucy Iron Range occurs at the top of volcanic Cycle I and at the base of Cycle II. Figure 3 illustrates the lithologic succession at this location. Faulting occurs at the top and bottom of the Lucy section. The various cycles, subcycles and partial cycles outlined so far in the Michipicoten supracrustals are as follows:

Subcycle I

Subcycle I has been identified only east of Wawa Lake and underlies less than 50 percent of Esquega Township. Future mapping to the east along the supracrustal granite contact may

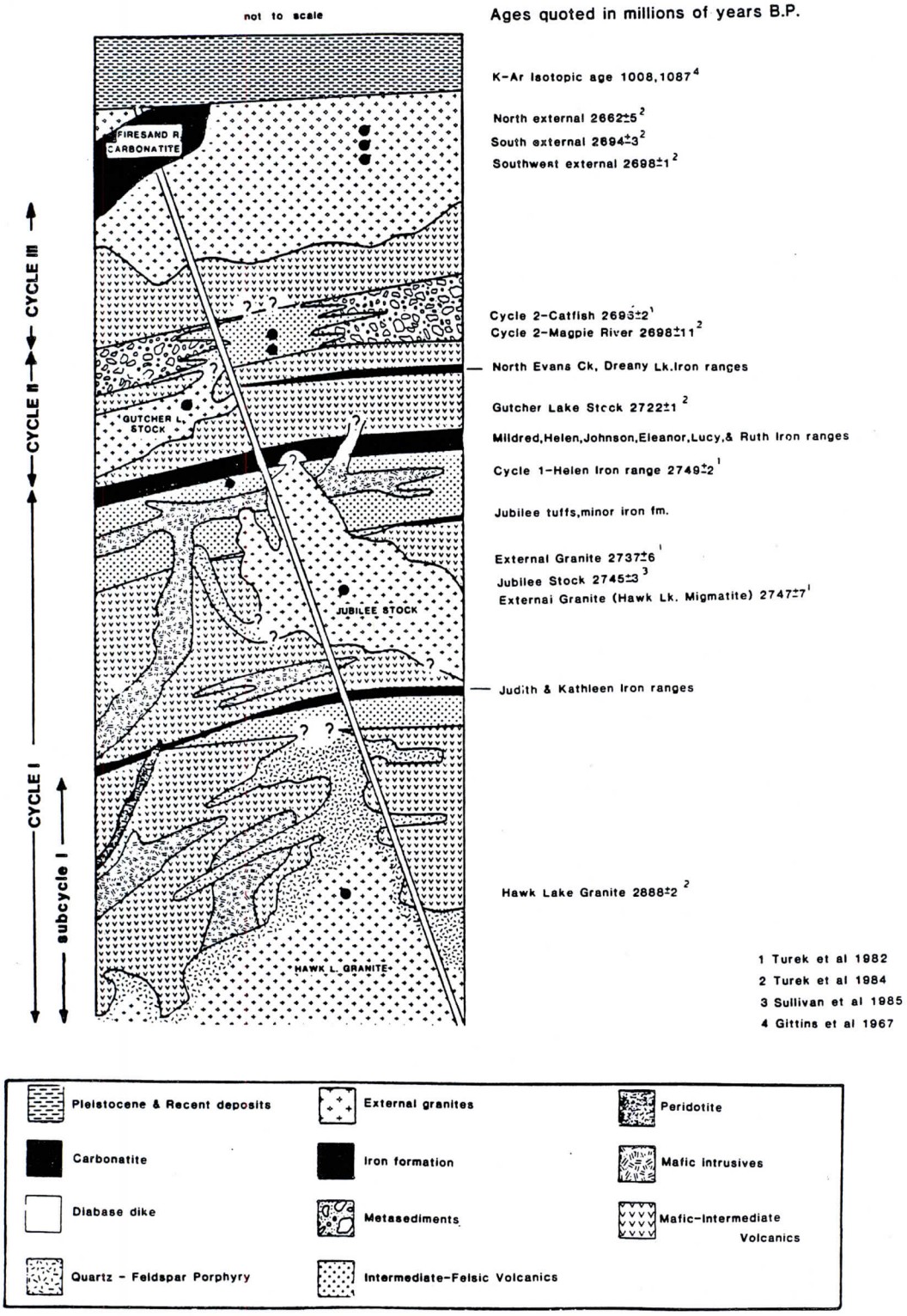


Figure 2 Schematic diagram illustrating relationships of lithologic units, Michipicoten supracrustal rocks.

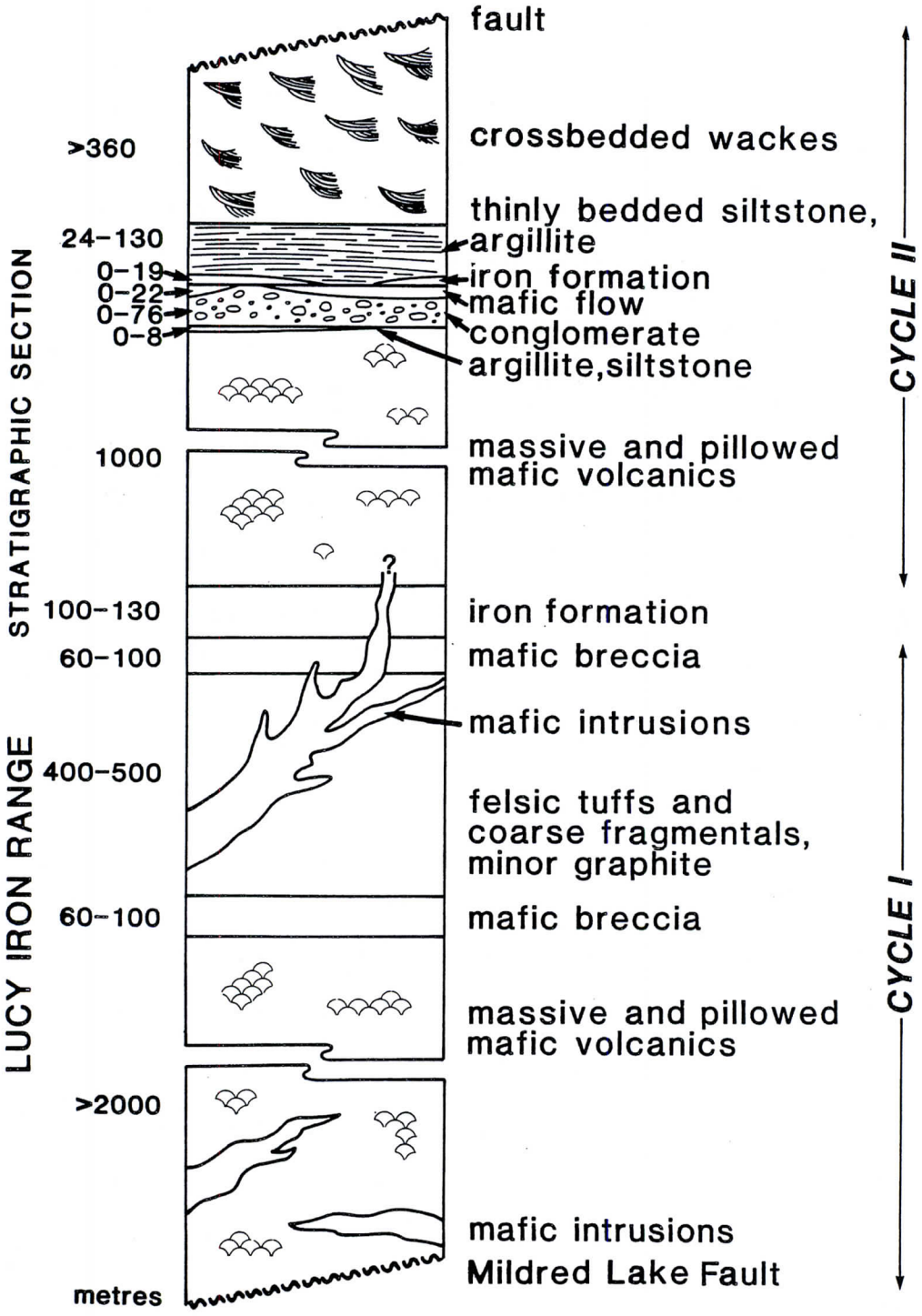


Figure 3 Idealized stratigraphic section for Lucy Iron Range.

identify additional remnants of this cycle.

The lower part of this subcycle is represented by massive and pillowed units of high-iron tholeiite and basaltic komatiite. The upper intermediate to felsic part of this subcycle consists of lapilli-tuff, tuff, quartz-feldspar crystal tuff and breccia of rhyolitic and dacitic compositions. The intermediate to felsic metavolcanic rocks are capped by iron formation consisting of a laminated chert top and a sulphide-rich base. The base of this subcycle has been intruded by the Hawk Lake granite complex and apophyses of quartz feldspar porphyry from the complex. The Hawk Lake granite has been dated by U-Pb isotopic techniques as 2,888 $\pm$ 2 Ma (Turek et al. 1984). Model ages based on lead isotope compositions for galena samples collected from mineralized veins within this subcycle are discussed in another section of this review and indicate an age comparable with the Hawk Lake granitic complex.

Cycle I

The bottom of Cycle I lies on iron formation of Subcycle I at the east end of Wawa Lake and in other areas the bottom is either unexposed, absent, or has not been covered by present mapping. At the base of this cycle rare variolitic flows have been observed. Moving up section amygdules increase in size and number until they compose 10 percent or more of the upper part of individuals flows and commonly exceed 1 cm in diameter. The rocks are commonly heavily carbonated, particularly in the upper part of the section. In the Josephine Mine area the upper 130 m

section of pillowed and massive mafic metavolcanics contains up to 10 percent chloritoid, commonly concentrated in the pillow selvages.

Smith and Farquhar (1986), using a whole-rock U-Th-Pb isotope method have obtained a model age of 2760 ± 34 Ma for the upper part of the intermediate to mafic metavolcanic section of Cycle I, exposed on the south shore at the east end of Wawa Lake.

Lying above the pillowed and massive metavolcanics is a heterolithic, intermediate to mafic breccia that has been traced from the Lucy Iron Range to the east end of the Josephine Iron Range. This is a distance of approximately 13.7 km. Thin discontinuous cherty, graphitic iron formation units with thin lenses, concretions, and irregular masses of pyrite are locally present between the mafic breccia and the underlying flows in the Josephine area.

Above the intermediate to mafic breccia lies a ferruginous dolomite that commonly exceeds 30 m in thickness. This unit weathers rusty brown and is criss-crossed on the weathered surface by numerous stringers of milky quartz. This unit has been traced from the Ruth Iron Range to the east end of the Josephine Iron Range, a distance of approximately 10 km.

Lying above the carbonate unit is a thick section of intermediate to felsic metavolcanics. This unit reaches a maximum thickness of approximately 2,000 m below the Helen Iron Range at Wawa and tapers to approximately 300 m at the east end of the Josephine Iron Range. The rocks consist of tuff, lapilli-tuff, monolithic and heterolithic breccias, feldspar crystal tuff, quartz-feldspar crystal tuff, spherulitic flows, flow

banded flows, and massive flows. Fiamme-bearing units occur throughout the section and have been identified as far east as the Josephine Iron Range. Thinly laminated tuffs, crossbedded tuffs, and rare graded tuff beds have been observed. While lithic tuffs and coarser fragmental rocks are the dominant lithologies, crystal tuffs are a major component of the stratigraphic section.

The upper part of the sequence of intermediate to felsic metavolcanic rocks below the Helen Iron Range has been dated by U-Pb techniques as 2749 $\pm$ 2 Ma and the Jubilee Stock has been dated by U-Pb techniques as 2745 $\pm$ 3 Ma (Turek et al. 1982, Sullivan et al. 1985). This U-Pb dating establishes a possible relationship between granitic intrusion and Cycle I intermediate to felsic volcanism.

The intermediate to felsic metavolcanic rock types are consistent with a Plinian style of volcanism which can be associated with caldera formation (Fisher and Schmincke 1984).

Capping Cycle I volcanics is the Michipicoten Iron Formation. This iron formation is characterized by a siderite base and a graphite-rich top. The iron formation represents chemical and clastic sedimentation separating Cycle I and Cycle II volcanics. This iron formation forms a distinctive marker horizon throughout the Michipicoten greenstone belt, which prior to folding and faulting, most likely exceeded 100 km in strike length. Within 50 m of the base of the iron formation, numerous cross-cutting silica-and siderite-cemented phreatic explosion breccias are present. These breccias have been found from the Helen to the Josephine Iron Ranges. The explosion and boiling

that must have been associated with the formation of these breccias implies a shallow-water, low pressure system since boiling cannot occur at depths greater than 400 m with 5 percent brine at a temperature of 250°C (Finlow-Bates and Large 1978).

Cycle II

Cycle II volcanics lie above the Michipicoten Iron Formation and represent a second complete cycle of mafic to felsic volcanism. The base of the Cycle II volcanics is a thick sequence of massive and pillowed amygdaloidal flows that overlies the Michipicoten Iron Formation. Above the Lucy Iron Range the section is one km thick, but in the Goudreau area the equivalent section is approximately 5.6 km thick. Amygdules up to 1 cm across are common in the pillowed units and some are elongated and pipe-like perpendicular to the pillow selvage.

Above the intermediate to mafic rocks are intermediate to felsic metavolcanics, or their stratigraphically equivalent Dore sediments. The true thickness of the sediments is uncertain, but on the order of 1.0 km. The intermediate to felsic metavolcanics of Cycle II interdigitate with the metasediments and it is often difficult to subdivide the two (Collins and Quirke 1926, Bruce 1940, and Massey, 1985). This interdigitating pattern is well developed north of the Magpie River in west-central Chabanel Township.

In the Goudreau area the upper part of the intermediate to mafic metavolcanic section consists of intermediate to mafic tuff and the boundary between the metasediments and metavolcanics is

difficult to place precisely, perhaps in part due to limited exposure. However, above the Lucy Iron Range the metasediment-metavolcanic boundary is sharp and well constrained in outcrop.

The intermediate to felsic metavolcanics of Cycle II are well exposed in Chabanel Township and the adjoining area to the west (Massey 1985). These volcanics consist of tuff, lapilli-tuff, monolithic and heterolithic breccias, feldspar-crystal tuff and quartz-feldspar crystal tuffs. Blocks up to 4 m across have been observed in the coarse breccias and locally the units display some bedding. The clasts within the coarse breccias commonly contain quartz phenocrysts as much as 1 mm in diameter in quantities up to 5 percent. Quartz-feldspar crystal tuff is a major rock type and likely an important source rock for the stratigraphically equivalent sediments. As with Cycle I intermediate to felsic metavolcanics, the lithologies of Cycle II intermediate to felsic metavolcanics suggest a Plinian style of eruption (Fisher and Schmincke, 1984).

From a sample collected west of Catfish Lake, most likely in the upper part of the intermediate to felsic metavolcanic section, Turek et al. (1982) reported a U-Pb isotopic age of 2696 $\pm$ 2 Ma. From the area north of the Magpie River, lower in the stratigraphic section, Turek et al. (1984) reported a U-Pb isotopic age of 2698 $\pm$ 11 Ma. Since the Dore sediments interdigitate with the intermediate to felsic metavolcanics, and are derived therefrom, the isotopic ages on the metavolcanics provide an age for the metasediments. Iron formation is not known to occur associated with Cycle II intermediate to felsic

metavolcanic rocks. In the Goudreau area chert-magnetite-wacke iron formation occurs at the base of the Dore metasediments or with tuffs in the upper part of Cycle II intermediate to mafic volcanics. This iron formation does not have a carbonate facies nor does it contain appreciable sulphide.

Cycle III

Above the metasediments and conformable with them is a thick sequence of massive and pillowed metavolcanics. This may be only a partial cycle since mapping has not clearly demonstrated an associated intermediate to felsic metavolcanic phase. Rocks of this cycle are well exposed along Highway 17 north of Wawa. Present mapping has not completely delineated the width and possible extent of proposed Cycle III volcanics.

General Observations

The most complete and best exposed parts of Cycles I and II display similar lithologic characteristics interpreted to represent a Plinian style of eruption. Sampling of these two cycles in the immediate area of Wawa showed that the two are indistinguishable based on major element chemistry. The compositions of specimens from the metavolcanic cycles are strongly bimodal, reflecting an essentially bimodal stratigraphic subdivision (refer to Petrology Section).

Iron Formation

A voluminous literature has developed on the iron formation

of the Michipicoten greenstone belt since 1900. This literature has been summarized by Sage (1987a), and only the highlights will be presented here. The reader should refer to Goodwin (1962, 1964); Goodwin et al. (1976); Karkanis et al. (1979); Thode and Goodwin (1983) and Goodwin et al. (1985) for data relating directly to the origin of the Michipicoten Iron Formation.

Mapping of the iron formation has disclosed a minimum of 5 facies which differ greatly in degree of development from place to place. The carbonate facies rocks always occur at the bottom, and graphite or chert at the top. When it has been possible to determine the facies distribution across stratigraphy at a given site, it has proven to be a reliable stratigraphic facing indicator. The contacts between the various facies of iron formation within the iron formation unit are gradational in nature but contacts between iron formation and the upper and lower metavolcanics are sharp. From the stratigraphic bottom to the stratigraphic top the iron formation consists of siderite (carbonate facies), pyrite (sulphide facies), chert-magnetite wacke (oxide facies), chert-wacke, and argillite-pyrite-graphite (Figure 4). Within the Goudreau area calcite substitutes for siderite in several iron ranges such as the McPhail and "A" Ranges.

In addition to the geochemical and isotopic studies cited above, LeSeelleur (1980) examined oxygen isotopes and concluded that the Michipicoten Iron Formation was deposited at temperatures less than 200°C. Applying this temperature to 5 percent brine boiling curves of Finlow-Bates and Large (1978) the

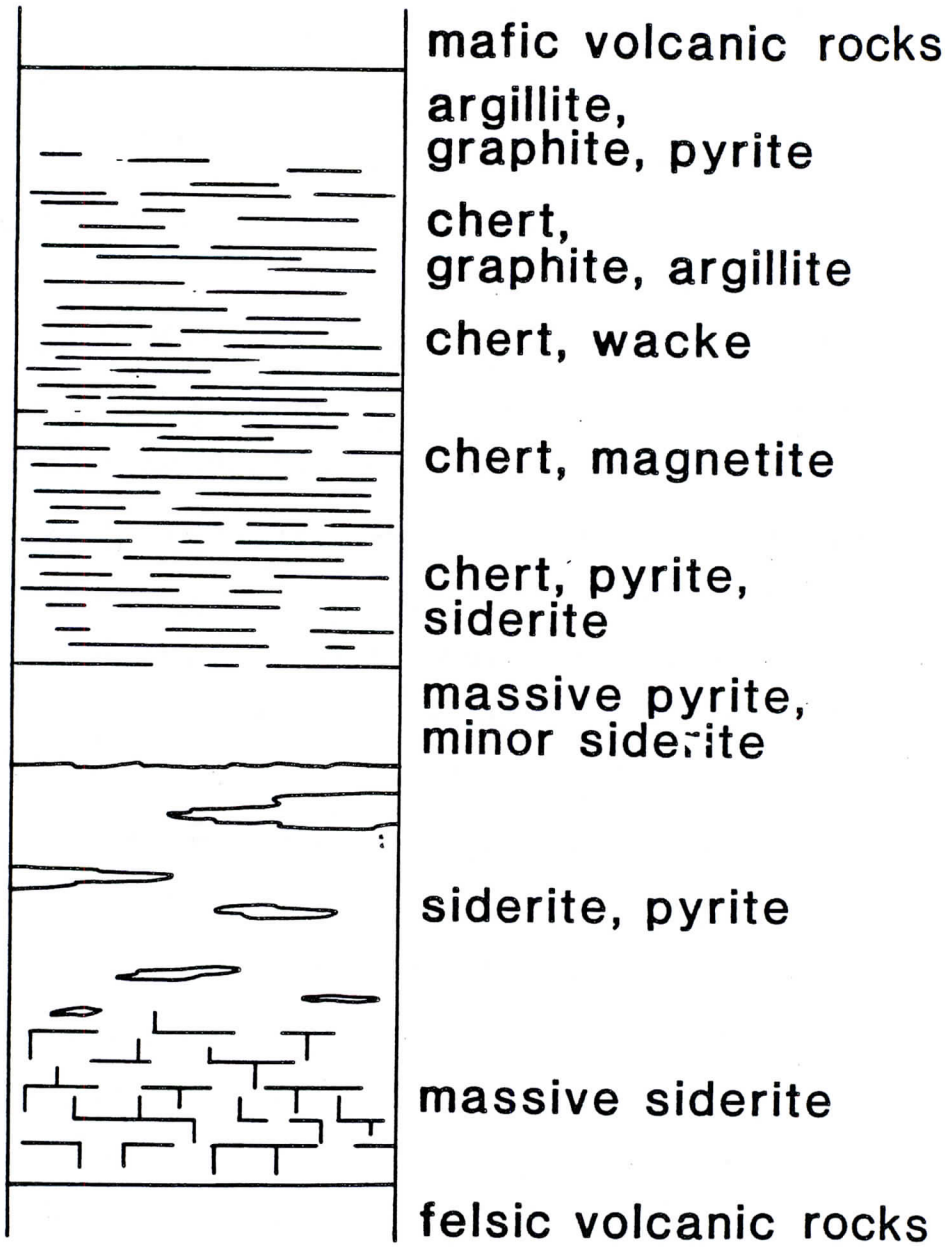


Figure 4 Idealized section through Michipicoten Iron Formation.

water depth at the time of deposition may have approximated 200 m.

A summary of the conclusions concerning the origin of the Michipicoten Iron Formation as prepared by Sage (1987a) is as follows:

1) The regional extent of the Michipicoten Iron Formation and its consistent position within the stratigraphy supports a primary depositional origin.
2) The carbon and oxygen isotopes and organic geochemistry support biological activity as playing a major role in deposition. Increasing graphite content stratigraphically upward may infer increasing biological activity (Goodwin et al. 1985).
3) Graded bedding and conformable interformational slump breccias indicate both subaqueous deposition and periodic tectonic activity.
4) Oxygen isotope data suggest iron formation deposition occurred below 200°C (LeSeelleur 1980).
5) Large amygdules within the intermediate to mafic meta-volcanic rocks above and below the iron formation imply low confining pressure and thus shallow to moderate water depths.
6) Overlying Dore metasediments indicate a shallow water, fluviatile environment that locally was subaerial. This implies relatively shallow basin deposition.
7) The iron formation was deposited from a deep, convecting seawater and a CO_2-rich metasomatic fluid representing

defocused, tortuous discharge (LeSeelleur 1980).

8) The iron and silica, plus some minor elements, comprising the iron formation were leached from the underlying metavolcanic rocks, most likely the high-iron tholeiites (Goodwin, 1964).

The volume of sulphides in the Michipicoten Iron Formation is impressive and an analogy with massive base metal sulphide deposits is of interest. The first and most obvious difference is the fact that the iron formation if unfolded and unfaulted would probably have a strike length of 100 km or more. This far exceeds any commercially viable base metal sulphide deposit. Base metal sulphide deposits commonly display an underlying alteration pipe through which focused high volume fluid discharge has occurred (Franklin et al. 1981), and it has been proposed that the chloritoid-bearing rocks underlying some sections of iron formation outline a classic alteration pipe (Morton and Nebel, 1984; Goodwin et al. 1985). Alteration pipes tend to be smaller than the associated base metal massive sulphide deposits and localized by synvolcanic faults or fractures (Franklin et al. 1981).

Synvolcanic fractures possibly associated with caldera collapse and resurgence could not be traced north of Wawa Lake during the present mapping and thus structures which may have acted to focus discharge could not be identified. This may account for the nonfocused discharge implied by the stratiform alteration pattern outlined by chloritoid distribution. The chloritoid alteration, in addition to being crudely stratiform, covers an area of approximately 600 x 2000 m which greatly

exceeds the dimensions of any known alteration pipe below a base metal massive sulphide deposit. The chloritoid-bearing zone covers a much greater lateral than vertical extent which contrasts with normally accepted alteration pipes as described by Franklin et al. (1981). The choritoid-bearing rocks have been extensively studied by Lockwood (1983, 1986) who concluded that they resulted from unfocused fluid discharge and overall low water/rock ratios under low pressure, subaqueous to subaerial conditions.

Archean massive base metal sulphides at Quemont were deposited at 240 to 440°C (Franklin et al. 1981), and base metal sulphides require a temperature of approximately 350°C in a mid-ocean ridge environment (Murnane and Claque, 1983). The temperature of 200°C or less suggested by oxygen isotope data (LeSeelleur, 1980) for the Michipicoten Iron Formation indicates that the depositing fluids were at a temperature too low to transport base metals.

It has been suggested that smectite or nontronite are precursor to chloritoid (Lockwood 1983, MacMillan 1981). These minerals form at relatively low temperatures (Cole 1983, Murnane and Claque 1983) which would be in agreement with the indication of oxygen isotope data for quartz within the iron formation that low temperatures were prevalent at the time of iron formation deposition. This assumes that iron formation and chloritoid alteration formed during the same event, which may not be the case.

The Michipicoten Iron Formation contains large amounts of iron and several percent manganese. Hydrothermal deposition of

iron and manganese is consistent with a distal low temperature environment, while base metal sulphide deposition is characteristic of proximal high temperature deposition (Edmond et al. 1974).

On the basis of existing data, the Michipicoten Iron Formation is not analogous to a massive base metal sulphide deposit; therefore it is not likely to contain a base metal enriched section. Where the iron formation has been tectonically deformed and fractured, both precious and base metal mineralization may occur in cross-cutting structures. This cross-cutting style of mineralization occurs in the Goudreau area.

Clastic Metasediments

The clastic metasediments found within the Michipicoten greenstone belt consist dominantly of volcanic debris. In the vicinity of Michipicoten Harbor and eastward across Highway 17 a spectacular conglomerate, known as the Dore, is locally well exposed. This conglomerate is noted for large rounded boulders of buff to white trondhjemite. These boulders on first impression dominate any given exposure, but upon closer inspection lie in a matrix of clastic debris derived from volcanic rocks. These boulders have been dated by U-Pb isotope techniques as 2698 ± 1 Ma (see abstracts and proceedings, this conference). Granitic rocks of the type described above have not been recognized within the enclosing granitic terrain. The boulders may represent fragments from subvolcanic stocks

associated with Cycle II volcanics which give equivalent U-Pb isotopic ages. These coarse boulder conglomerates were interpreted as skree by Collins and Quirke (1926), and a model of subaerial,proximal braided stream deposits was recently proposed by Massey (1985, personal communication). Moving eastward from Lake Superior the volume of conglomerate diminishes rapidly and in the area immediately north of Wawa, siltstone, wacke, and mudstone are dominant, and conglomerate relatively uncommon. Sediment transport direction is from west to east and thus the source for the granitic boulders is likely covered by waters of Lake Superior.

In the vicinity of Steephill Falls, just north of Wawa, thinly bedded mudstone, siltstone and wacke lie in sharp contact with intermediate to mafic metavolcanics of Cycle II. Excellent exposures of these rocks occur at Steephill Falls and south along the Mapgie River. The metasediments display excellent grain gradations, flame structures, and mud chip breccias. Very rare crossbedding occurs locally within the thin, coarser-grained wacke beds.

The section of metasediments exposed above the Eleanor Iron Range has been interpreted by Neale (1981) as resulting from several depositional environments. The basal section represents alluvial fan mass-flow processes; it is separated from an overlying braided river subarkosic sandstone facies by a thin sequence representing an interval of marine deposition below storm wave base (Neale 1981). The marine sediments were interpreted by Neale (1981) to represent levee and interchannel deposits on submarine fans. The upper braided river deposits display trough cross bedding, assymetrical ripple marks and

ripple cross-laminated structures. Transport direction on the basis of ripple marks was from west to east (Neale 1981).

Stratigraphically above the Lucy Iron Range, Thomas (1984) interpreted the basal part of the section as submarine fan and basinal facies associations, or alluvial fan with lacustrine facies associations. This section contains thinly to thickly bedded matrix- and clast-supported conglomerates which in places display both reverse and normal clast size gradations (Thomas 1984). These conglomerates consist dominately of laminated chert clasts, likely from an iron formation source, and were considered by Thomas (1984) to represent mass flow deposits. These deposits are overlain conformably by a resedimented facies characterized by submarine overbank turbidite deposits and mass-gravity flow and debris deposits in upper submarine fan channels (Thomas 1984). This facies is characterized by thinly bedded siltstone, mudstones, wackes and rare pebble conglomerate.

Above the resedimented facies is a non-marine braided river subarkosic wacke section (Thomas 1984). This section displays excellent cross bedding and soft sediment slump features. In addition, ripple marks, dessication cracks and rare flame structures have been found. The presence of dessication cracks indicates shallow water to subaerial deposition and implies that the intermediate to felsic volcanics from which the metasediments were derived were also in part subaerial.

While the chert pebble and cobble conglomerates at the base of the section above the Lucy Iron Range may imply shallow water fluviatile deposition, the general pattern of sedimentation above Cycle II intermediate to mafic metavolcanics is one of deeper to shallower water. Shallow water sediments dominate, which, in

conjunction with the large amygdule size of the associated intermediate to mafic pillowed volcanics and phreatic activity in the section below the iron formation, indicates that the basin of sedimentation was relatively shallow and restricted, not oceanic.

Internal Granitic Stocks

A number of granitic stocks have been emplaced within the Wawa supracrustals. The Jubilee quartz diorite to granodiorite stock, located south of Wawa Lake, contains nearly 50% metavolcanic xenoliths and blocks and is likely exposed at a relatively high structural level. The stock has been dated by U-Pb isotopic techniques as 2745 $\pm$ 3 Ma old and is thus comparable in age to the upper part of the intermediate to felsic metavolcanics of Cycle I dated by U-Pb isotopic techniques at 2749 $\pm$ 2 Ma (Sullivan et al. 1985, Turek et al. 1982). The Jubilee Stock may be one source for the intermediate to felsic metavolcanics of Cycle I. The Jubilee Stock displays sharp contacts with its enclosing wall rocks and enclosed xenoliths and has a poorly defined contact metamorphism aureole.

The Gutcher Lake trondhjemite stock in the central part of the supracrustal sequence and has been described extensively by Studemeister (1982, 1983, 1985a, 1985b) has been dated by U-Pb isotopic techniques as 2722 $\pm$ 1 Ma old (Turek et al. 1984). It has a contact metamorphic aureole of chlorite-epidote-amphibole hornfels up to one km in width (Studemeister 1985b). The hornfelsic aureole to the stock has been retrograded and the

granitic rocks of the stock metamorphosed to the greenschist facies in response to a regional metamorphic event. On the basis of U-Pb age dates (Turek et al. 1982, 1984) approximately 30 Ma separate the age of the stock from Cycle II intermediate to felsic volcanism. Even though compositionally similar, it cannot be positively certain that the stock and Cycle II volcanism are related.

Along the northern portion of the Wawa supracrustal belt are a number of granitic intrusions that vary from granodiorite to granite in composition. Precise U-Pb age dates have not been completed on these stocks but Turek et al. (1984) suggested a possible age of 2662 Ma for the Troupe Lake quartz monzonite stock on the basis of one sample, and Frarey and Krogh (1986) indicated a U-Pb isotopic age of 2684.5 $\pm$ 2.7 to 2.6 Ma on a trondhjemite to granodiorite stock at the east end of the Michipicoten greenstone belt. Granitic stocks of this more potassium-rich series do not have a known extrusive equivalent and appear to be contemporaneous with a large portion of the external granitic terrain (Turek et al. 1984).

External Granitic Rocks

The external granitic rocks range from tonalite and trondhjemite to granite in composition. Isotopic U-Pb dating of the external granites by Turek et al. (1982) gave an age of 2747 $\pm$ 7 for external migmatitic granites at Hawk Lake east of Wawa. In 1984, Turek et al. published four additional U-Pb isotopic ages on external granites. These ages are 2694 $\pm$ 3, 2662 $\pm$ 5, 2694 $\pm$ 3 and 2888 $\pm$ 2 Ma (Turek et al. 1984). The oldest

greenstone sequences. In addition, the supracrustal sequence of the Michipicoten greenstone belt should contain even more stratiform carbonate units than it does if the seawater contained so much carbonate. The later ankeritic carbonate occurs in crosscutting fractures and veins, and, where it is present as disseminated grains, it commonly displays a well developed rhombohedral habit typical of metasomatic porphyroblastic carbonate.

Carbonated mafic intrusions are common within the supracrustals. These mafic sills, dikes, and small masses may comprise up to 40 percent orange carbonate rhombohedrons. Such features are inconsistent with sea water reaction.

The pervasive soaking of carbonate is most likely the result of metamorphism and devolatilization of carbonate-rich sequences in the root zone of the supracrustal succession. The carbonate rich Michipicoten Iron Formation and older ferruginous dolomite would be a good source of carbon dioxide for the proposed (Studemeister, 1982) carbon dioxide plus water fluid accompanying regional metamorphism. The upward migrating volatiles have become fixed at a higher structural level during greenschist facies alteration.

The presence of carbonate facies iron formation and ferruginous dolomite within the stratigraphic sequence would have provided a good source of CO_2 if the root zone of the supracrustal sequence was subjected to the appropriate pressure and temperature conditions. Three dimensional modelling of the Wawa supracrustals has not been attempted, so the depth of the keel of the greenstone belt is uncertain and thus it is uncertain if appropriate pressure and temperature conditions existed during

the Archean in the region.

The second common type of alteration in the Wawa area consists of the development of chloritoid. This mineral occurs as distinctive porphyroblasts throughout the greenstone belt and has been identified in most rock types except metasediments (one outcrop excepted) and felsic intrusions. The rocks containing chloritoid are dominantly intermediate to felsic metavolcanics, closely followed by intermediate to mafic metavolcanics. Some observations made during mapping in regards to chloritoid are:

1) Rocks containing chloritoid are invariably pervasively carbonatized, but zones of pervasive carbonate alteration do not necessarily contain chloritoid.
2) The widespread occurrence of chloritoid suggests that the alteration that resulted in a rock composition favourable for the development of chloritoid was likely closely related to original volcanic process.
3) The wide distribution of chloritoid indicates that the alteration process must have taken place in a simple rather than complex system. The process occurred more than once since chloritoid alteration is present within both Cycle I and II volcanics, although its greatest development is in the upper part of Cycle I volcanics and extending into the lower part of Cycle II volcanics.
4) Chloritoid occurs in comparable concentrations in both intermediate to felsic and intermediate to mafic metavolcanics, and in minor amounts in mafic intrusions. It has been identified in only one outcrop of metasediments.
5) The process that brought about the alteration of the

original volcanic rocks is one of homogenization; felsic and mafic rocks have been altered to similar-appearing carbonate-chloritoid rocks, the original composition of which is difficult to determine.

6) The chloritoid crystals display a random orientation, implying that they were dominantly formed post-tectonically in response to a regional metamorphic event.

7) In some fragmental units, the chloritoid shows a preferential development in the clasts over the matrix; in other outcrops, the opposite is true. Fracture-controlled (possibly cooling cracks) chloritoid development has been observed in rare instances . In the pillowed to massive units, chloritoid commonly preferentially occurs in the pillow selvages, although outcrops displaying equal distribution of chloritoid throughout the pillow structures are not uncommon.

8) Chloritoid is most common in rocks that form the stratigraphic footwall to the Michipicoten Iron Formation, but it has also been found in the stratigraphic hanging wall. Latour (1980) recognized, in thin section, chloritoid in the mafic metavolcanic hanging wall of the Helen Iron Range and the author has recognized it in outcrop. At the Rand No.2 Iron Formation chloritoid is equally developed above and below the iron formation. At the Helen Iron Range, the chloritoid occurs in felsic to intermediate volcaniclastic rocks directly beneath the iron formation (Sage, 1980). Samples of iron formation on the waste dump

at the McLeod Mine and observations by Collins and Quirke (1926, p.69) indicate chloritoid occurs as isolated grains, streaks and bands within the iron formation. At the Josephine-Bartlett Iron Range, which is the eastern stratigraphic extension of the Helen Iron Range, the chloritoid occurs in pillowed and massive, intermediate to mafic flows that lie stratigraphically below felsic to intermediate metavolcanics.

9) Although chloritoid zones are commonly associated with iron formations, particularly the carbonate and sulphide facies, such zones without associated iron formation are also common.

10) While the longest dimensions of chloritoid zones typically conform to stratigraphy, some specific zones can encompass many individual flow units and are thus not confined to specific units. In addition, chloritoid-bearing pipe-like bodies that crosscut the stratigraphy and could thus be interpreted as feeders or pathways for the fluids causing the alteration, have not been recognized.

11) The much greater strike length of chloritoid units, in relation to their thickness indicates that the hydrothermal system operated in a broad regional aquifer controlled by rock permeability which was probably to some degree related to lithology.

In thin section chloritoid porphyroblasts traversed by shear planes have been observed, so some chloritoid is syn- or pre-deformational. Since most chloritoid porphyroblasts however are unsheared and randomly oriented the metamorphic event giving rise to the chloritoid peaked immediately after deformation ceased.

Most chloritoid grains are polysynthetically twinned, poikiloblastic, and have ragged ends. The crystals occur in isolated porphyroblasts or as radiating aggregates of grains.

Lockwood (1983, 1986) completed a study of the chloritoid found in the Wawa supracrustals and some of the conclusions resulting from this study are as follows:

1) Three fluids were involved in the alteration process.
   A) Circulating seawater that redistributed K and Na (fluid I).
   B) Seawater that circulated deeply, to a depth of 6 km, and became enriched in Fe, Mn, H_2S, and CO_2 at temperatures up to 385°C and under low water/rock ratio conditions (fluid II).
   C) Fluid II that boiled and evolved CO_2 and H_2S vapour phases, and mixtures of these CO_2- and H_2S-rich vapours with cold seawater that resulted in calcite and dolomite precipitation (fluid III). H_2S discharged at surface.
2) Circulating fluids were at least at 200°C, but less than 385°C.
3) The semi-conformable and widespread distribution of chloritoid indicates low velocity unfocused discharge.
4) Chlorite formation, which preceded chloritoid development occurred during metamorphism and was facilitated by Fe-metasomatism.
5) Chloritoid development occurred syn- to post-tectonically accompanying regional metamorphism. Lockwood (1983) has proposed Fe-chlorite or smectite as chloritoid precursors.
6) Chloritoid alteration is not an indicator of close proximity to economic mineralization.

Two other styles of alteration have been identified within the Wawa supracrustals. These are a Ca-Na metasomatism in the area of the Magpie Mine, and an area of tourmalinization alteration in an area in Musquash Township within the centre of the supracrustal sequence. These styles of alteration are of a local nature.

Structure

The structure of the Michipicoten supracrustals is still being examined and the present interpretation should be considered as a progress report. The reader should refer to Goodwin (1962) for an earlier interpretation of the structure of the Wawa Belt.

Mapping of the Michipicoten supracrustals has indicated a systematic change in the stratigraphic succession with time through volcanic Cycles I and II. This sequence is: intermediate to mafic volcanics, intermediate to felsic volcanics, Michipicoten Iron Formation, intermediate to mafic volcanics, intermediate to felsic volcanics coeval with Dore sediments, and in some places intermediate to mafic volcanics above the sediments. This stratigraphy, although varying locally, provides an aid in working out the regional structure when taken in conjunction with facing data. The well exposed stratigraphic sequence of the Lucy Iron Range near Wawa is identical to the less well exposed sequence near Goudreau. At the Lucy Iron Range the north-facing intermediate to mafic metavolcanics are overlain by north-facing Dore metasediments. In the Goudreau area a similar stratigraphic sequence is recognizable. At the Lucy Iron Range the upper part of the metasedimentary sequence has been

removed by faulting so nothing is known about former stratigraphy or structural relations above the metasediment at this location. In the Goudreau area the metasediments appear to face northward into the granitic terrain and locally are cut by granitic intrusions. Tentatively the Wawa supracrustals appear to be a monoclinal sequence younging northward which has been subjected to regional compression to form a central anticline and concomitantly sheared and/or attenuated in an east-west direction. In this model the northern portion of the belt moved west with respect to the southern portion; this movement accounts for the overturned recumbent south limb of the Centre Anticline and its vertically dipping north limb. The Centre Anticline is thus an infolded section of the original monoclinal stratigraphy. In the Goudreau area the Michipicoten Iron Formation has locally been stacked in units one above the other by low angle crosscutting faults and very tightly folded into "S" shaped folds in response to the east-west shear movement.

On the basis of an inferred Plinian style of eruption and presence of abundant shallow water sediments with indications of subaerial deposition, the Michipicoten supracrustals are interpreted to have been deposited in relatively shallow basins which subsided as volcanism took place. The above feature combined with large scale bimodal volcanism supports continental arc and continental rift models rather than island arc or back arc basin models. The arguments for a continental model are succinctly given by Thurston and Ayres (1986). Existing U-Pb isotopic ages on granitic rocks surrounding the Michipicoten supracrustal segments of the Michipicoten belt have failed to

identify a granitic terrain older than the supracrustals, although the Pb isotope data indicate early crustal material was present at the time of supracrustal development.

The east-west shearing component has imprinted a large number of shears and strike-slip faults on the Michipicoten supracrustal sequence. Locally these shears and faults follow lithologic trends, but regionally they cut across the stratigraphy at a low angle. These shears and faults are envisaged as synchronous with folding and in the Goudreau area take on economic importance as a features that have controlled gold mineralization. In general little can be said about the amount of offset or depth of penetration of these early faults. At Wawa the Wawa-Hawk-Manitowik Lakes Fault is strike-slip however at Manitowik Lake it is a transverse fault cutting across stratigraphy and also striking parallel to and likely forming part of the Kapuskasing Structural Zone. The Kapuskasing Structural Zone hosts a number of mantle derived late Proterozoic carbonatite intrusions. The late Proterozoic Firesand River carbonatite is at the intersection of the Wawa-Hawk-Manitowik Lakes Fault and the transverse Firesand River Fault. The implication is that this fault is rooted in the upper mantle. South of Wawa and Hawk Lakes lamprophyre dikes are very abundant, but north of these lakes they are rare to non-existent. This fault may represent the western limit of alkalic rock and carbonatite magmatism associated with the Kapuskasing Structural Zone. It is at present inconclusive but folding, and east-west shearing may be related to upthrusting and

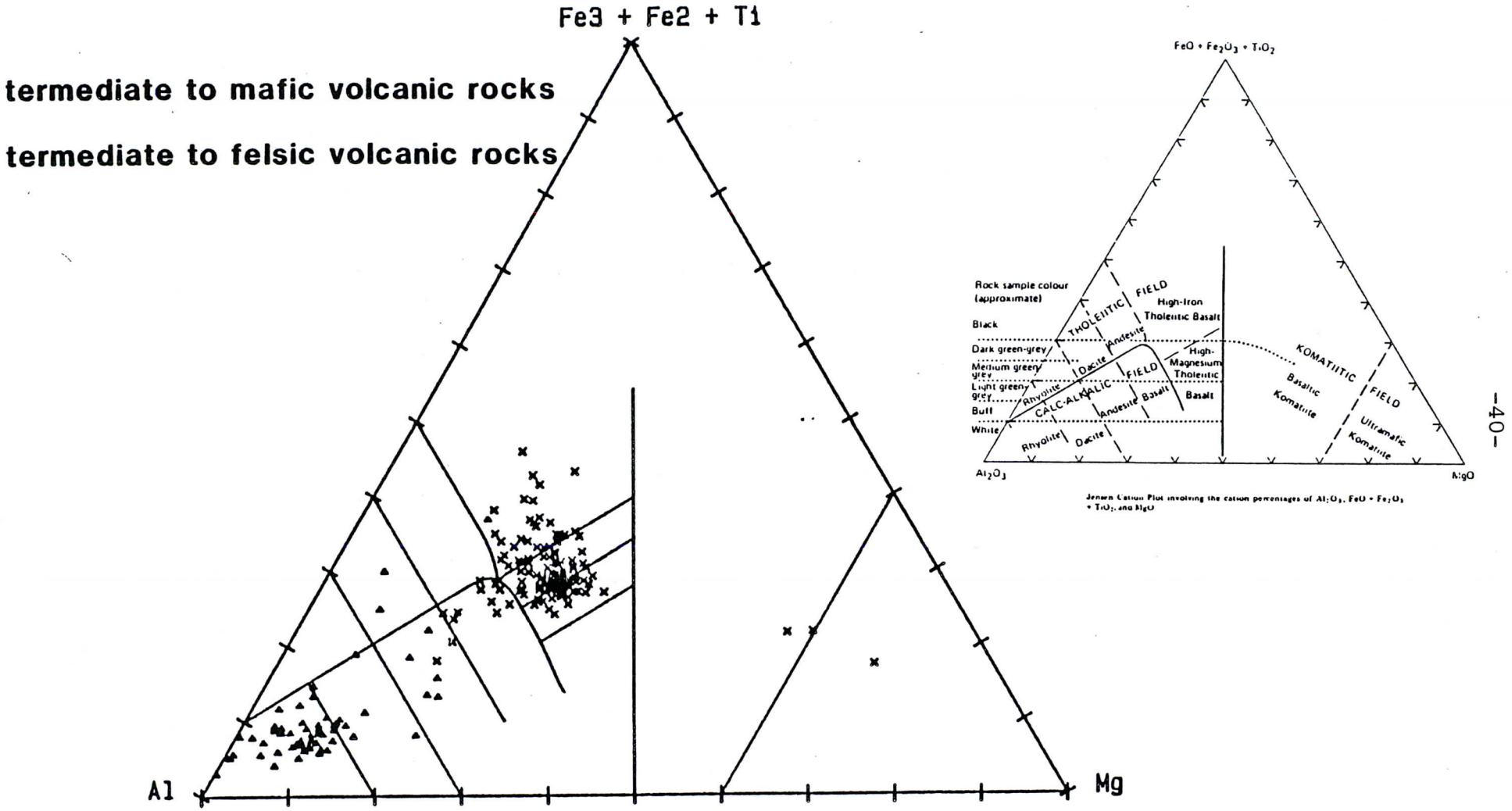


Figure 5 Jensen (1976) Cation Plot of Cycle I volcanics.

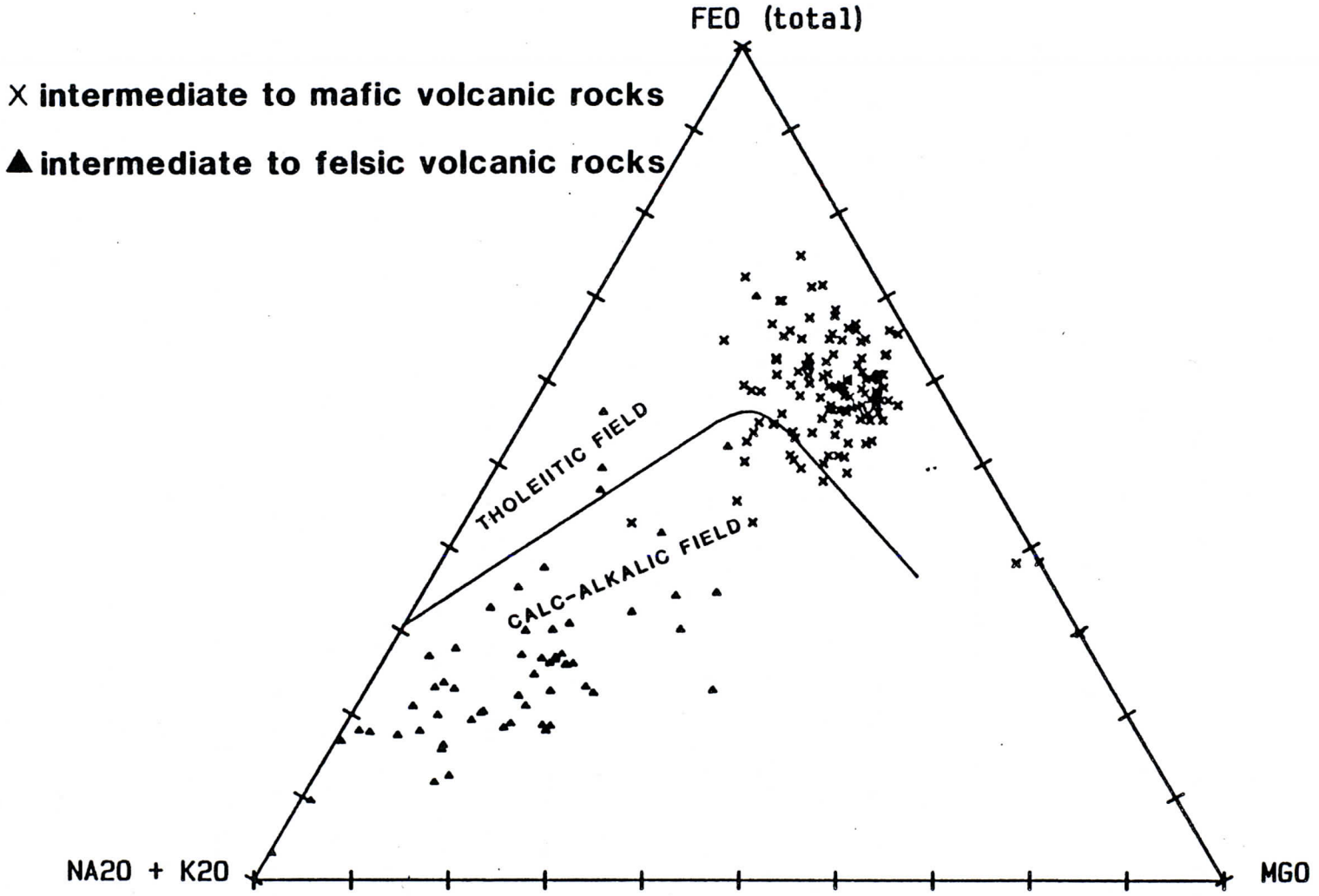


Figure 6 Irvine and Baragar (1971) AFM diagram of Cycle I volcanics.

was conducted in the Wawa and Goudreau areas and farther east at Renabie. Mining of siderite for iron was started on the Helen Iron Range and continues to the present day. Gold mining activity ceased during World War II and has only recently taken on new vigor. Prospecting for and testing of gold showings is currently intense with activity being concentrated near Wawa, between Goudreau and Lochalsh, and in the Renabie area. During the 1960s iron mining activity was briefly stimulated by expanding industrial development. This open pit mining was short lived.

During the late 1950s, the 1960s and into the late 1970s numerous exploration programs sought to locate base metals. These programs were unsuccessful in finding base metal concentrations of economic interest even though the geology is apparently favourable for such deposits.

The economic iron deposits are associated with a single iron formation unit separating Cycle I and Cycle II volcanics. Over the years this unit has been drill tested for iron many times and large volumes of siderite and pyrite outlined. Further development of these deposits will depend on economic conditions; large unknown deposits are not likely to be present.

The gold is hosted in classical Archean quartz vein-shear zone-type gold deposits. The gold mineralization is dominantly associated with early east-west strike-slip shears and faults and splays from these major shear zones. Intense alteration is commonly associated with gold mineralization. The alteration involved the addition of CO_2 (ankeritic carbonate), SiO_2

(quartz and/or cherty quartz), K (potassium feldspar and sericite), S (pyrite plus pyrrhotite) and water. Current prospecting and development efforts are concentrated on previously known showings. In some areas, and in particular the Goudreau-Lochalsh area, there is extensive sand cover. It can be safely assumed that the sand covered areas were not prospected effectively in the past, therefore the potential for additional gold deposits in those parts of the Michipicoten supracrustal belt is excellent.

LEAD ISOTOPE DATA

by

R.I. Thorpel

The lead isotope data for galenas from deposits and occurrences in the Wawa region are of significant interest from two points of view, the old model lead ages for a few deposits and the high $^{207}Pb/^{204}Pb$ values for many of the specimens. In addition, a Ph.D. thesis study in progress by P.E. Smith is contributing important whole rock lead isotope data for the area.

Whole Rock Lead Isochron

The thesis study by P.E. Smith at the University of Toronto has resulted in a Pb-Pb isochron for basalts along Highway 101 at a locality east of Wawa Lake. The indicated age, not model-dependent as are model lead ages for galenas, is 2759±30 Ma (Smith et al., in press; P.E. Smith, personal communication). These rocks lie stratigraphically below the Michipicoten iron formation and the age result is in accord with zircon U-Pb ages at 2749±2 Ma for the felsic volcanic rocks associated with the iron formation (Turek et al. 1982; P.E. Smith, personal communication).

Model Lead Ages

Thorpe (in preparation) has recently defined parameters for two lead evolution models that account for lead isotope compositions of Archean volcanogenic massive sulphide deposits in

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1 This lead isotope summary is recorded as Geological Survey of Canada contribution no. 45586.

the Superior Province. In addition to the lead isotopic data, these models are based on precise zircon U-Pb analyses for the volcanic sequences hosting the deposits (Mortensen, 1987 and personal communication; plus many published results by D.W. Davis, T.E. Krogh and F. Corfu of the Jack Satterly geochronology laboratory, Royal Ontario Museum). The models have been termed the Abitibi and Western Superior on the basis of the regions where they are generally applicable. Model ages by the two models differ by 40 to 45 Ma for the leads considered here.

Lead isotope analyses for some deposits west of the Kapuskasing Structural Zone in the Superior Province have yielded model ages greater than the general 2695 to 2740 Ma age range for supracrustal rocks east of the zone. The Lumby Lake epigenetic mineralization in western Wabigoon Subprovince has provided a striking example. A model lead age of about 2990 Ma (Table 2) has been convincingly shown to be reasonable by subsequent zircon U-Pb studies by Davis and Jackson, (1985). The lead isotope data (Table 2) also suggest a comparable age for some of the rocks in the Tashota area, in Wabigoon Subprovince, and a minimum age of about 2830 Ma (reduced somewhat from that reported by Hall and Rigg, 1986) for host rocks to the Musselwhite (Opapimiskan Lake) gold deposit, Sachigo Subprovince. In the Wawa area, analyses for galenas from the BCH vein and J. Vein just east of Wawa Lake indicate a host rock age of at least 2879 Ma if the Western Superior model is applicable and a comparable age is suggested for the Lakemount mineralization. These results are in general agreement with a zircon U-Pb age of about 2888 Ma for the

Wawa-Goudreau Region	Lat (N)	Long.(W)	Model Ages: W.Superior Model	Model Ages: Abitibi Model	W.Superior Model: Calc.u	W.Superior Model: Calc.Th/U
Soocana	48°03	84°36'	2587 Ma	2548 Ma	9.975	4.02
BCH vein'	48°02'54"	84°38'24"	2873 Ma	2832 Ma	10.096	4.12
J.vein'	48°03'11"	84°37'04"	2879 Ma	2838 Ma	10.055	4.06
Lakemount (E-vein)	48°03'36"	84°37'35"	2830 Ma	2790 Ma	9.974	4.05
MacLeod East	48°01'20"	84°45'	2657 Ma	2617 Ma	9.713	4.02
MacLeod East	48°01'20"	84°45'	2658 Ma	2618 Ma	9.774	4.06
MacLeod East	48°01'20"	84°45'	2649 Ma	2609 Ma	9.714	4.05
Ranson	47°54'02"	84°51'23"	2631 Ma	2587 Ma	8.844	4.06
Rengold	48°19'55"	83°57'47"	2654 Ma	2609 Ma	8.686	4.06
Braminco Prospect	48°21'43"	83°51'14"	2637 Ma	2591 Ma	8.629	4.07
Renabie	48°22'33"	83°52'25"	2723 Ma	2678 Ma	8.714	4.07
Michipicoten	47°53'45"	84°47'25"	2699 Ma	2655 Ma	9.043	4.06
Kozak	48°12'14"	84°32'53"	2770 Ma	2724 Ma	8.630	4.07
LeClaire Twp.	48°12'45"	84°41'41"	2670 Ma	2627 Ma	8.954	4.01
Edwards Prospect	48°18'07"	84°26'35"	2709 Ma	2670 Ma	9.978	4.00
Kremzar	48°18'07"	84°26'35"	anomalous		29.4	3.07
Other localities, Superior Province						
Tashota (Onaman)-A	50°14'04"	87°40'45"	2964 Ma	2921 Ma	9.689	4.04
Tashota (Onaman)-B	50°13'37"	87°40'47"	3022 Ma	2978 Ma	9.751	4.06
Tashota (Onaman)-C	50°13'30"	87°40'36"	2824 Ma	2783 Ma	9.971	4.07
Headvue (Onaman)	52°01'14"	87°39'38"	2807 Ma	2764 Ma	9.383	4.05
Headvue (Onaman)	52°01'14"	87°39'38"	2810 Ma	2768 Ma	9.476	4.07
Con Creek (Onaman)	49°57'30"	87°38'45"	2791 Ma	2748 Ma	9.283	4.07
Con Creek (Onaman)	49°57'30"	87°38'45"	2796 Ma	2752 Ma	9.288	4.06
Cane Resources (Onaman)	49°54'	87°42'	2808 Ma	2765 Ma	9.435	4.06
Musselwhite(Opapimiskan)	52°37'	90°25'	2863 Ma	2819 Ma	9.289	3.95
Musselwhite(Opapimiskan)	52°37'	90°25'	2872 Ma	2828 Ma	9.317	3.94
Musselwhite(Opapimiskan)	52°37'	90°25'	2871 Ma	2827 Ma	9.322	3.93
Elizabeth	48°48'05"	91°43'20"	2848 Ma	2805 Ma	9.491	4.02
Harold Lake	48°47'10"	91°52'40"	2739 Ma	2696 Ma	9.364	4.10
Lumby Lake	49o01'55"	91o20'30"	2992 Ma	2946 Ma	9.058	4.10

Table 2 Lead isotope data for the Wawa region and other selected localities in the Superior Province.

biotite granite phase of the Hawk Lake complex (Turek, et al., 1984), which is adjacent to the host rocks to these mineralized zones. It is interesting that the model age for the J vein, which is at a slightly lower stratigraphic position than the BCH vein (R.P. Sage, personal communication) is slightly greater than the BCH Vein. These model ages, of 2879 Ma and 2873 Ma, respectively, by the Western Superior model, are in accord, when analytical uncertainties in isotopic compositions and in the model are considered, with the zircon result for a phase of the Hawk Lake complex. The model uncertainty is significant in this case because the isochrons, established for volcanogenic massive sulphide leads with much lower $^{207}Pb/^{204}Pb$ values have been projected some distance to these more ^{207}Pb-rich compositions. The J and BCH veins thus may be synvolcanic and zircon U-Pb dating of their host rocks may demonstrate that the biotite granite phase that was dated from the Hawk Lake complex is also synvolcanic.

The Kozak Lake or Golden Spoke (analysis not shown in Figure 7) Pb-Zn-Ag mineralization in felsic volcanic rocks in Abotossaway Township yields model lead ages of 2770 and 2724 Ma by the Western Superior and Abitibi models, respectively. The Kozak mineralization and associated silicification zones have been subjected to regional (?) deformation and may tentatively be interpreted as synchronous with volcanism (Lockwood et al., 1985). In view of its close similarity to many Abitibi Belt zircon U-Pb ages (e.g. Mortensen, 1987), the younger model age is considered to be most likely.

It is noteworthy that model ages of 2657 Ma and 2658 Ma by

the Western Superior Model for two of the MacLeod East galena specimens and of 2670 Ma for LeClaire Township galena are within analytical uncertainties of the 2662±2 Ma zircon U-Pb age for the Northern Granite (granitic gneiss) that is located along the northern boundary of the greenstone belt (Turek et al., 1984). The Troupe Lake trondhjemite is apparently of the same 2662 Ma age (Turek et al., 1984). These ages may indicate a genetic relationship between these galenas and some of the plutons in the region.

Ancient Lead Source

Analyses that have high $^{207}Pb/^{204}Pb$ ratios in relation to their $^{206}Pb/^{204}Pb$ values are generally considered to indicate that the leads evolved in sources that had high U/Pb ratios (expressed as $^{238}U/^{204}Pb$ or μ values) for an extended period of geological time prior to ore formation. Figure 7 shows that many leads from the Wawa region plot well above the fields for Superior Province massive sulphide deposits with ages in the range 2695 to 2770 Ma, and for most Superior Province gold deposits. They mostly lie within the field for Zimbabwe gold deposits (Robertson, 1969, 1973; Kramers and Foster, 1984; and unpublished data). These high-μ leads are from the J vein, BCH vein, Lakemount property, MacLeod East mine (Michipicoten iron formation), Edwards prospect, Soocana property and the Mammoth Metals lead-zinc property (analysis for the latter in Franklin et al., 1983). Calculated source μ values for these leads range from 9.713 to 10.096, in contrast to a range of 8.457 to 8.910

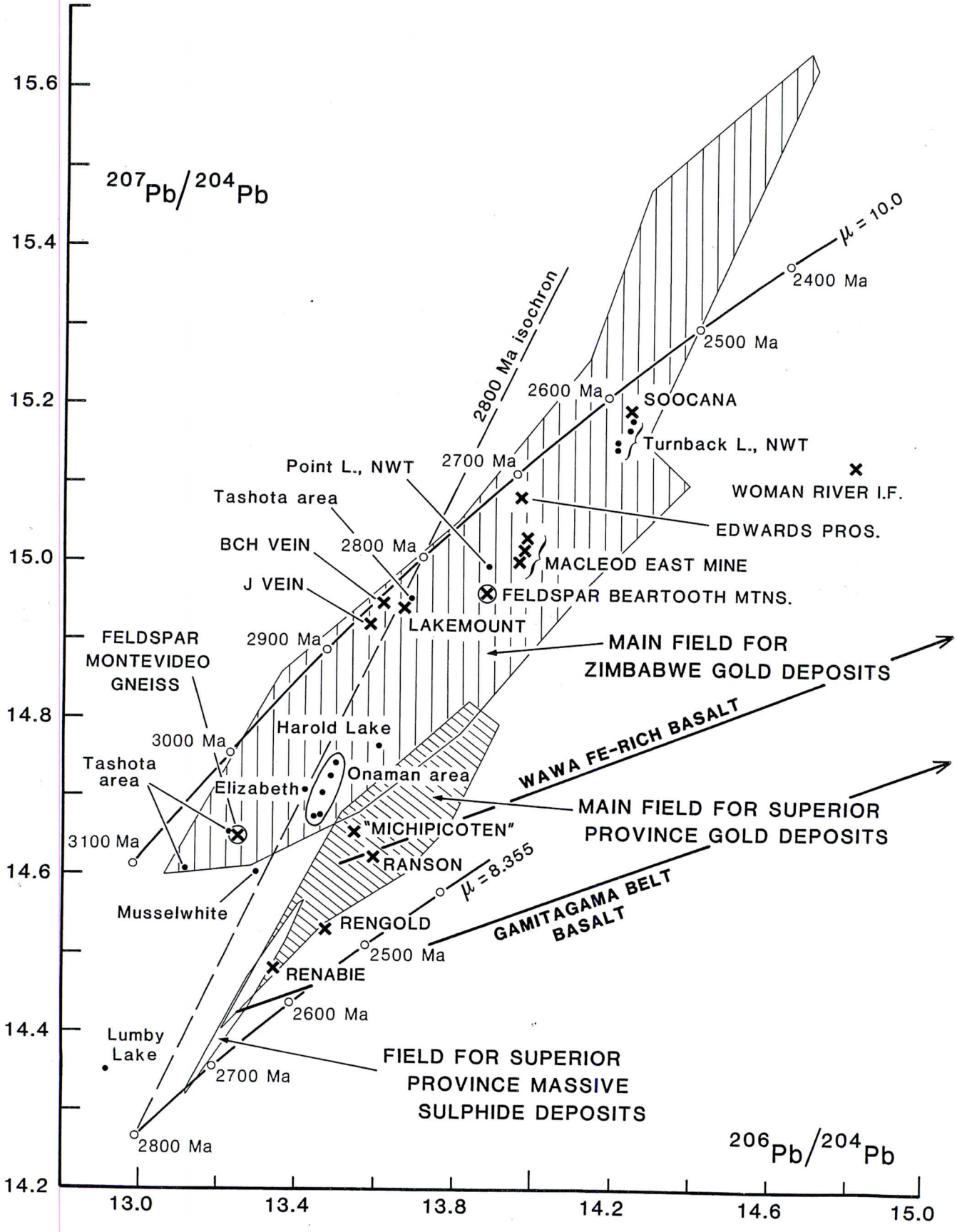

15.6
15.4
15.2
15.0
14.8
14.6
14.4
14.2
$^{207}Pb/^{204}Pb$
13.0
13.4
13.8
14.2
14.6
15.0
$^{206}Pb/^{204}Pb$
2800 Ma isochron
$\mu = 10.0$
2400 Ma
2500 Ma
2600 Ma
2700 Ma
2800 Ma
2900 Ma
3000 Ma
3100 Ma
$\mu = 8.355$
2500 Ma
2600 Ma
2700 Ma
2800 Ma
SOOCANA
Turnback L., NWT
WOMAN RIVER I.F.
EDWARDS PROS.
MACLEOD EAST MINE
FELDSPAR BEARTOOTH MTNS.
LAKEMOUNT
Point L., NWT
Tashota area
BCH VEIN
J VEIN
FELDSPAR MONTEVIDEO GNEISS
Harold Lake
Tashota area
Elizabeth
Onaman area
"MICHIPICOTEN"
RANSON
RENGOLD
RENABIE
Musselwhite
Lumby Lake
MAIN FIELD FOR ZIMBABWE GOLD DEPOSITS
WAWA FE-RICH BASALT
MAIN FIELD FOR SUPERIOR PROVINCE GOLD DEPOSITS
GAMITAGAMA BELT BASALT
FIELD FOR SUPERIOR PROVINCE MASSIVE SULPHIDE DEPOSITS

Figure 7 Wawa region lead isotope data (crosses) in relation to the fields for Superior Province massive sulphide deposits (Thorpe et al., 1986), most Superior Province gold deposits (Thorpe et al., 1984), and Zimbabwe gold deposits (Roberston, 1969, 1973; and unpublished data). Also shown for comparison purposes are whole rock isochrons for basalts in the Wawa and Gamitagama belts (Smith et al., in press; P.E. Smith, personal communication), feldspar analyses for the Montevideo gneiss, Minnesota (Goldich et al., 1975) and for the Beartooth Mountains (Wooden et al., 1985; Wooden and Mueller, 1986), and selected lead isotope analyses for deposits in Slave Province (Franklin and Thorpe, 1982; Thorpe, 1982) and Wabigoon Subprovince (unpublished data). There is an obvious similarity between some analyses for Wawa district leads and some of those for Wabigoon Subprovince leads. The ages shown are based on the Abitibi model.

for Superior Province massive sulphide deposits with 2695 to 2770 Ma model ages and 8.630 to 9.204 for the main field of data for Superior Province gold deposits. Whole rock lead isotope data indicate a similar pattern. Data by Smith et al. (1986a) for basalts of the Gamitagama and Wawa belts have resulted in higher source u values for the calculated initial lead compositions in the case of the latter belt (Figure 7). Apparent initial $^{207}Pb/^{204}Pb$ values as great as 14.95 have been reported for some of the rocks of the Wawa (Michipicoten) belt (Smith et al., 1986b).

Leads from Point Lake and from the Turnback Lake-Victory Lake area in the Northwest Territories (Franklin and Thorpe, 1982; Thorpe, 1982), from the Harold Lake and Elizabeth gold occurrences in western Wabigoon Subprovince, and from the Tashota-Onaman area in eastern Wabigoon Subprovince share the high - $^{207}Pb/^{204}Pb$ character. In view of what is known about the geological settings of these deposits, derivation of the lead, at least in part, from significantly older crustal terranes seems reasonable.

In the Wawa region the leads from some deposits are more isotopically "normal". Leads from the Ranson gold occurrence, Rengold property (Stover Township), Kozak Property, Braminco Prospect, LeClaire Township, Renabie Mine and a gold property located about 11 km south of Wawa (older analysis in Franklin et al., 1983) are from sources that had more normal μ values (Figure 7).

The most commonly invoked explanation for leads from high-μ sources is that they have been derived from long-lived crustal

environments or contain a major component from such a source (e.g. Gariepy and Allegre, 1985; Deloule et al., 1986; Smith et al., 1986; Smith et al., 1986b). In the case of such leads in the Wawa region an ancient source of "Minnesota River Valley-type" can be postulated. Evidence that tends to support such a source includes that used to explain similar leads in Zimbabwe Gold deposits (Robertson, 1973; Kramers and Foster, 1984), and limited evidence for old $^{207}Pb/^{204}Pb$-enriched crust in North America(Figure 7; Goldich et al., 1975; Wooden et al., 1985; Wooden and Mueller, 1986; Manhes et al., 1980).

Summary

Model ages for leads from deposits and occurrences in the Wawa area are in accord with known age constraints on the supracrustal sequences. An age of at least 2835 Ma for the host rocks to the J and BCH veins is indicated by the lead isotope data. These host rocks have not yet been directly dated by zircon U-Pb study.

It is not known which of the models defined by Thorpe (in preparation) for massive sulphide deposits in the Superior Province (Abitibi or Western Superior) should be applied in the Wawa area. The Wawa belt, because of the close agreement in reported zircon U-Pb ages and the interpreted general stratigraphic equivalence, is considered an extension, west of the Kapuskasing Structural Zone, of the Abitibi Belt. On this basis it might be anticipated that the Abitibi model should apply. Unfortunately the ages of mineral deposits in the region are not constrained well enough to permit a conclusion in this regard. The Abitibi model yields a very believable 2724 Ma model

age for the possible syn-volcanic Kozak Lake mineralization. If the Abitibi model applies, then a mineralization event as young as about 2590 to 2620 Ma would appear to be indicated by the Rengold, Ranson and MacLeod East analyses. However, with the Western Superior model these leads would yield model ages of about 2630 to 2660 Ma, in much better agreement with a plutonic event in the area defined at 2662±2 Ma by U-Pb analyses (Turek et al., 1984).

The high $^{207}Pb/^{204}Pb$ values (high μ sources) defined for some Wawa district leads appear to indicate a significant geochemical similarity, and probably genetic relationship, to terranes in the Wabigoon Subprovince. A first interpretation would be that the compositions of these leads are a consequence of derivation of at least a major component of the lead from long-lived crustal sources. An alternative is that the leads with high $^{207}Pb/^{204}Pb$ ratios reflect an enriched subcontinental mantle source that has not been well defined to date. It will be interesting to see if future tests can be designed and research carried out to resolve this question.

Geology and Stratigraphy of the Michipicoten Iron Formation

Leader: R.P. Sage, Geologist, Precambrian Section, Ontario Geological Survey.

Co-leader: M. B. Lockwood, Carleton University, Ottawa

Preface

The purpose of the tour is to familiarize the participants with the geology associated with the Michipicoten Iron Formation. The tour is a condensed version of a three day tour that has been given by R.P. Sage from 1980 to 1985. As a consequence of condensing three days of activity into one, only easily accessible outcrops will be visited. The outcroppings to be visited are an extremely small sampling of what is available for study in the Wawa area.

The treeless area north of Wawa gives geologists a rare opportunity to study Archean rocks without the encumbering cover of vegetation. This particular treeless area has greatly aided mapping and modelling of supracrustal development of the Michipicoten belt. Many problems of structure, volcanism, sedimentation, iron formation development, alteration, metamorphism, and economic geology remain to be tackled. Due to the large number of sites to be visited, a brisk pace is to be maintained. Figures 8, 9 and 10 present the stop locations with respect to simplified geology maps.

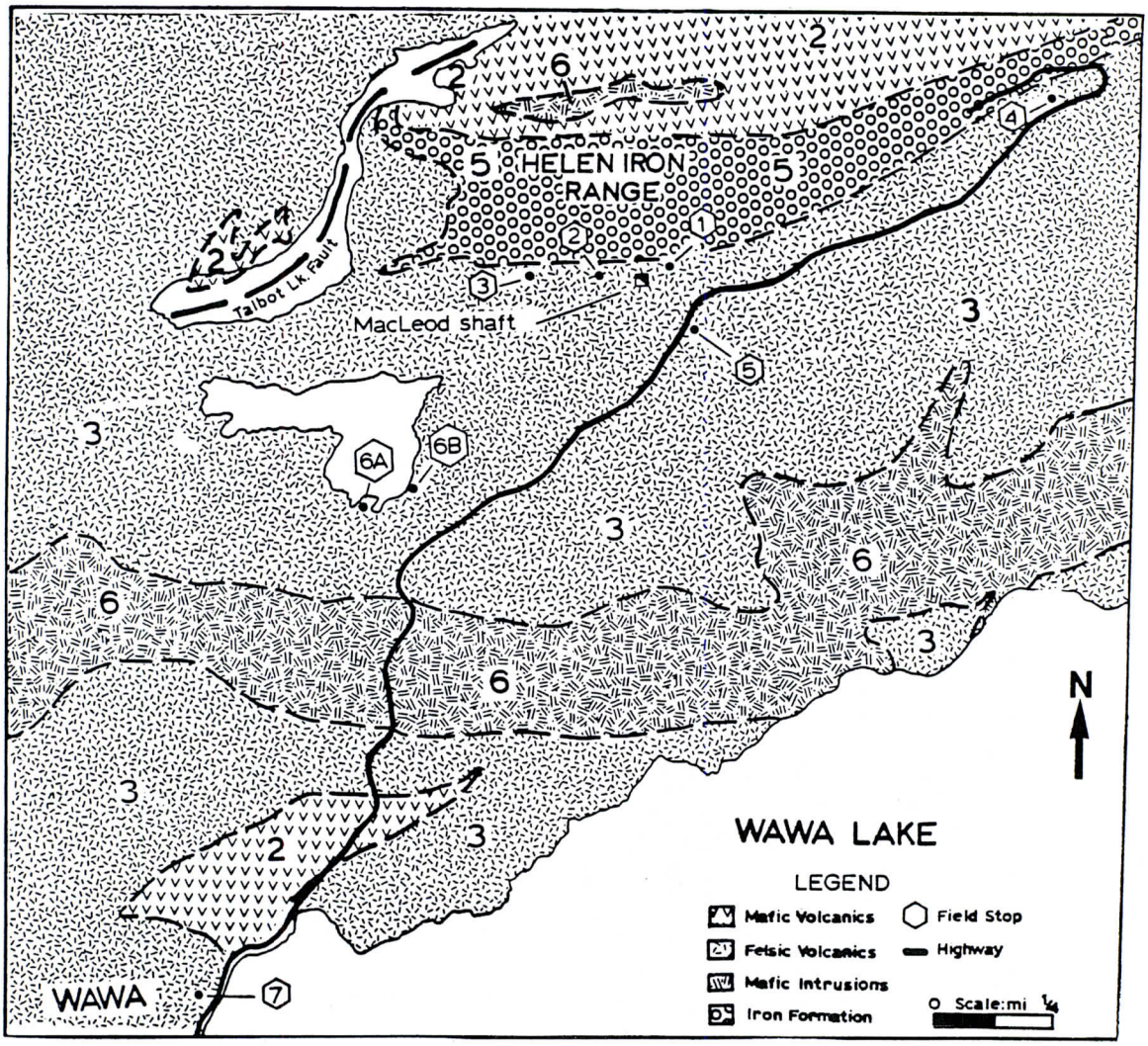


Figure 8 Stop location map Helen Iron Range.

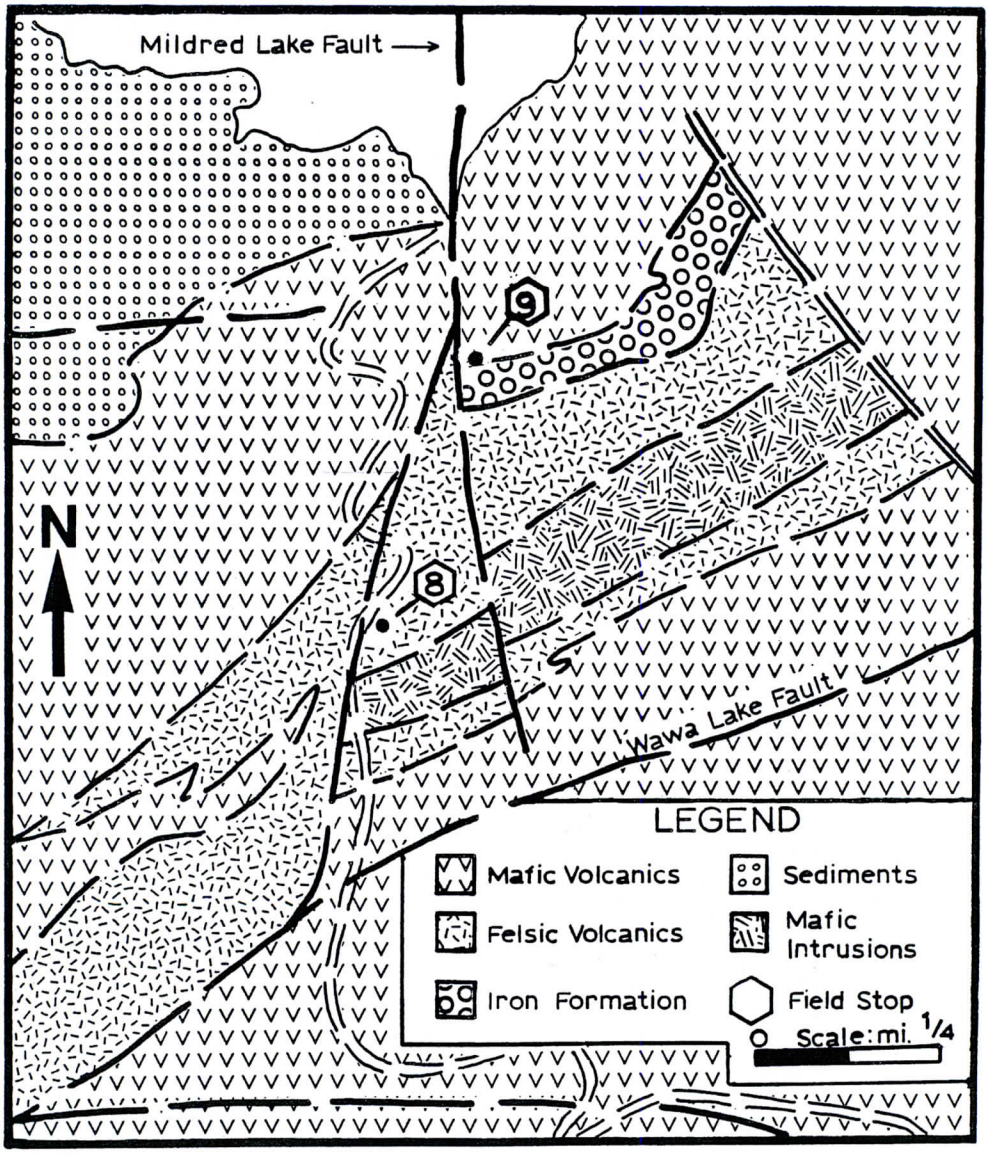


Figure 9 Stop location map Eleanor Iron Range.

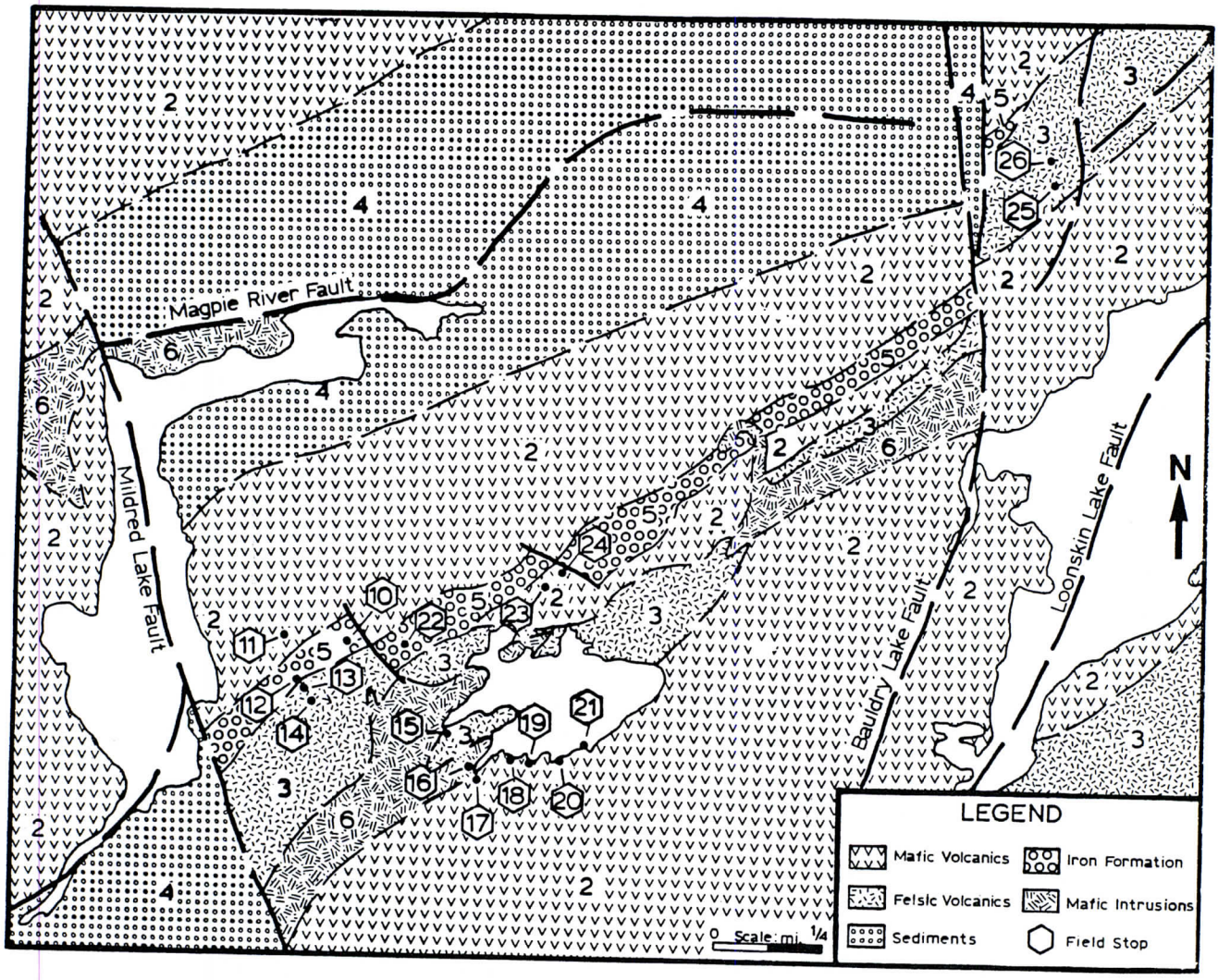


Figure 10 Stop location map Lucy and Ruth Iron Ranges.

Stop 1: MacLeod Mine parking lot

The first stop is the MacLeod Mine parking lot which lies on the footwall of the Helen Iron Range. The parking lot overlooks abandoned surface workings on the Helen Iron Range, from which was mined by open pit techniques, a hematite-goethite gossan above the siderite and sulphide facies iron formation. These operations took place from 1900 to 1918 and produced an estimated 2,780,236 tons of ore. Operations did not resume until 1939 when mining development began to open pit mine the unweathered siderite. Underground mining of siderite began in 1949 and continue to the present. An estimated 83,711,391 tons of siderite have been produced up to 1986; reserves as of 1984 were estimated at 58,246,000 tons (E. Berdusco, Geologist, MacLeod Mine, personal communication 1985, 1987). The mine workings are now serviced by the No. 5 Shaft or MacLeod Shaft. This shaft extends to a depth of 2788 feet from surface. Ore is transported to the sintering plant, located on the lake terrace north of Wawa, by a recently completed 3-mile-long conveyer system.

The north wall of the open pit consists of thinly bedded chert-wacke-magnetite iron formation. Moving from east to west along this iron formation unit, folding within the thinly bedded unit becomes increasingly common as the Talbot Lake Fault is approached. The minor fold axes within the iron formation plunges east at approximately 60 degrees. The Helen Iron Range has been tectonically thickened due to movement along the Talbot Lake Fault and reaches an estimated width of approximately 1000 feet (305 m) due north of the MacLeod shaft. This tectonic thickening has helped produce the siderite ore bodies being mined

within the Helen Iron Range. The U-Pb isotopic age of 2,749±2 Ma for the footwall rocks was obtained from samples of quartz-feldspar crystal tuff collected immediately south of the iron formation on the hill due east of the parking lot (Turek et al., 1982).

The iron formation of the Helen Iron Range faces north, dips south, and is overturned (Figure 11). The stratigraphic footwall is the mining hanging wall.

The reader should refer to Goodwin (1962, 1964), Goodwin and Shklanka (1967), Goodwin et al. (1976, 1985), Thode and Goodwin (1983), Karkanis (1979), Latour et al. (1980), MacMillan (1981), Nebel (1982), Osterberg (1982), and Morton and Nebel (1983, 1984) for data on rocks immediately surrounding the mine site.

Stop 2: Chloritoid in Lapilli-tuff

Walk west through the parking lot to the south side of the large outcrop northwest of the shaft. This is a good exposure of a schistose lapilli-tuff in which the chloritoid content of the clasts exceeds the chloritoid content of the matrix. The clasts range from rounded to angular in outline and occur at random throughout the outcrop. Chloritoid occurs as porphyroblasts up to 1 mm across and in amounts as great as 20 to 40 percent within the clasts.

Stop 3: Coarse Intermediate to Felsic Metavolcanic Breccia

Continue west from the lapilli-tuff of Stop 2 across a ravine and up to the top of the next hill. Upon crossing the

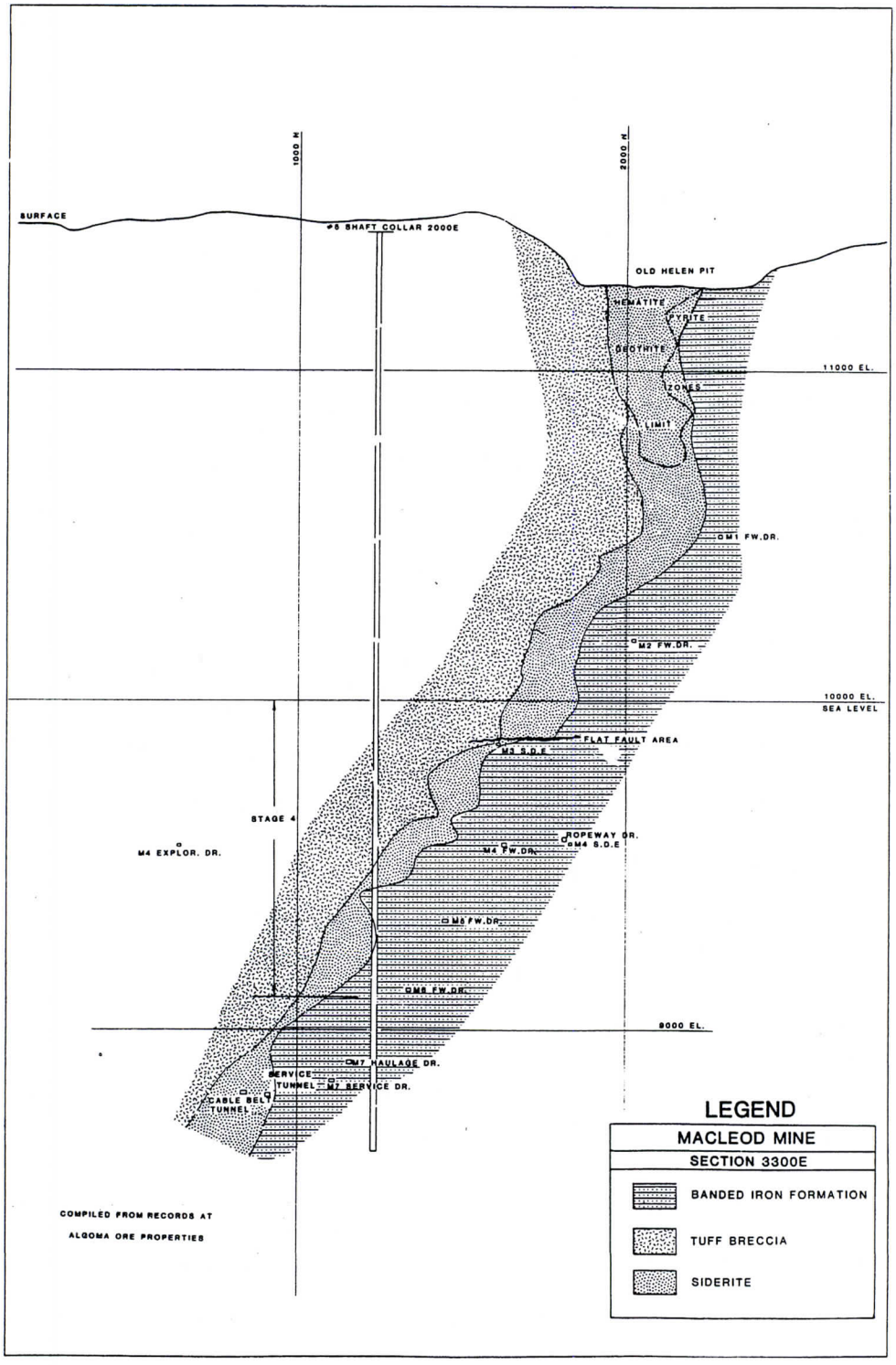


Figure 11 Schematic cross-section through the MacLeod shaft, Helen Iron Range. The siderite ore body pinches and swells in vertical section.

ravine the rocks display only a poorly-developed schistosity and no chloritoid. The ravine probably represents a minor fault. At the base of the hill a zone of siliceous, siderite-cemented breccia probably represents a feeder zone to the overlying iron formation.

The hill consists of angular to subangular clasts in a tuffaceous matrix. The clasts are as much as 1 m in size and the breccia is matrix-supported. Some clasts display bleached rims and grey cores. The chemical composition of the breccia clasts is relatively homogeneous, but texturally the fragments exhibit a wide variety. Clasts of spherulitic, flow banded, and aphanitic felsic volcanics compose the breccia. Rare carbonate-rich mafic metavolcanic clasts are present and possible glass shards have been located in one part of the outcrop.

The monolithic chemical nature of the rock in combination with textural variability suggests that the breccia was derived from a number of flow units and may represent the collapse of a felsic volcanic edifice proximal to a vent. This collapse may have been the result of phreatic activity. The coarseness of the breccia near the Helen Iron Range suggests this iron range is more proximal to a vent area than other segments of the same range farther to the east.

Danger

Do not proceed north of the crest of the hill. Mining has reached surface, and open stopes are present in the iron formation overlying the breccia but underlying the hill.

Prior to stoping to surface, the author examined the

volcanic section up to the iron formation. The clast size diminishes rapidly up section, bedding becomes increasingly apparent, and directly below the iron formation the felsic tuffs are fine-grained and thinly bedded. The upper part of this felsic unit has undergone considerable reworking.

Stop 4: (Optional) Thinly Bedded Lapilli-tuff Displaying Graded Bedding

Return to the vehicles and drive to the east end of the open pit area. Park vehicles and walk north to outcrop exposed at edge of pit. At this site siliceous, siderite-cemented intermediate to felsic lapilli-tuff displays excellent bedding and a facing direction based on clast size gradation. This size gradation indicates stratigraphic tops to the north, consistent with the direction indicated by wacke layers within the iron formation and by pillow shapes within flow units lying stratigraphically above. This exposure lies directly below the base of the Michipicoten Iron Formation. The beds range from 1 to 20 cm in thickness and clasts appear to be essentially of one texture and chemical composition.

Return to Vehicle and drive to the Eagles' Nest

Stop 5: Chloritoid within Intermediate to Felsic Metavolcanics

No Sampling - Please!

The first site at this stop is located in a grassy area west of the mine access road. This outcrop consists of coarse breccia

extensively replaced by chloritoid. There appears to be a preference for chloritoid to occur in the clasts rather than the matrix and the outcrop on the upper surface is dark grey in places due to the abundance of chloritoid. On the east-facing surface of the outcrop fracture-controlled chloritoid is in evidence. This chloritoid likely occurs along former cooling cracks.

Return to mine access road and walk along roadcut on east side of road. Abundant chloritoid occurs in heavily carbonated intermediate to felsic tuffs. Chloritoid porphyroblasts up to 4 mm in diameter are present. At the bottom of the section and just a very short distance east of the road is a typical example of a highly carbonated mafic intrusion. Similar heavily carbonated intrusions are abundant throughout Cycle I and Cycle II volcanics. This particular outcrop is part of an apophysis that can be traced lower into the stratigraphy where it eventually joins a thick sill-like mass in the centre of the stratigraphic section.

Return to vehicle

Stop 6: (Optional) Spherulitic Intermediate to Felsic Flows and Coarse Intermediate to Felsic Breccias at Abandoned Ropeway

Location 6a: A spherulitic flow is well exposed at the southeast corner of Moran Lake. The spherulites are up to 1.5 cm in

diameter and are not true spherulites but, rather, most likely represent vapour phase recrystallization around gas cavities since their cores are hollow.

Location 6b: East of the opening to the former ropeway and on the north side of the outcrop, well exposed intermediate to felsic coarse breccias are present. The clasts are angular to subangular and consist dominantly of fine-grained, massive felsic volcanics. There is no recognizable bedding. This breccia lies approximately 0.8 km below the Michipicoten Iron Formation.

Return to vehicle

Stop 7: Flow banded Intermediate to Felsic Metavolcanics at the West End of Wawa Lake

A spectacular unit of flow banded spherulitic intermediate to felsic metavolcanics occurs at the west end of Wawa Lake. Again the spherulites are not true spherulites; they are hollow and likely the result of vapour phase recrystallization around a gas cavity. The flow banded unit dips south at approximately 80 degrees, and thus the section is overturned. The largest spherulitic structures in some cases exceed 2 cm in diameter and occur approximately 60 metres north of the southern limit of exposures. The cavities are filled with rusty weathering ankerite. Very rarely a weak radiating structure is visible within the rims enclosing the cavities.

At approximately 70 metres the spherulitic unit becomes a

flow top breccia that contains flow banded clasts with local patches of solid, possibly true spherulites. The flow banding is highly convoluted.

Continuing to approximately 90 metres, a contact between the spherulitic unit and an ash flow breccia is observable. The contact is highly irregular and flow layering in the ash flow is well developed. On the upper surface are wispy fragments with cuspate ends interpreted to be fiamme. These possible collapsed pumice fragments are present in various units throughout the footwall stratigraphic sequence of the Helen Iron Range.

Above the ash flow at approximately 120 metres is a coarse breccia containing flow banded clasts up to 0.7 metre across. The clasts are angular and set in a tuffaceous matrix. The clasts are dominately heterolithic in texture, carbonated and the matrix contains no visible fiamme.

At 130 metres a thick section of intermediate to felsic tuff with rare lapilli is present. This unit is relatively massive.

Return to vehicle

Eleanor Iron Range

The Eleanor Iron Range was mined by open pit methods from 1958 to 1967 and produced 7,646,000 tons of siderite. The Sir James Dunn open pit is exhausted. Underground development was started but ceased in 1967 before the ore horizon was reached. Reserves below the pit floor are estimated at 1,250,000 tons (E. Berdusco, Geologist, MacLeod Mine, personal communication).

convoluted bedding can be seen.

Walk along access road back to the west end of the Lucy Pit and south across the waste rock pile. The outcrops to the west consist of intermediate to felsic metavolcanics cut by intermediate to mafic intrusions. The felsic rocks consist of breccia, lapilli-tuff, tuffs and quartz-feldspar crystal tuff.

Stop 15: Intermediate to Felsic Breccia and Lapilli-tuff

At the base of the trail from the waste dump stretched, bomb and lapilli size clasts are in evidence. The rock is very schistose and heavily carbonated. The breccia is heterolithic and poorly bedded.

Stop 16: Lapilli-tuff with Fiamme Cut by Intermediate to Mafic Intrusion

Continue along trail on west side of Brooks Lake to a small stream. Back from the stream is an exposure of intermediate to felsic lapilli-tuff with fiamme-like clasts. The volcanic unit has been sharply cut by fine-grained intermediate to mafic intrusive rock. Previous mapping in this area failed to recognize that most intermediate to mafic rocks within the intermediate to felsic metavolcanics are intrusive. Mafic volcanic rocks, when present, consist of tuffs, lapilli-tuffs, and rare breccias.

Stop 17: Feldspar Crystal Tuff

Continue south across the stream to examine a feldspar

crystal tuff. This rock type is uncommon in Cycles I and II. The outcrop displays a herring-bone ridge-like weathering pattern due to fracture-controlled alteration. Move to the shore of Brooks Lake and examine the wave washed outcrops at the base of the unit. Rounded clasts of feldspar porphyry similar to the crystal tuff matrix can be seen. Some are ghost-like in appearance.

Stop 18: Intermediate to Felsic Lapilli-tuff

South of the feldspar crystal tuff unit is a thin unit of intermediate to felsic lapilli-tuff. This unit is carbonated and weathers with a rusty stain. It lies in sharp contact with an underlying mafic tuff.

Stop 19: Mafic Tuff, Lapilli-tuff and Breccia

No Hammers - please

Immediately south of the thin unit of lapilli-tuff a thick unit of mafic breccia is present. The unit is heavily carbonated, approximately 100 m thick, and displays a crude stratification. A breccia dike cuts the mafic breccia at one location near the shore of Brooks Lake. The geologist should observe that some clasts are amygdaloidal, some display bleached reaction rims, and some are enclosed within an accretionary rim of fine-grained tuff. At this site the breccia is relatively homogenous in clast type, but along strike it is very heterolithic. This breccia unit occurs just above the

intermediate to mafic metavolcanics of Cycle I and forms a distinctive marker horizon from the Lucy Iron Range to the east end of the Josephine - Bartlett Iron Range, a distance of approximately 13.7 km.

Stop 20: Intermediate to Mafic Metavolcanics of Cycle I

Continuing south from the mafic breccia several small outcrops on the shore of Brooks Lake indicate the presence of highly carbonated pillowed mafic metavolcanics. In the outcrop exposed at the southwest corner almond-shaped amygdules up to 1 cm in size are present and comprise up to 10 percent of the rock. This represents the top of Cycle I intermediate to mafic metavolcanics.

Stop 21: (Optional) Pillowed Intermediate to Mafic Metavolcanics

Walk east along the lake shore to a small outcrop on the south shore of Brooks Lake. At this site pillow shapes indicate a north-facing stratigraphic sequence and the outcrop is cut by an Archean mafic intrusion displaying a chilled contact.

This stop completes the Lucy stratigraphic section from the bottom of Cycle I to the top of Cycle I intermediate to mafic metavolcanics.

Return to the west end of the Lucy Pit.

Stop 22: Lucy Pit

Danger - No hammering or climbing on pit walls

The west face of the pit displays the lower contact of the Michipicoten Iron Formation. This contact is knife-edge sharp contrasting with many reports that the contact is gradational. The gradational interpretation probably reflects the failure to recognize two ages of carbonate; one associated with iron formation deposition, and a second with later regional metamorphism.

As one enters the pit large blocks of footwall rock display highly amygdaloidal breccia clasts. The amygdules are up to 1 cm, constitute up to 20 percent of the clasts, and are filled with quartz.

The massive siderite exposed in the pit wall contains arsenopyrite crystals up to several centimeters in length which are usually doubly terminated and unattached in the siderite. The crystals probably grew within the siderite at the time of deposition.

The massive siderite grades northward into laminated siderite and then into sulphide facies iron formation. Good samples of sulphide facies iron formation are scattered on the floor of the pit. Samples of this sulphide facies iron formation displaying a branching bulbous pattern of pyrite in a siderite matrix are easy to collect.

Northward from the sulphide zone cherty bands increase in number and eventually the iron formation grades into continuous

banded chert. The chert becomes increasingly dark in colour as the graphite content increases northward to the pit wall. The upper contact is unexposed and oxide (magnetite plus hematite) facies iron formation is absent.

In the rib projecting into the centre of the pit some folds and minor faults can be observed. At the southern end of this rib thinly laminated siderite and pyrite are exposed and circular sulphide structures can be found.

Mining operations at the Lucy Pit were short lived and ceased in 1970 after 3 years of operation. The operation produced 1,073,000 tons of siderite and reserves are estimated at 1,300,000 tons (E. Berdusco, Geologist, MacLeod Mine, personal communication 1987).

Return to vehicle and move to the east end of the Lucy Pit.

Stop 23: Phreatic Explosion Breccia

After parking vehicle walk along the first level to near the east end of the Lucy Pit. Exposed in outcrop is a silica-cemented breccia that is interpreted to be a steam explosion breccia. Similar breccias crosscut the stratigraphy and have been observed at the bottom of the Helen Iron Range and as far east as the Josephine Iron Range. These breccias occur within 50 metres of the base of the iron formation and are known to be pre-regional deformation since the regional schistosity cuts through them.

Stop 24: Intermediate to Mafic Breccia

At the Lucy Iron Range a unit of breccia of undetermined

thickness occurs directly below the iron formation and is interpreted to have been originally mafic in composition since the style of amygdule development is typical of rocks of mafic composition. The breccia is heavily carbonated; some clasts contain up to 40 to 50 percent amygdules filled with quartz and ankerite. Scattered grains of chloritoid as great as 0.5 mm in diameter can be observed.

One should note that the iron formation passed on the way to Stops 23 and 24 is south of the iron formation in the Lucy Pit. A small fault offsets the iron formation in this area. Such small faults are relatively common.

Return to the vehicle

Ruth Iron Range

The Ruth Iron Range is the faulted eastern extension of the Lucy Iron Range. The fault separating the east end of the Lucy Iron Range from the west end of the Ruth Iron Range is the Bauldry Lake Transverse Fault. Left-lateral offset along the fault is approximately 600 metres.

The parking area is a short distance from the south end of Bauldry Lake; from the boat landing at the south end of the lake the west end of the Ruth Iron Range can be seen to crop out on the east shore of the lake.

The access road to the Ruth Iron Range was constructed in preparation for mining. The range has been extensively drill tested but has never been mined.

Stop 25: (Optional) Ferruginous Dolomite

Within the intermediate to felsic metavolcanics below the Ruth Iron Range a unit of rusty-brown weathering very fine-grained, siliceous, ferruginous dolomite is exposed. The weathered outcrop is criss crossed by thin, milky quartz stringers. The lower contact with felsic lapilli-tuff is sharp. The carbonate is thinly laminated at the contact. This carbonate unit varies in thickness radically from place to place and has been traced at this relative stratigraphic position to Siderite Lake near Hawk Junction. The strike length is approximately 10 km. At the north end of the Ruth Iron Range the carbonate unit lies directly on the mafic breccia unit previously examined on the south shore of Brooks Lake, Lucy Iron Range. This carbonate unit indicates that carbonate deposition occurred before deposition of the Michipicoten Iron Formation.

Return to Access Road

Stop 26: (Optional) Polymictic Breccia

Walk a short distance along the road and examine the very coarse angular heterolithic breccia exposed in the high outcrop on the south side of the road. This breccia contains intermediate to felsic metavolcanic blocks up to 1 m in size that have a wide variety of textures. In addition to the felsic clasts, large clasts of ferruginous dolomite and sulphide are present. The source of the sulphide is unknown, but the dolomite

likely came from the underlying unit of ferruginous dolomite examined in the previous stop. Structures in several clasts have been interpreted to indicate the presence of stromatolites. Continuing north along the road the breccia grades rapidly into fine-grained laminated tuff. The breccia cannot be traced laterally and likely occupies a depression or channel within the pre-existing volcanic terrain.

Tables

1) Table of lithologic units, Michipicoten supracrustal rocks.
2) Lead isotope data for the Wawa region and other selected localities in the Superior Province.

Figures

1) Schematic diagram of the Michipicoten supracrustal belt with tour sites indicated.
2) Schematic diagram illustrating relationships of lithologic units, Michipicoten supracrustal rocks.
3) Idealized stratigraphic section for Lucy Iron Range.
4) Idealized section through Michipicoten Iron Formation.
5) Jensen (1976) Cation Plot of Cycle I volcanics.
6) Irvine and Baragar (1971) AFM diagram of Cycle I volcanics.
7) Wawa region lead isotope data (crosses) in relation to the fields for Superior Province massive sulphide deposits (Thorpe et al., 1986), most Superior Province gold deposits (Thorpe et al., 1984), and Zimbabwe gold deposits (Roberston, 1969, 1973; and unpublished data). Also shown for comparison purposes are whole rock isochrons for basalts in the Wawa and Gamitagama belts (Smith et al., in press; P.E. Smith, personal communication), feldspar analyses for the Montevideo gneiss, Minnesota (Goldich et al., 1975) and for the Beartooth Mountains (Wooden et al., 1985; Wooden and Mueller, 1986), and selected lead isotope analyses for deposits in Slave Province (Franklin and Thorpe, 1982; Thorpe, 1982) and Wabigoon Subprovince (unpublished data). There is an obvious

similarity between some analyses for Wawa district leads and some of those for Wabigoon Subprovince leads. The ages shown are based on the Abitibi model.

8) Stop location map Helen Iron Range.

9) Stop location map Eleanor Iron Range.

10) Stop location map Lucy and Ruth Iron Ranges.

11) Schematic cross-section through the MacLeod shaft, Helen Iron Range. The siderite ore body pinches and swells in vertical section.

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