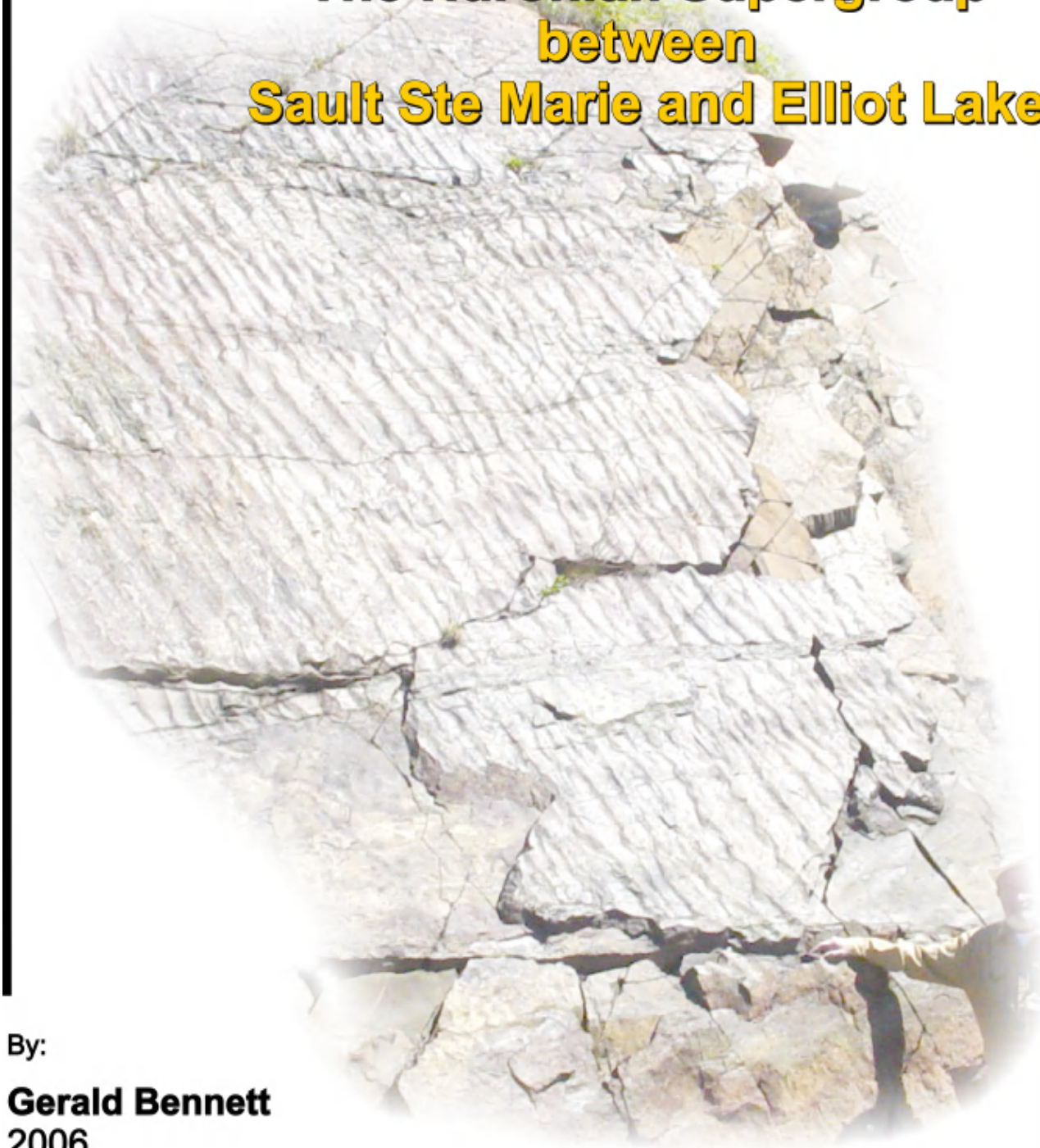


# **The Huronian Supergroup between Sault Ste Marie and Elliot Lake**



By:

**Gerald Bennett**  
2006

**Field Trip Guidebook, Volume 52, Part 4**  
**Institute on Lake Superior Geology**  
**Sault Ste Marie, Ontario**

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## Acknowledgements

I would like to acknowledge the rocks of the Huronian Supergroup for providing me with so many years stimulating and rewarding work and for teaching me so much, only to eventually show me how much more there was to learn.

I would like to thank my wife and children for their love and support during my long absences while a field geologist for the Ontario Geological Survey.

Dr. Ron Sage edited an early version of this manuscript and made many useful suggestions.

Cover and page layout by Victoria L. Sage, BSc.

Cover Photo: Ripple marks in the lower red quartzite member of the Lorrain Formation at Stop S2.2, Highway 17, west of the Town of Desbarats.

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## ILSG Field Trip Number 1 - Day 1

### Part 1 - Overview of the Huronian Supergroup

These first pages are intended to give participants new to the Huronian Supergroup of Ontario a summary of what we think we know of these ancient rocks. Much of the material is borrowed from an earlier ILSG guidebook (Bennett et al., 1997). The important contributions to that guidebook by K. D. Card and Kirsty Tomlinson are acknowledged with thanks.

### Introduction

The Huronian Supergroup is one of the Earth's most studied sequences of rocks. Since the turn of the century the results of hundreds of studies of Huronian rocks have been published in scientific journals and government publications. These studies have led geoscientists, to present evidence for the Earth's earliest glacial periods, the development of free oxygen in the atmosphere of the early Earth, the deposition of paleoplacer deposits of uranium, and evidence for plate tectonic activity during the Paleoproterozoic. Much of the evidence presented is based on rock exposures, which will be visited during this field trip.

The Huronian Supergroup, of the Southern Tectonic Province of the Canadian Shield, is a sequence of Paleoproterozoic sedimentary and minor volcanic rocks lying unconformably upon Archean rocks of the Superior Province of the Canadian Shield. The Huronian rocks extend eastward from Lake Superior, along the north shore of Lake Huron to Sudbury and then northward to the Noranda area of Quebec, a distance of about 450 km (270 miles) (Figures 1.1, 1.2). The Huronian Supergroup attains its greatest thickness of 12,000 meters (40,000 feet) southeast of Sudbury. The sequence thins northward due to the wedging out of basal units, thinning of clastic units, and erosion within the sequence (Roscoe, 1969; Frarey and Roscoe, 1970).

The 2219 Ma radiometric age of the Nipissing intrusions places an upper limit on the age of the Huronian Supergroup, while the Copper Cliff Ryolite (2450 Ma) is probably close to the date of initial Huronian deposition in the Sudbury area.

The Huronian Supergroup consists of four groups, which in ascending stratigraphic order are: The Elliot Lake Group, Hough Lake Group,

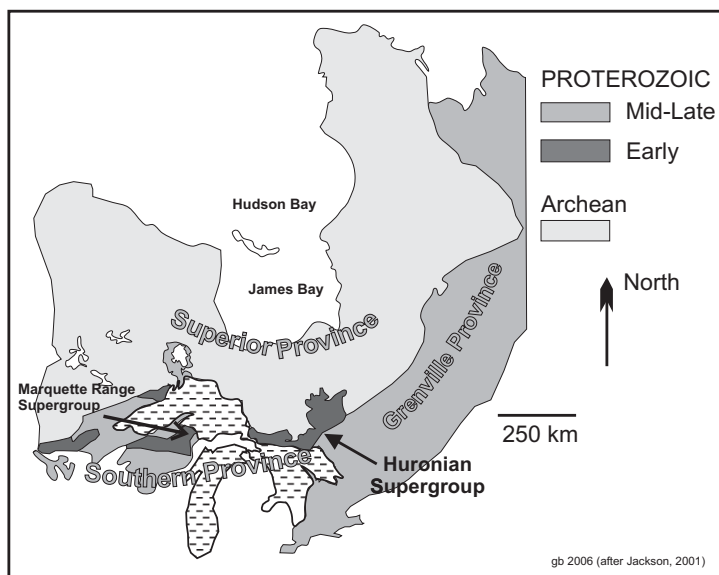


Figure 1.1: Distribution of Early Proterozoic Rocks in the Great Lakes region.

Quirke Lake Group and Cobalt Group (Figure 1.3). Formations of the three upper groups, with the exception of the Serpent Formation of the Quirke Lake Group, show stratigraphic continuity, and display a remarkable cyclicity of lithological units. Each cycle begins with matrix-supported conglomerate (diamictite/mixtite), followed by mudstone,

Figure 1.2: A rock-time chart for the southeast Lake Superior region.

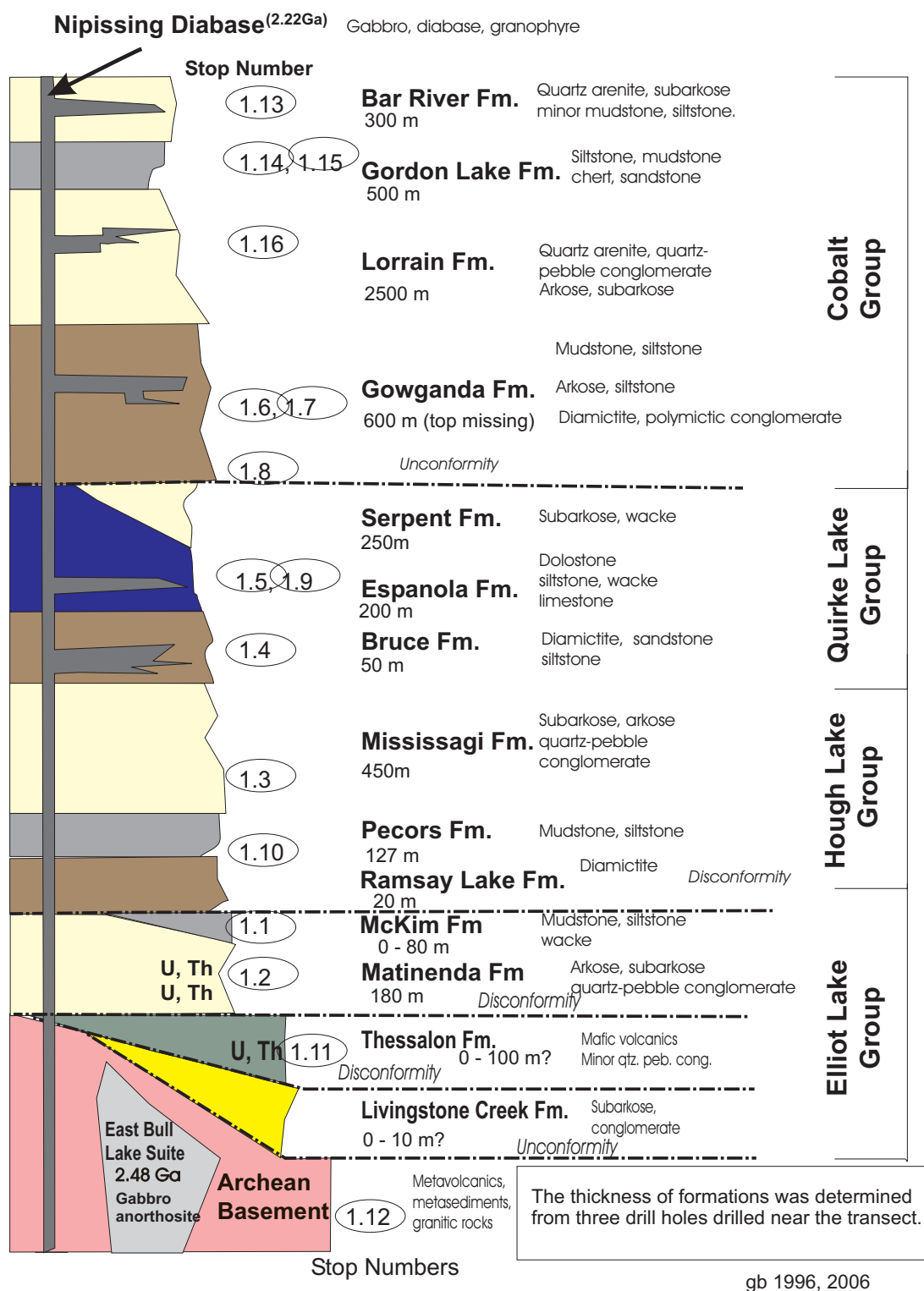


Figure 1.3: A Stratigraphic column for the Elliot Lake transect

siltstone or limestone and capped by a thick sequence of coarse, cross-bedded sandstone (Figure 1.5). Many paleocurrent studies have shown paleocurrent flowed south to southeast, with southeast being the predominant direction (Figure 1.5).

### The Elliot Lake Group

The Elliot Lake Group differs from the overlying Huronian groups in that: (1) Its internal stratigraphy is generally discontinuous and less extensive. (2) It does not show the diamictite-mudstone-sandstone sequence of the overlying groups. (3) It contains the only important uranium deposits and the only volcanic rocks of the supergroup. (4) Most formations have disconformable surfaces.

### The Livingstone Creek Formation

The conglomerates and sandstones of the Livingstone Creek Formation (Frarey, 1967, 1977) form the lowermost Huronian formation. The Livingstone Creek Formation is at least

1200 feet (400 m) thick in the Sault Ste Marie area and between 300 feet (100 m) and 1000 feet (300 m) thick in the Thessalon area. It consists of two distinctive rock types: an upper, well-sorted, grey sandstone and clast-supported polymictic conglomerate (Bennett et al, 1991), (Figures 1.3, 1.6, 1.7).

Clast-supported, polymictic conglomerate is the prominent rock type in the lower sections of the Livingstone Creek Formation of most areas. Cobble- to boulder-sized clasts generally of grey granitic rocks and minor mafic plutonic and metamorphic rock clasts are set in a sparse matrix of coarse, grey arkose or arkosic grit. The writer has not observed clasts of Huronian volcanic rocks in these conglomerates. Thin units of cross-bedded, grey arkose are locally interbedded with the conglomerate (Frarey, 1977, Bennett et al., 1991). The granitic mega-clasts of the conglomerate member are predominately pale grey in contrast with the predominantly reddish hues of the underlying Archean basement rocks. A few of the granitic

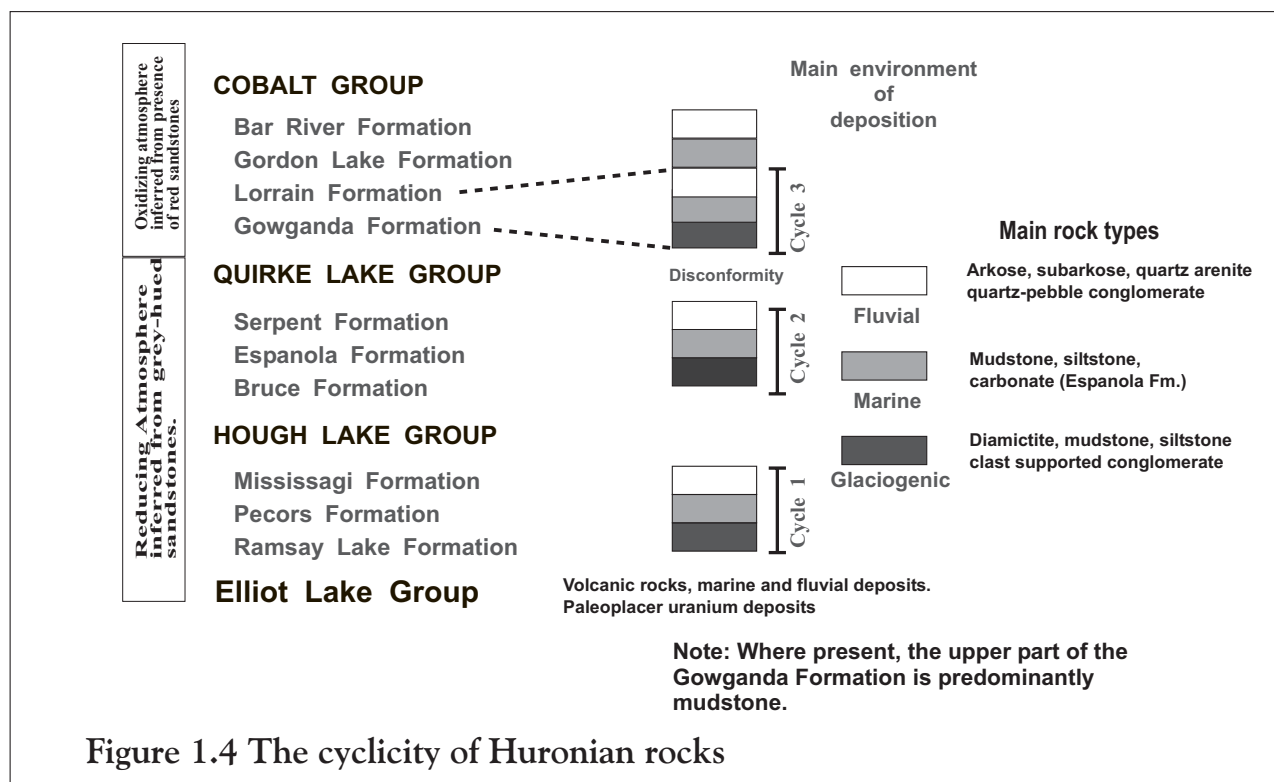


Figure 1.4 The cyclicity of Huronian rocks



Figure 1.15: Paleocurrents in the Mississagi and Matinenda Formations

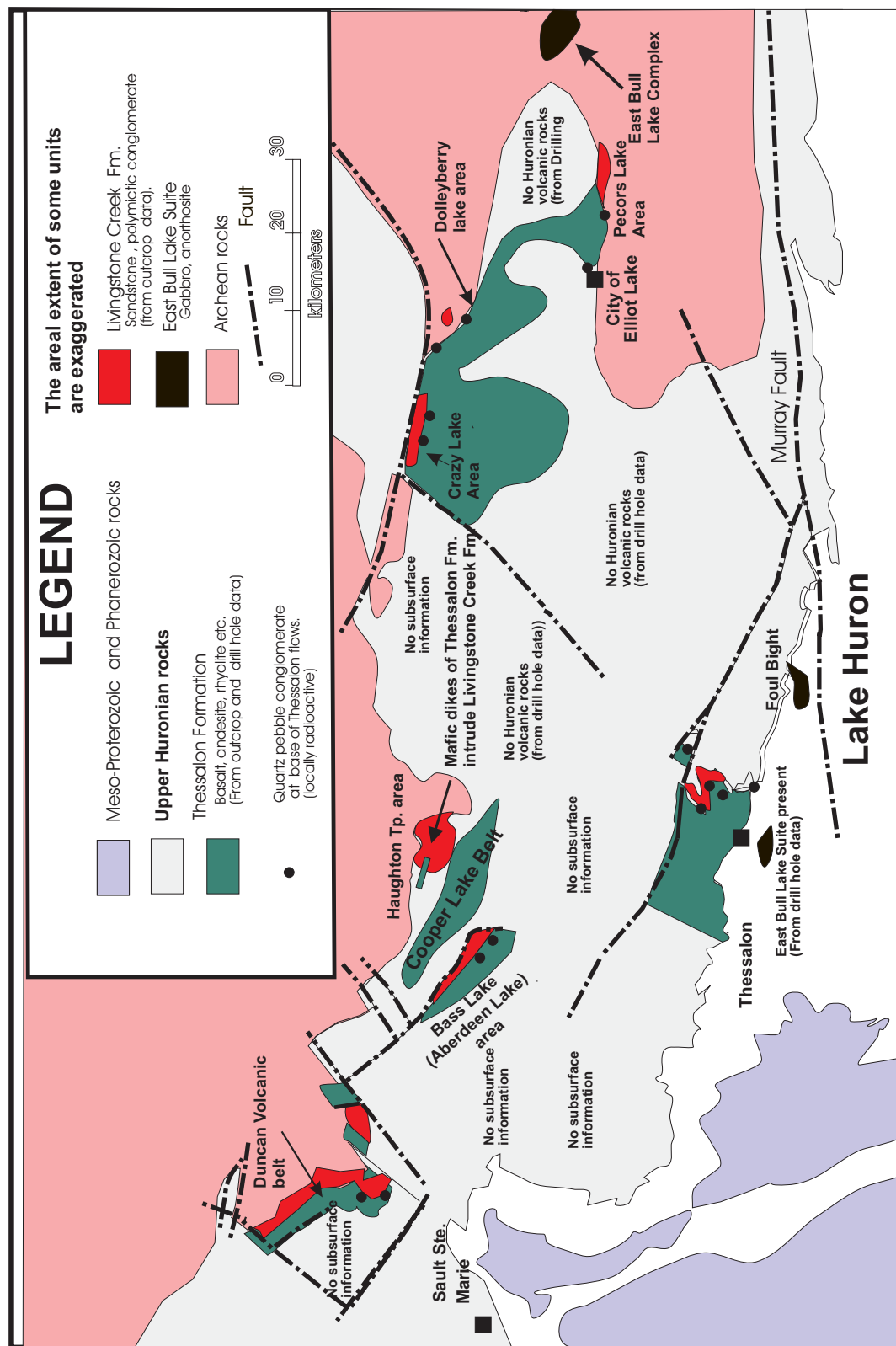


Figure 1.6: The distribution of some formations in the Elliot Lake Group

megaclasts in the predominately grey conglomerate near the south end of Pine Ridge Road show the distinct texture of the typical Archean, massive, pink, k-spar megacrystic granite – but with only a hint of the pink color in the phenocrysts. The grey colour of the Livingstone Creek Formation conglomerates appear to be due to the reduction of ferric iron in the feldspars of the granitic clasts, and not a result of differing provenance as some authors have suggested. This conclusion is supported by the writer's observation that granitic rocks in a "paleosol zone" a few meters to a few tens of meters below the base of the Livingstone Creek Formation commonly display a grey colour as well.

The grey, sandstone member of the Livingstone Creek Formation may be distinguished from most Huronian sandstones by the uniform grain size (fine- to medium-sand) of the former. Mudstone and pebbly units are lacking within the sandstone member of the Livingstone Creek Formation. Another characteristic feature of the sandstone units is the presence of carbonate along the foreset beds of the commonly well-developed trough cross-beds.

At Maud Lake in Duncan Township near Sault Ste Marie fine to medium-grained, pale-grey quartz-arenite forms the upper few meters of the Livingstone Creek Formation, suggesting a more prolonged period of weathering in that area.

In addition to the well-known exposures in the Thessalon and Sault Ste Marie areas the Livingstone Creek Formation has been correlated with grey sandstone and conglomerate near Crazy Lake in Nicholas Township (Bennett, 1978; Bottrill, 1971) (Figure 1.6). The writer correlated a basal grey sandstone unit directly underlying the Matinenda Formation in Haughton Township (Figure 1.6) with the Livingstone Creek Formation (Bennett et al. 1991). An area of clast-supported, grey granite-cobble conglomerate near Samried Lake reported by Jackson (2001) is probably an erosional remnant of the Livingstone Creek Formation. Other probable remnants of the

conglomerate member occurs as far east as Pecors Lake (Figure 1.6) on the south limb of the Quirke Lake Syncline (Jensen, 1990) and below Huronian volcanic rocks south of Stinson Lake in the Elliot Lake area. The Livingstone Creek Formation has not been recognized east of the Quirke Lake Syncline.

The clast size, local source and low stratigraphic position of the Livingstone Creek conglomerates are consistent with deposition on an alluvial fan. The uniform, fine- to medium-grained sand of the trough cross-bedded sandstone member suggests a different, although probably related, more distal depositional environment than that of the conglomerate. The sandstone member may represent deposition by median streams flowing in a fault-bounded valley with walls of Archean rocks partly covered by alluvial fans (Bennett et al., 1991). The well-sorted nature of the sandstone suggests an aeolian component or even aeolian deposition as proposed by Meyer (1983).

## Huronian Magmatism

### Introduction

Four distinct more-or-less coeval (ca. 2450 Ma), post-Kenoran igneous rock sequences are associated with the Huronian Supergroup: (1) Mafic dike swarms in the basement rocks but not found cutting the Huronian Supergroup. (2) Igneous complexes of layered gabbro/anorthosite. (3) Mafic to felsic volcanic flows. (4) 2.48 Ga. felsic plutons in the Sudbury area (Krogh et al., 1996).

The widespread intrusion of post-Huronian (Ca 2200 Ma) Nipissing gabbro/diabase dikes and sills have yet to be placed in a plate tectonic context.

### Basement Dikes

The north to northwest trending Matachewan-Hearst dike swarm is the second largest dike swarm of the Canadian Shield. The 2.45 Ga age of the swarm (Heaman, 1988) is

essentially the same as that of the East Bull Lake Suite and the Huronian volcanic rocks of the Copper Cliff Formation.

### ***Layered Gabbro/Anorthosite Complexes***

Several petrographically distinctive, mafic to ultramafic sills and cone-shaped bodies have been recognized between the eastern end of the Sudbury Igneous Complex and the nose of the Quirke Lake Syncline. The intrusions are characterized by the presence of anorthositic phases, and locally by a well-developed, primary rhythmic layering of alternating anorthositic and gabbroic layers. Segregations, dikes and sheet-like bodies of granophyre are locally present (Card and Palonen, 1976; Peck et al., 1995). Major intrusions of gabbro-anorthosite are found at Agnew Lake (Card and Palonen, 1976) and at East Bull Lake (Born and James, 1978; Kamineni et al., 1984)

Krogh et al. (1984) reported a U-Pb age  $2491 \pm 5.5$  Ma for zircons from the gabbro-anorthosite intrusion at Agnew Lake and  $2480 \pm 10.5$  for the East Bull Lake gabbro-anorthosite body. The similarity of these ages to the  $2450 \pm 25.10$  Ma (U-Pb zircon) age of rhyolite of the Huronian Copper Cliff Formation (Krogh et al., 1984) suggests that these gabbro-anorthosite intrusions form part of the early Huronian volcanic events. Bennett et al. (1991) report two additional bodies between Blind River and Thessalon. Layered anorthosite and associated coarse-grained gabbroic rocks form a sill-like body about 5 km long at Foul Bight on the North Shore of Lake Huron (Figure 1.8). A drill-hole drilled from the ice south of the Town of Thessalon intersected layered gabbroic rocks (Figure 1.6). All gabbro-anorthosite bodies found to date have been emplaced in the Archean basement at, or just below, the Archean-Huronian boundary.

### ***Huronian Volcanic Rocks of the Sudbury Area***

The Huronian bimodal volcanic sequence in the Sudbury area has been subdivided in the predominately mafic Elsie Mountain (1000 m

thick), and Stobie Formations (1500 m thick) and the felsic, Copper Cliff Formation (760 m thick). Krogh et al. (1984) obtained an age of  $2450^{+25}_{-10}$  Ma (U-Pb zircon) age for rhyolite of the Huronian Copper Cliff Formation; the only Huronian supracrustal rock for which there is an absolute age. The volcanic rocks of the Sudbury area show evidence of submarine eruption from fault controlled vents along the edge of a depositional basin into which arkosic sandstones were being transported from the Archean granitic terrain to the north, while turbidites were deposited from sediment from both the volcanic and rejuvenated basement marginal to the basin (Card, 1978).

The volcanic rocks of the Sudbury differ in terms of internal stratigraphy, overall thickness and depositional environment from the Huronian volcanic rocks in the Sault Ste Marie-Elliot Lake area.

### ***The Huronian Volcanic Rocks of the Sault Ste Marie-Elliot Lake area***

Frarey (1967) named the Huronian volcanic rocks in the Thessalon and Sault Ste Marie areas that overlie the Livingstone Creek Formation as the "Thessalon Formation" (Figures 1.3, 1.6).

This writer has examined all known exposures of Huronian volcanic rocks as well as all available drill-core and drill-hole logs reporting volcanic rocks in the Elliot Lake-Sault Ste Marie area. It was concluded that there is no credible evidence for more than one period of Huronian volcanism in the area of the study and that all the Huronian volcanic rocks west of the nose of the Quirke Lake Syncline are stratigraphically correlative with the Thessalon Formation (Figure 1.6) (Bennett 1978, Bennett et al 1991).

Unfortunately, none of the many attempts to obtain an absolute age determination from rocks of the Thessalon Formation have been successful. However, the spatial association of the East Bull Lake intrusions with the Huronian volcanic rocks of the Quirke Lake Syncline suggests Huronian volcanism in that area

# LEGEND

## HOUGH LAKE GROUP



## ELLIOT LAKE GROUP



## MATINENDA FM.

Arkose, grit  
quartz-pebble conglomerate

The thickness of some units is exaggerated  
purposes of visualization

## THESSALON FM.

Basalt, andesite, rhyolite flows  
basalt dike

## LIVINGSTONE CREEK FM.

Grey arkose, subarkose  
Polymictic conglomerate

## ARCHEAN BASEMENT

Granite, greenstone

## Quartz-pebble conglomerate

## Unconformity or discontinuity

1000

METERS

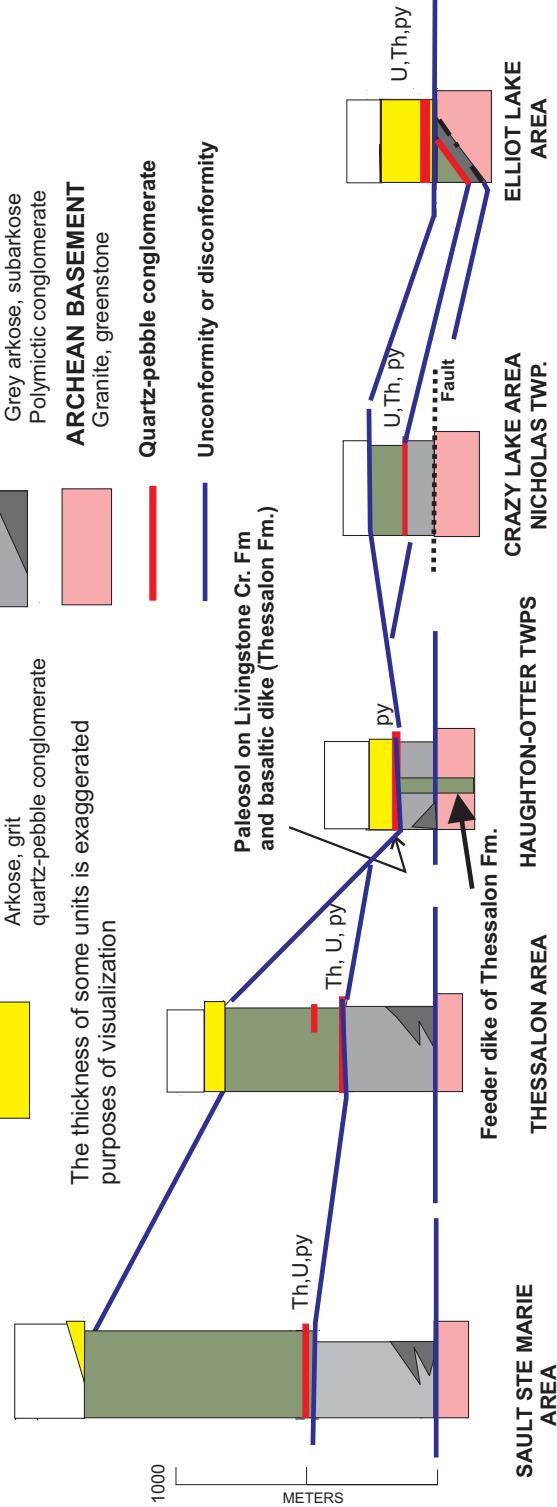


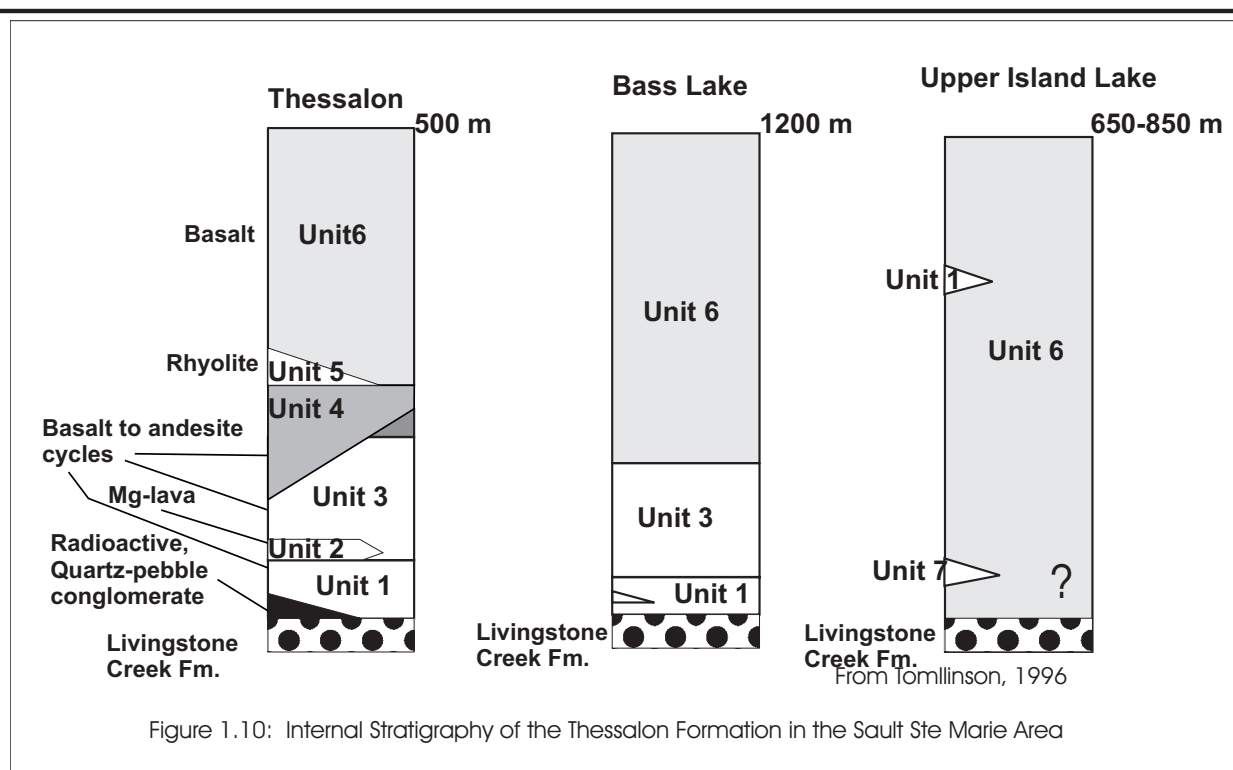
Figure 1.7: Stratigraphic relationships in the Elliot Lake Group.



Figure 1.8: Layered anorthositic gabbro. Foul Bight, Lake Huron.



Figure 1.9: Stratigraphic relationships at Cullis Lake, Thessalon area.



occurred about the same time as the emplacement of the East Bull Lake intrusions (2480 Ma). Given the potential error for the relevant age dates (Krogh et al., 1984), the age of the Thessalon Formation may not differ significantly from that of the Copper Cliff Formation of the Sudbury area (2450 Ma).

The maximum thickness of the Thessalon Formation in the Sault Ste Marie area is approximately 650 m (2100 feet) and 820 m (2700 feet) (Frarey, 1977). Diamond drilling has indicated at least 670 m (2200 ft) of Thessalon volcanics under Lake Huron south of the town of Thessalon. The Thessalon Formation may be as much as 1080 m (3500 feet) thick north of Bass Lake in Aberdeen Township.

In the Sault Ste Marie, Thessalon and Aberdeen Lake areas the Huronian volcanics rocks can be subdivided into upper tholeiitic basalt unit and lower complex or "mixed member" (Bennett et al 1991) which includes more fractionated rocks including basaltic andesite, tholeiitic andesite, mugearite, hawaiite, rhyolite, basalt. Magnesium-rich basalts with some of the chemical characteristics of komatiites are present

in the Dollyberry Lake, Pecors Lake and Thessalon areas. The lower flow sequences show much lower concentrations of Ni, Cr, and contain higher amounts of Ti and P than the upper flows. In the Dollyberry Lake area the upper basalts appear to be missing. This is assumed to be due to erosion (unpublished analyses in the writers files).

Tomlinson (1996), completed a comprehensive analysis the geochemistry of the Huronian volcanic rocks between Sault Ste Marie and Thessalon, concluded that the lavas of the Thessalon Formation are divisible into 7 distinct units based on mapping, petrography and major and trace element geochemistry (Figures 1.10, 1.11). The 7 units were grouped into two "lava series". The upper lava series (units 6) of Tomlinson, 1996) is equivalent to the upper tholeiitic basalt sequence of Bennett et al. (1991). The lower lava series (units 1-5, of Tomlinson, 1996) consists mainly of basaltic andesite with subordinate, local rhyolite, mugearite, andesite and high magnesium basalt flows; and corresponds to the "diverse member" of Bennett et al. (1991).

Bennett et al. (1991) proposed that the upper, basaltic flows of the Thessalon Formation (upper lava series) probably represent part of a continental flood basalt sequence, while the diverse member (lower lava series) appears to have erupted from central vents. The Huronian volcanic rocks of the Quirke Lake Syncline display lithological and geochemical similarities to the lower lava series of the Thessalon Formation west of the Quirke Lake Syncline (G. Bennett, unpublished data).

The upper, tholeiitic basalt flows of the Thessalon Formation (upper lava series of Tomlinson, 1996) are almost uniformly greenish-grey fine- to medium-grained tholeiitic metabasalt. The essential minerals are albite, actinolite, chlorite, clinozoisite, epidote and Fe-Ti oxides. Primary clinopyroxene is present in only a few samples of basalt from the Sault Ste Marie area. The andesitic rocks of the lower lava series of are generally darker coloured and commonly contain stilpnomelane and biotite with green pleochroism (Fe+3 rich?) in addition to albite and actinolite (Bennett et al. 1991). Tomlinson (1996) reported the presence of tremolite in some flows. Quartz is a minor component of basaltic and andesitic types.

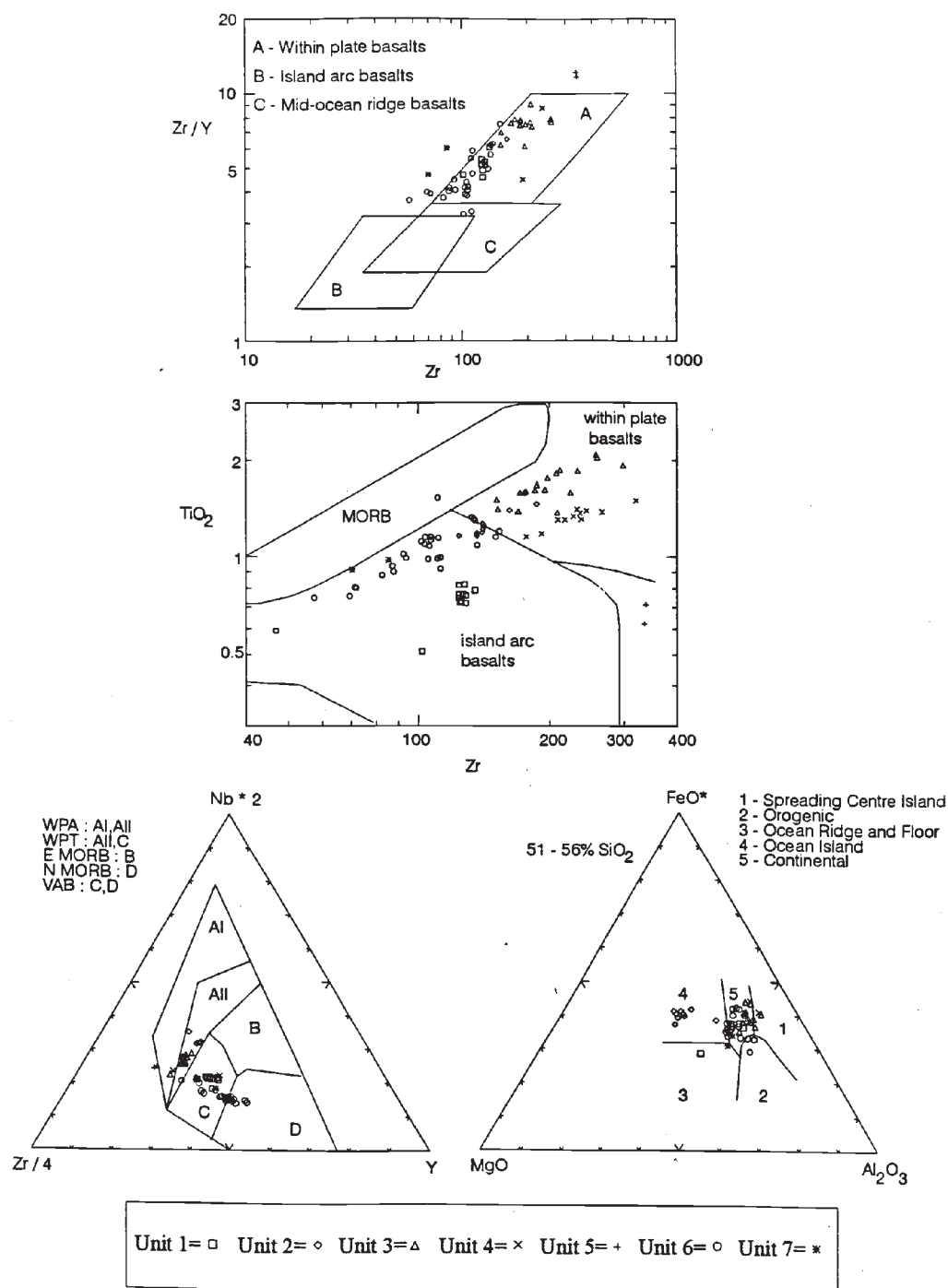
In most areas the metamorphic grade of the Thessalon Formation flows is lower greenschist facies although the presence of albite and primary pyroxene along with elevated soda indicates sub-greenschist grades at the northern end of the Duncan volcanic belt near Sault Ste Marie.

Amygdules of epidote, chlorite, calcite, quartz and stilpnomelane, in complex zonal arrangements, are common. Flattened chlorite-filled amygdules a centimeter or less across is a distinctive feature of most mafic flows of the Thessalon Formation. Pillow structures are rare but were observed in most areas. Scoriaceous flow-tops and crosscutting breccias are commonly filled with a fine-grained mixture of quartz and grey to red secondary albite.

Tomlinson (1996) states:

“The field and geochemical data indicate that the lavas are comparable to modern day continental basalt and andesites but that their source was similar to that of island arc basalt. Figure 1.11 shows the lavas plotted on a variety of discrimination diagrams where they are most comparable to modern within-plate basalt. Their arc-basalt geochemical characteristics result from their derivation from an upper mantle that had been metasomatically enriched during subduction in the Kenoran orogeny. Units within the sequence were generated from different pulses of magma, each of which stemmed from a different region of the relatively homogenous Huronian mantle. Only the unit 2 lavas require generation from part of the mantle with slightly different characteristics to a source similar to that required to generate island arc basalt ID16 (a primitive basalt used by Tomlinson (1996) in making calculations. gb). Different degrees of partial melting of this source that contains garnet in the residue (at less than 29.8% partial melting) are responsible for the REE characteristics of each unit. In the generation of the lower lava series, different batches of magma underwent crustal contamination to a greater or lesser extent within the lower or upper crust (or both) prior to eruption. The upper lavas series rocks are not contaminated. In all but the unit 2 lavas crystal fractionation occurred both early, as magma ascended to shallower depths, and later, in shallow level sills or magma chambers. Early fractional crystallization was responsible for the low Mg, Ni and Cr values in most units, while later stage crystal fractionation was responsible for the major element and compatible element trends within single units, as shown on bi-element plots”(Tomlinson, 1996).

On the geochemistry and tectonic setting of the Thessalon volcanic rocks Tomlinson (1996) states:



WPA = within plate alkali basalt, WPT=within plate tholeiite, E-MORB=enriched type mid-ocean ridge basalt, N-MORB=normal mid-ocean ridge basalt, VAB=volcanic arc basalt.

Discrimination diagrams for volcanic rocks of the Thessalon Formation  
(from Tomlinson, 1996).

Figure 1.11: Discrimination diagrams for the Thessalon Formation in the  
Sault Ste Marie area. From Tomlinson, 1996.

“Various lines of evidence from the Elliot Lake Group as a whole can be used to characterize the Huronian rifting event. Active rifting involves deep mantle upwelling or plume magmatism, which splits the continental crust, whereas passive rifting involves mantle diapirism and adiabatic upwelling induced by differential stresses and stretching in the lithosphere.....The geochemical evidence from the Thessalon Volcanic Formation indicates that the source of the lavas was metasomatised upper mantle rather than a deep mantle or plume component. Structural subsidence patterns in the Archean basement (Zolnai et al., 1984) are thought to be responsible for lithospheric stretching, in-turn causing mantle upwelling, episodic partial melting and volcanism. This is supported by the presence of syndepositional faults in up to

Archean basement. These features indicate that initially volcanism was a consequence of rifting. In active rifts just one uplift and melting event occurs as a plume impacts the lithosphere, but in passive rifts uplift and melting are episodic ..... Multiple erosional surfaces within the Elliot Lake Group indicate that numerous episodes of uplift occurred. Based on these lines of evidence the Huronian rifting event can best be characterized as a typical passive rifting event” (Tomlinson, 1996).

Jolly (1987) concluded the Thessalon Formation is a continental flood basalt sequence associated with continental rifting.

### ***Sedimentary Rocks Associated with the Thessalon Formation***

Some early reports refer to the presence quartz-pebble conglomerate within the Livingstone Creek Formation. The writer has examined most of the known occurrences of the Livingstone Creek Formation between Sault Ste Marie and the Quirke Lake Syncline and found no interbedded quartz-pebble conglomerate. However at many locations a thin unit (< 1 m) of radioactive, pyritic, quartz-pebble conglomerate overlain by a few meters of coarse, arkose was found to lie upon the Archean basement or directly upon the Livingstone Creek Formation where the latter is present. In the absence of



Figure 1.12: Sandstone of the Livingstone Creek Fm. Overlain by radioactive quartz-pebble conglomerate and grit of the Thessalon Fm. Thessalon Township.

400 meters of Huronian sedimentary rocks below the volcanics. G. Bennett (personal communication, 1996) has also described syndepositional features (at 2 locations near Elliot Lake and Sault Ste Marie) where sedimentary rocks of the Livingstone Creek Formation infill fractures in the underlying

the Livingstone Creek Formation the quartz-pebble conglomerate lies directly upon the basement rocks. In Duncan Township of the Sault Ste Marie and Thessalon areas this quartz-pebble conglomerate-arkose sequence is found within the lower flows of the Thessalon Formation. (Hay, 1963; Bennett et al., 1978; Meyer, 1983) (Figures 1.6, 1.7, 1.9, 1.12).

Bennett et al. (1991) proposed that the conglomerate-arkose units indicate the presence of a disconformity between the Huronian volcanics of the Thessalon Formation and the Livingstone Creek Formation. The wide distribution of these units (Figure 1.6) suggests that they reflect early Huronian erosional period of regional extent. The resistate nature of the mineral assemblage in the quartz-pebble conglomerate (assuming an oxygen deficient atmosphere) points to a period of extreme weathering. Some of this quartz-rich regolith may still be visible as a quartz breccia upon the granitic basement west of Highway 639 (Stop 1-11 of this guide).

### ***The Matinenda Formation***

The Matinenda Formation of the Elliot Lake Group is a sequence of arenites and intercalated quartz-pebble conglomerates which host the once important uranium deposits of the Elliot Lake area. The Matinenda Formation is up to 180 m (600 feet) in the Elliot Lake area

where it lies on Huronian volcanic rocks and Archean basement (Roscoe, 1969; Robertson, 1968, 1976). In the Thessalon and Sault Ste Marie areas the Matinenda Formation consists predominantly of fine- to medium-grained, subarkose to subwacke and is probably less than 50 m (150 ft) thick (Bennett et al., 1978). In Haughton Township the Matinenda Formation lies upon grey sandstones that the writer equates with the Livingstone Creek Formation (Figure 1.7).

In the Sudbury area clastic units correlated with the Matinenda Formation are as much as 600 m (2000 ft) thick but they thin rapidly eastward and is intercalated with the mainly metavolcanic rocks of the Stobie Formation and the

mudstones of the McKim Formation (Card, 1978).

The most abundant rock type of the Matinenda Formation in the Elliot Lake area is generally described as medium- to coarse-grained subarkoses, arkoses and grits consisting of poorly sorted quartz and feldspar grains set in a matrix of sericite and comminuted rock and mineral

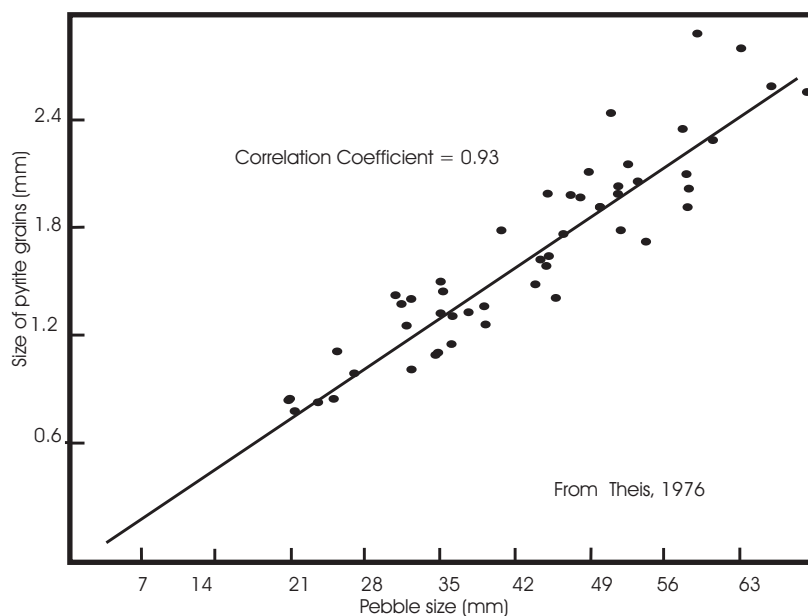


Figure 1.13: Quartz pebble size vs. pyrite grain size in the ore beds of the Matinenda Formation.

fragments. The ratio of K-spar to sodic feldspar is about 8:1. Minor constituents are pyrite, calcite, chlorite, zircon and rarely, leucoxene coated iron oxides and monazite. Variable amounts of sericite produce what has various been described as a green, apple green or greenish-yellow colour. Well-sorted quartz-pebble conglomerate beds, containing well-rounded pebbles and cobbles of quartz and chert, and pebbly subarkose units are scattered throughout the coarse subarkose units of the Matinenda Formation, but are more common near the base. (Robertson, 1968; Pienaar, 1963).

Trough cross-bedding, scour and fill structures are common in arkosic units (Robertson, 1968; Roscoe, 1969). Paleocurrent studies by

McDowell (1957) and Long (1977) have established a northwest source area for the sediment of the Matinenda Formation (Figure 1.5). Fralick and Miall (1989) suggest the Matinenda Formation was deposited from shallow braided streams flowing down a south dipping paleoslope which underwent tilting to the southeast during deposition. Kimberly et al. (1980) reported that the uraniferous conglomerates contained almost no magnetite-ilmenite and had very high potash/soda ratios. These are also features of Huronian paleosols, and suggest the sediment of the Matinenda Formation was formed by the intense weathering of a granitic source terrain as proposed by Roscoe (1969).

Two southeast trending ore zones were recognized since the early days of uranium mining in the Elliot Lake camp. The Nordic zone, east of the City of Elliot Lake is about 1 mile (1.6 km) wide and 3.6 miles (5.6 km) long. The Quirke Zone, in the Quirke Lake area, is about two miles (3.2 km) wide and six miles (9 km) long. Paleotopographic features of the basement are thought to have had a determining influence on the position and orientation of the zones. Ore grade (circa 0.1 % U<sub>3</sub>O<sub>8</sub>) conglomerate occurs as persistent lenses with individual units up to 15 feet (4.5 m) thick. The uraniferous quartz-pebble conglomerates are commonly well developed at the base of the Matinenda Formation but also occur within the arkose up to 150 feet (45 m) above the base (Roscoe, 1969, Robertson, 1968).

The quartz-pebble conglomerate consists mainly of well rounded pale-grey to dark-grey quartz and chert pebbles set in matrix of pyrite with some quartz/feldspar grit and sericite. Pyrite commonly forms from about 15% of minable units. Radioactive minerals include uraninite, brannerite, and uranothorite (Roscoe, 1968). Monazite and zircon are characteristic heavy minerals.

The sedimentological and mineralogical features of the uranium bearing zones of the Elliot Lake camp are now generally believed to support a

modified paleoplacer origin of the ores as outlined by Roscoe (1969). Advocates of this hypothesis propose that prior to the accumulation of significant free oxygen in the Earth's atmosphere, southeastward flowing streams carried quartz, pyrite and uraniferous minerals released by the extensive weathering of the Archean granitic terrain, and deposited them as southeast trending units determined by basement topography.

Evidence supporting the paleoplacer hypothesis was provided by Theis (1979) who demonstrated that a direct relationship exists between the size of quartz pebbles and pyrite grains (Figure 1.13), and the concentration of many other components of the ore zones.

### ***The McKim Formation***

The McKim Formation is the uppermost formation of the Elliot Lake Group. It is mainly a turbidite sequence of generally dark grey, subarkosic wackes, mudstones, subarkoses, lithwacke and litharenite that extends from the Blind River area to the Grenville Front. Graded beds, parallel laminations, ripple marks, ripple-drift cross-laminations and Bouma cycles, indicative of deposition by submarine turbidity currents are reported (Parvianen, 1973; Card et al., 1977).

Robertson (1968) gives a thickness of 0-380 feet (0-100 m) for the McKim Formation on the south limb of the Quirke Lake syncline. It is missing on the north limb. The McKim Formation is thickest in the Sudbury area, where it is up to 2400 meters (8000 feet) thick.

The Murray Fault appears to have exerted an important influence on the deposition of the McKim sediments. North of the Murray Fault the McKim rarely exceeds a few hundred meters in thickness, whereas south of the fault the thickness of the McKim Formations is at least 2400 meters. Card (1978) noted the change from laminated siltstone in the west to more wacke in the east indicated a change from more distal to proximal facies, in turn suggesting more tectonic activity and possibly a source for the

McKim sediments in the east. Fralick and Miall (1989) concluded that the McKim Formation of the Elliot Lake area represents a marine transgression that gradually drowned the Matinenda fluvial plain.

### ***Stratigraphic Relationships within the Elliot Lake Group of the Sault Ste Marie-Elliot Lake Area.***

The stratigraphic relationship between the Matinenda Formation, Thessalon Formation and Livingstone Creek Formation is revealed on a rock face near the northern boundary of Houghton Township about 30 km (18 miles) north of the town of Thessalon (Figures 1.6, 1.7). At this location pyritic quartz-pebble conglomerate of the Matinenda Formation (Chandler, 1976) directly overlies an apple-green paleosol on grey, fine-grained sandstone, which the writer correlated with the Livingstone Creek Formation (Bennett et al. 1990). About 600 meters (380 feet) northwest of the above occurrence arkose and quartz-pebble conglomerate of the Matinenda Formation disconformably overlies a steeply dipping, east-striking, mafic dike; the upper few meters of which is a sericite-leucoxene paleosol. The dike intrudes grey sandstone and apple-green paleosol of the Livingstone Creek Formation (Bennett et al. 1990, Bennett et al, 1991; Sutton and Maynard, 1993). Less than 2 km south of the above location Chandler (1976) identified a fault-bounded block of Thessalon Formation volcanic rocks with a minimum thickness of approximately 500 m. The mafic dike referred to above was a feeder for Thessalon flows, since the Thessalon Formation is the only known igneous activity at this stratigraphic position

The above observations show clearly and unequivocally that there was a period of volcanic activity, as well as a significant period of erosion, separating the Matinenda Formation and the Livingstone Creek Formation. Since paleosols are well known upon Huronian flows in the Elliot Lake area, the sub-Matinenda unconformity seen in Houghton Township

extended to the Quirke Lake Syncline as well. The outcrop pattern of the Huronian volcanic rocks on geological maps also suggests that the volcanic rocks are erosional remnants preserved in basement depressions.

The Thessalon Formation may once have extended beyond the limit suggested from its present outcrop distribution. Its present distribution may be but erosional remnants of a once extensive continental flood basalt sequence. This is to be expected on consideration of Macdougall's (1988) statement "Since many CFB provinces have been uplifted and occur as elevated plateaus, dissection and removal is rapid". He notes as well that the general scarcity of pre-Cretaceous Continental flood basalt provinces is probably due to their erosion.

## **Hough Lake Group**

### ***Introduction***

The Hough Lake Group (Robertson, et al., 1969; Roscoe, 1969) is lowest of the three Huronian groups that display the cyclic deposition of diamictite followed by a mudstone, siltstone, and turbidite or carbonate sequence; and overlain by a cross-bedded arenite unit. Each cycle is generally thought to represent a sequence of glaciogenic - marine - fluvial and/or shallow marine deposition (Figure 1.4).

### ***Ramsay Lake Formation***

The Ramsay Lake Formation is the lowermost formation of the Hough Lake Group and is the oldest of three such conglomerate units that define the base of Hough Lake, Quirke Lake and Cobalt Groups (Roscoe, 1969; Pienaar, 1963) (Figures 1.3, 1.4).

The Ramsay Lake Formation is a widespread, relatively thin unit, which is up to 41 m thick in the Bass Lake area (Chandler, 1973). In the Elliot Lake area the thickness of the Ramsay Lake Formation is from 0 to just over 30 m. (Diamond drill logs Assessment files, Sault Ste Marie District Geologist's Office). The Ramsay

Lake Formation is from 70 to 170 m thick in the Sudbury-Manitoulin area (Card 1978).

Matrix supported polymictic conglomerate (diamictite) is the most abundant rock type in the Ramsay Lake Formation, especially near the base. The lowermost few meters of the formation usually reflects the underlying rock type (Robertson, 1968; Parviainen, 1973). Minor amounts of mudstone, wacke and arenite are locally present.

Subrounded to well rounded pebbles and cobbles of grey granitic rocks and angular to rounded clasts of very dark green to black volcanic rocks generally form less than 30 percent of the total volume of the diamictite. The dark matrix consists of quartz, feldspars, chlorite, muscovite-sericite-illite and pyrite (Parviainen, 1973).

Although some writers have argued for a debris flow origin, most writers now accept the Ramsay Lake Formation as having a significant glaciogenic component (Roscoe, 1969; Robertson, 1976). Fralick and Maill (1989) identified an ice proximal association of pebbly sandstone and diamictite; subaqueous gravity flows and ice rainout deposits; and ice-proximal, fluvial outwash deposits.

### ***Pecors Formation***

The Ramsay Lake Formation is conformably overlain by a sequence of generally dark, bedded and laminated wackes, mudstone, siltstones and sandstones of the Pecors Formation (Roscoe, 1969). The Pecors Formation is 30 m thick at Quirke Lake (Robertson, 1968) but is as much as 900 m thick south of the Murray Fault in the Sudbury area (Card, 1978). It was not identified in the area between Thessalon and Sault Ste Marie (Frarey, 1977). Ripple marks, graded bedding, cross-laminations parallel laminations, ball and pillow structures, clastic dikes and slumpage features have been reported in the formation. The basal part of the formation is commonly laminated resembling varves and, in places, has dropstones (Robertson, 1968; Parviainen, 1973). Partial Bouma sequences are

common (Card, 1978; Robertson, 1976). The Pecors Formation is the result of transgressive units formed in deep water by turbidity currents (Card, 1978). The presence of drop stones is evidence of a cold paleoclimate, and provides supporting evidence for the glaciogenic origin of the underlying Ramsay Lake Formation.

### ***Mississagi Formation***

The Mississagi Formation is a thick sequence of predominantly grey, arenitic rocks extending throughout most of the length of the Huronian outcrop belt. Within the Quirke Lake syncline the Mississagi Formation is from 344 to 704 m thick. South of the Murray Fault the formation is notably thicker, being more than 3000 m in the Sudbury area (Card, 1978; Long, 1978). By far the dominant rock type in the Mississagi Formation is moderately well sorted, medium to coarse-grained subarkose and arkose. Small to medium quartz/chert pebble conglomerate is a minor component of the formation, but is more common in the western and northeastern parts of the Huronian belt. Fine-grained pyrite along forsets commonly results in rusty staining of outcrops. Greenish, sericitic units form relatively thin planar-bedded units between cross-bedded sandstones. Palonen (1973) provided evidence supporting a marine origin for the Mississagi Formation; however, Long (1978) argued that the abundance of mud-grade matrix in the immature arenites, and the predominance of unimodal paleocurrent directions, and the lack of quartz arenites argued against a marine environment for the Mississagi Formation. He concluded that the Mississagi Formation was deposited from braided streams with low to intermediate sinuosity and high width to depth ratios.

Bedding units are commonly about a meter thick but range from a few centimeters to over four meters. Trough cross-stratification and ripple cross-stratification are common sedimentary structures (Long, 1978). Individual cross-stratified beds may show grain size gradation (McDowell, 1957).

Long (1978) measured over 2500 cross-stratified units in the Mississagi Formation (Figure 1.5). Two major stream systems were recognized: a stream system flowing southeast to easterly from the Sault Ste Marie area joined a stream system flowing southwestward from the Cobalt Plain to form southward flowing system southwest of the Sudbury area. These observations suggest that the area now occupied by the Sudbury Igneous Complex was elevated during the period of Mississagi deposition (Long, 1978).

### **Aweres Formation**

In the Sault Ste Marie area, the 1700 m thick sequence of conglomerate and sandstone of the Aweres Formation (McConnell, 1927) unconformably overlies the mafic volcanics of the Thessalon Formation (Figures 2.1, 2.2). The internal stratigraphy and lithologies of the Aweres Formation is consistent with deposition in an alluvial fan environment. The base of the formation is almost entirely of mafic volcanic clasts while higher levels show a progressive increase in granitic components. The uppermost rocks of the Aweres Formation south of Aweres Lake are mainly arkose with thin pebble conglomerate beds. The lithological variation with stratigraphic height indicates the continual erosion of an uplifted fault-bounded plateau of Huronian volcanic rocks.

The distinct lithology of the Aweres Formation prevents its direct correlation with other Huronian rocks. The upper surface is partly fault bounded but is unconformably overlain by the Gowganda Formation on Highway 556 (Figure 2.3). It is possible that the Aweres Formation is an erosional remnant of a once extensive alluvial

fan system that extended in a more or less northeast direction beyond the present northern limit of the groups below the Cobalt Group. The Mississagi Formation may represent a more distal depositional environment than that of the Aweres Formation.

### **Quirke Lake Group**

#### **Bruce Formation**

The Bruce Formation extends from the Garden River Indian Reserve near Sault Ste Marie to about 70 km northeast of Sudbury. It consists mainly of matrix supported and minor clast



Figure 1.14: Diamictite of the Bruce Fm. Highway 108, Elliot Lake area.

supported conglomerate. Pebbly wacke, arkose, wacke and siltstone are locally present. Robertson (1968) reports the Bruce Formation is from 79 m (260 feet) to 12 m (40 feet) thick in the Elliot Lake area. It is 26 m (85 feet) to 37 m (120 feet) thick under the greater part of the Quirke Lake Syncline.

Pebble- to boulder-sized, angular to subrounded clasts generally consist of pale-grey granitic rocks, Archean supracrustal rocks and fine-grained mafic clasts. The upper parts of the formation may contain up to 5% carbonate (Robertson, 1968).

The Bruce Formation is generally interpreted as a tillite with minor beds and lenses of glacially derived sandstone. Dropstones have been observed in laminated units (Robertson, 1968). Casshyap (1969) concluded the formation was deposited from terrestrial wet-base glaciers. However Sims et al. (1981) proposed that the Bruce Formation is an accumulation of debris flows released as a result of normal faulting, a sudden increase in paleoslope and a sudden increase in water depth.

### ***Espanola Formation***

The Espanola Formation is the only widespread carbonate unit of the Huronian Supergroup. It is present from the Sault Ste Marie area to the Maple Mountain area about 70 km northeast of Sudbury. Its widespread distribution and distinctive lithology make it the most useful stratigraphic marker unit of the Huronian Supergroup. In the Elliot Lake area the Espanola Formation can be subdivided into three parts: a lower limestone member (the Bruce Limestone), a middle siltstone, wacke, arenite member (the Espanola Greywacke) and an upper dolomite member (The Espanola Limestone) (Robertson, 1968). The latter generally contains 3 - 4% total iron which gives a distinctly brownish colour to weathered surfaces. All 3 members are generally thinly bedded to laminated. The threefold subdivision is not so well developed south of the Murray Fault (Young, 1982). Contacts between members tend to be gradational.

Intraformational breccias, mud cracks, ripple-marks, flame structures and ball-and-pillow structures are common sedimentary features. Hofmann et al. (1980) described stromatolites in the Espanola Formation on Quirke Lake. These features suggest deposition in a quiet shallow water environment with carbonate deposition being interrupted by influx of fine-grained sediment. Young (1973) proposed that the relatively sharp change from the diamictites of the Bruce Formation suggests warm climatic conditions following a glacial advance. However, the recognition of carbonate deposition at high latitudes (Williams, 1975) and the association of detrital uranium with intense chemical weathering (Maynard et al, 1991) adds uncertainty to attempts to model Huronian paleoclimate.

### ***Serpent Formation***

The Serpent Formation is found throughout much of the Huronian belt; however, it is locally removed by erosion during a period of tectonic

activity preceding deposition of the Gowganda Formation of the Cobalt Group. Reported thickness estimates of the Serpent Formation range from 150 up to 1500 m (Bennett et al., 1991). Robertson (1968) states that nowhere in the Blind River-Elliot Lake area is there any evidence that the total thickness of the Serpent Formation has been preserved.

The Serpent Formation is mainly fine to medium-grained, quartz arenite and arkose. Conglomeratic units have been noted, especially near the base of the Formation. Carbonate is a significant component near the base of the formation in the Elliot Lake area (Robertson, 1968). Planar cross-bedding, festoon cross-bedding, rip-up clasts, fine-laminations and mud cracks have been reported. Long (1976) proposed that the Serpent Formation was deposited in a distal braided stream environment with calcareous units representing a sabkha environment. Young (1982) noted that the presence of very large cross-beds and a bi-modal size distribution suggest aeolian processes may have been active at least locally.

## **Cobalt Group**

### ***Gowganda Formation***

The Gowganda Formation is a complex sequence of conglomerates, sandstones, siltstones and mudstones, which comprise the lowermost formation of the Cobalt Group. Its thickness ranges from 1070 m in the Sault Ste Marie area; from 970 to 1150 m around Whitefish Falls, on the North Shore of Lake Huron; and from 950 to 2700 m near Sudbury. Near Dunlop Lake, in the Elliot Lake area, the Gowganda Formation is about 600 m thick.

Matrix-supported conglomerates are common, especially in the lower parts of the formation. However, these are commonly intercalated with clast-supported conglomerates, sandstone, wacke units. Laminated mudstones and siltstone are especially prominent in the upper parts of the Gowganda Formation. Many occurrences of ice-rafted drop-stones have been reported in laminated mudstone/siltstone units. Individual

units are generally relatively thin and discontinuous making subdivision of the Gowganda formation difficult except in well-exposed areas.

Most granitic clasts of Gowganda conglomerates have a distinctly pinkish or reddish hue, in comparison to the grey, granitic clasts in the matrix-supported conglomerates of the stratigraphically inferior Ramsay Lake and Bruce Formations. Also, pink and red hued sandstones first make their appearance in the Gowganda Formation. Roscoe (1969) pointed out the appearance of red coloration (i.e. ferric iron) just above the basal units of the Gowganda Formation, and argued that it represents the appearance of free oxygen in the Earth's atmosphere, and a change from the previously reducing atmospheric conditions that allowed the accumulation of readily oxidized minerals such as pyrite and uraninite in a fluvial environment.

The depositional environment of the diamictites in the Gowganda Formation have been the subject of discussion since Coleman (1905) proposed a glacial origin for the matrix supported conglomerates. Many later writers including Owenshine (1965); Casshyap (1969); Lindsay (1971); Young and Nesbitt (1985), and others have also supported a glacial, glacial-marine or glaciolacustrine origin for the Gowganda Formation.

Card (1968) concluded that, although glaciation may have supplied coarse detritus to the basin initially, debris flows and turbidity currents, released by vertical tectonic movement, may better explain the thickness variations, rock associations and distribution he observed in the Sudbury Manitoulin area. Roscoe (1969) also emphasized that glaciation is only one of the several processes responsible for the deposition of Gowganda sediments.

### ***Lorrain Formation***

The Lorrain Formation is generally well exposed throughout most of the Huronian belt, where it commonly forms a background to some of the most scenic views in northern Ontario. It is overwhelmingly an arenitic sequence, with local siltstone units present in lower parts of the section. The formation is up to 2500 m thick near Sault Ste Marie and in the LaCloche Syncline, southwest of Sudbury. It is up to 2300 m thick in the Cobalt Embayment.

In general, the lower part of the Lorrain Formation is dominated by pink, arkosic sandstones; the middle by hematite-rich subarkose and quartz-arenite; and the upper portion by pale grey to white mature, quartz-arenite. A distinctive jasper-pebble conglomerate found in the Sault Ste Marie area is a popular decorative stone, known locally as "pudding stone".

The presence of aluminous minerals is a characteristic feature of the upper, quartz-arenites of the Lorrain Formation. Diaspore and kaolinite are common in the quartz-arenite of the Sault Ste Marie area and north of Elliot Lake (Wood, 1973) while kyanite, andalusite and kaolinite are present as metamorphosed equivalents in the LaCloche Lake-Kilarney area (Card, 1978). Young (1973) and Wood (1973) interpret the presence of diaspore and kaolinite as the result of post-depositional in-situ alteration of feldspar under hot and humid climatic conditions.

The presence of abundant detrital hematite in the Lorrain Formation and the occurrence of thorium-rich, monazite-bearing, quartz-pebble conglomerate north of Elliot Lake has been interpreted by Frarey and Roscoe (1970) as indicating an oxidizing environment.

Planar and trough cross-bedding are common, as are ripple marks and other primary depositional structures. There is no consensus as to the depositional environment of the Lorrain

Formation. Most of the sedimentary structures of the Lorrain Formation can be found in either shallow marine or fluvial environments. Wood (1973), Young (1973) and Frarey (1977) favored a fluvial model while Pettijohn (1970) supported a marine environment for the Lorrain Formation. Card (1976) proposed that the Lorrain Formation represents near-shore coastal shelf deposition during episodic marine transgression and regression.

### ***Gordon Lake Formation***

The Gordon Lake Formation displays a gradational contact with the underlying Lorrain Formation. It is made up predominantly of variegated mudstone, siltstone, chert and minor fine-grained sandstone. Robertson (1986) subdivided the Gordon Lake Formation of the Flack Lake area into a lower member of reddish arenite, siltstone, and chert with anhydrite and gypsum nodules; a middle member of green siltstone and mudstone; and an upper reddish mudstone, siltstone and chert. Abundant sedimentary features include small-scale cross-bedding, ripple marks and desiccation cracks.

Some of the features of the Gordon Lake Formation are unique for the Huronian Supergroup. Wood (1973) noted on the abundance of feldspar in the formation, a marked contrast to rocks of the immediately underlying Lorrain Formation. He also described hematite oolites and the abundance of grains in the 0.02 to 0.05 mm range, a relatively uncommon grain size in sedimentary rocks. Since this size is found in loess deposits, Wood (1973) proposed that the quartz silt of the Gordon Lake Formation was formed by glacial action and carried by the wind and deposited in a tidal flat environment.

### ***Bar River Formation***

The Bar River Formation is the uppermost formation of the Huronian Supergroup. It is characterized by quartz-arenite with minor ferruginous arenite and siltstone. It is approximately 300 m thick in the Flack Lake

area, north of Elliot Lake. Wright and Rust (1985) concluded that the Bar River Formation was deposited in a tidal environment.

### ***Nipissing Intrusions***

Dikes, sills, and cone sheets of gabbro, diabase and granophyre, commonly referred to, as "Nipissing diabase" are the most widespread igneous rocks associated with the Huronian Supergroup. Baddelyite from Nipissing gabbro sills in the Gowganda area has been dated at 2219 Ma; the minimum age for the Huronian Supergroup (Corfu and Andrews, 1986). Buchan and Card (1985) report that paleomagnetic data suggests at least two periods of Nipissing intrusive activity.

Olivine-bearing hypersthene gabbro, gabbro, feldspathic pyroxenite, two-pyroxene quartz gabbro, hornblende gabbro, granophyric gabbro and granophyre have been identified in Nipissing intrusions. Many of the Nipissing sills are characterized by chilled margins 50 cm to 5 m wide, overlain by 10-20 m of quartz gabbro, then 100-500 m of hypersthene-poor gabbro-norite and vari-textured diabase (Lightfoot and Naldredt, 1996)

Nipissing intrusions are widely and evenly distributed throughout the Huronian belt but, with few exceptions, are not recognized within the Archean terrain. Individual intrusions may be up to several hundred meters thick and extend over an area of several hundred square kilometers. The form and orientation of Nipissing intrusions indicate that their emplacement may be controlled by older faults, folds and competency of the enclosing rocks (Card and Pattison, 1973).

Lightfoot and Naldredt (1996) discuss the geochemical characteristics of the Nipissing magmas and the potential for platinum group metal deposits. They conclude that the Nipissing magmas were emplaced into the Huronian sedimentary sequence over a period of less than 10 million years. Parental magmas of remarkably uniform composition underwent

in-situ contamination and differentiation within the intrusions Lightfoot and Naldredt (1996).

A spatial association between Nipissing intrusions and both magmatic and vein-type mineralization have long been recognized.

### **Huronian Paleosols and Evidence for the Accumulation of Oxygen in the Huronian Atmosphere**

It has long been recognized that the study of Huronian paleosols (ancient soil profiles) could provide information pertaining to the development the Earth's atmosphere and climate during the Proterozoic. Since iron is much less soluble in the ferric state than when in the ferrous state, the behavior of iron in paleosols should provide some indication of the oxygen partial pressure of the environment.

Many of the best descriptions of Precambrian paleosols have been from those associated Huronian unconformities (Gall, 1992).

Grandstaff et al. (1986) identified 8 features of paleosols; most of which have been described in Huronian paleosols. These features are:

1. Stratiform
2. Relatively thin (<20 m)
3. Transitional lower boundary-sharp upper boundary
4. Colour variations
5. Destruction of primary rock textures accompanied by the development of soil textures
6. Destruction of primary minerals with formation of clay minerals or metamorphic equivalents
7. Dikes of material from overlying sediment washed down into desiccation cracks in the soil
8. Rip-up clasts of overlying sediments

Well-preserved paleosols below the Matinenda Formation in the Elliot Lake area have been described by many workers (Roscoe, 1969; Pienaar, 1963; Robertson, 1968; Freay and

Roscoe, 1970; Gay and Grandstaff, 1980; Kimberly et al, 1984; G-Farrow and Mossman, 1988; Prasad and Roscoe, 1991, Sutton and Maynard, 1992, 1993).

Bennett et al. (1991) have proposed that there are three disconformities or unconformities within the Elliot Lake Group, which have, potential for paleosol development (Figure 1.7). These are in descending stratigraphic order the sub-Matinenda disconformity, the sub-Thessalon Formation disconformity, and sub-Livingstone Creek Formation unconformity.

The sub-Livingstone Creek Formation unconformity is the basal unconformity of the Huronian Supergroup and is the only entirely sub-Huronian unconformity (Figure 1.3, 1.7). This unconformity is exposed in the Thessalon area, where the upper few meters of the Archean granitic rocks can be seen to progress from angular, slightly rotated blocks, separated by grey grit and fine-grained sandstone, upward, to more rounded boulders with a higher proportion of finer clastic material (Collins, 1925). This zone may be termed a "paleo-regolith", since there is little or no obvious development of the yellow, sericitic paleosol commonly found in the younger, sub-Matinenda paleosols.

Prasad and Roscoe (1996) described two paleosols in the same drill core from the Denison Mine at Elliot Lake. A paleosol was found above Huronian volcanic rocks and another, less well-developed paleosol, was found upon Archean tonalite below a short section of quartz-pebble conglomerate and grit (Prasad, personal communication, 1997) below the 9 m thick volcanic unit (Figure 1.15).

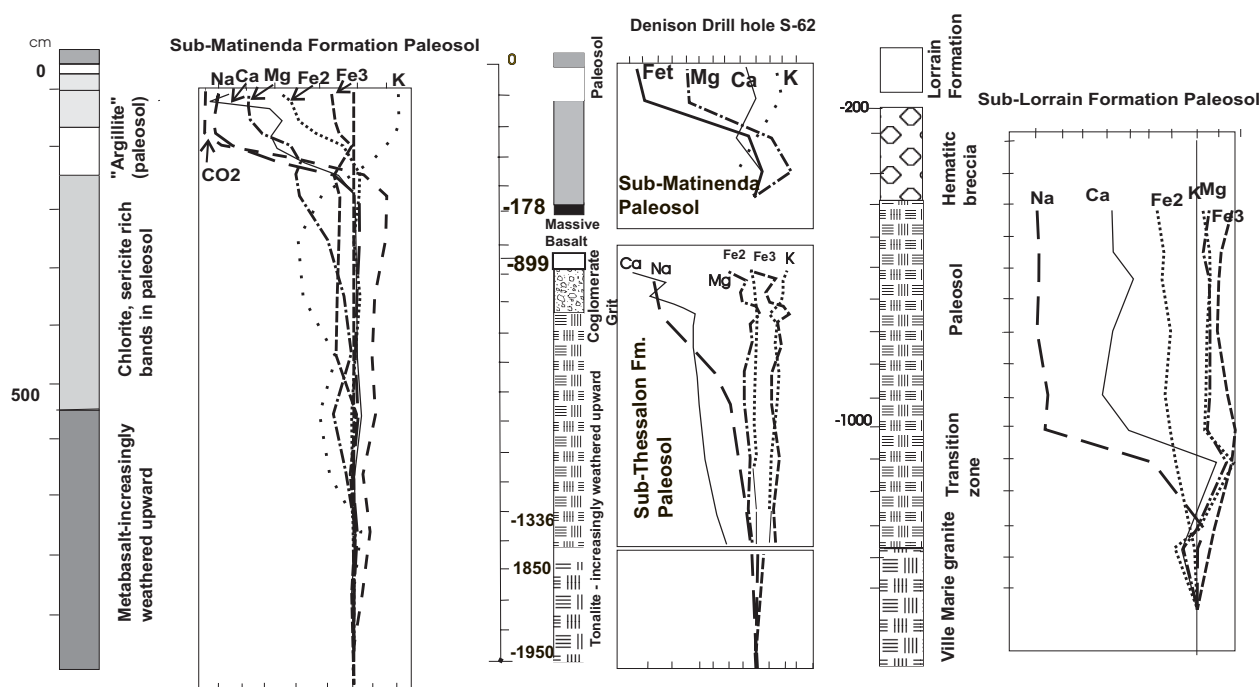
The best developed, and most studied, Huronian paleosols have been found directly below the Matinenda Formation. On mafic rocks, the sub-Matinenda paleosols can generally be recognized by the presence of an upper, distinctly apple-green to yellowish, sericitic zone which grades downward, over few centimeters to several meters, to an underlying,

black, fine-grained, chlorite-rich eluvial zone up to several meters thick. Abundant pseudomorphs of titanium oxides after ilmenite are a feature of paleosols on mafic igneous rocks. Rip-up clast of sericitic paleosol (the "argillite scraps" of mine geologists) are commonly found in the lower few meters of the overlying Matinenda Formation. Prasad and Roscoe (1996) report significant amounts of carbonate and pyrite in sub-Matinenda paleosols in the Elliot Lake area.

The uppermost sections of sub-Matinenda Formation paleosols on Archean granitic rocks

granitic rocks is generally lacking or relatively thin.

Sub-Matinenda paleosols commonly show the pronounced loss of soda found in most paleosols. Lime, and magnesia are also depleted, but there is generally a large increase in potash content (Gay and Grandstaff, 1980) (Figure 1.15). In most cases, iron and manganese are depleted in upper parts of the paleosol. This is held to provide good evidence of weathering in a reducing environment. However, Gay and Grandstaff (1980) noted an upward increase in total iron in paleosol from the Pronto Mine area.



After Prasad and Roscoe(1996), Rainbird et al. (1990).

Figure 1.15: A comparison of sub-Matinenda Fm. and sub-Lorrain Fm. Paleosols

and arkosic sedimentary rocks, is generally apple-green to yellowish rock composed mainly of quartz and sericite (Robertson, 1968; Gay and Grandstaff (1980); Sutton and Maynard (1992). Where the texture of the protolith is well preserved, but the original mineralogy is replaced, the paleosol may be termed a saprolith (Rainbird et al, 1990). The chlorite-rich eluvial zone of paleosols on

They concluded this upward increase in iron content indicated the presence of free oxygen in early Huronian atmosphere although at approximately 1% of the present level (Gay and Grandstaff, 1980). They suggested that the loss of iron shown in most Huronian paleosols could be due to local reducing environments. Some writers have concluded that the increase in potash (as sericite) in Huronian paleosols is largely due largely to diagenetic and

metamorphic processes which may mask the environmental and hydrologic conditions operative during paleosol development (Gay and Grandstaff (1980); G-Farrow and Mossman (1988).

The mineralogy and geochemistry of Sub-Lorrain Formation paleosols have been described by Rainbird et al. (1990) and Sutton and Maynard (1992). In contrast to the older, sub-Matinenda paleosols. Sub-Lorrain paleosols commonly show an enrichment of Fe+3 at the expense of Fe+2 without a significant loss of total iron. Hematite is a common mineral in the upper parts of sub-Lorrain paleosols, in contrast to the presence of pyrite in sub-Matinenda paleosols. In this respect the sub-Lorrain paleosols resemble many post-Huronian paleosols and are consistent with weathering in an oxidizing atmosphere (Prasad and Roscoe, 1996; Rainbird et al., 1990).

Since pyrite and uraninite are unstable under oxidizing conditions, the abundance of detrital pyrite and uraninite in the paleoplacer uranium ore zones in the Matinenda Formation provide good evidence for an oxygen deficient atmosphere during weathering, transport and deposition of early Huronian sediments.

In marked contrast to the common red beds of younger clastic sequences, sandstones (and most granitic clasts in conglomerates) below the Cobalt Group are almost all drab coloured in spite of the abundance of red and pink granitic rocks in the continental source area (Roscoe 1969, 1973). Frarey and Roscoe (1970) noted the above and proposed that the drab colour of lower Huronian clastic rocks is due to the lack of free oxygen in the atmosphere during the period of deposition of lower Huronian rocks.

Red hued, hematite bearing rocks, which Roscoe (1969) proposed mark the presence of an oxidizing atmosphere, make an appearance with the Gowganda Formation of the Cobalt Group, and are important in parts of the Lorrain and Gordon Lake Formations of that group. What may be the first true red-beds are found in the

purple siltstone member of the Lorrain Formation near Sault Ste Marie (Frarey, 1977).

Not all workers accept the above explanation for the preservation of uraninite and pyrite, and the observed change of colour with stratigraphy. Ohmoto (1996) has stated “ the loss of total iron in paleosols of all ages is not due to a reducing atmosphere but to the reductive dissolution of ferric hydroxides under an oxic atmosphere”.

### **Regional Tectonic Patterns and Metamorphism**

Major structures of the Huronian belt follow two main trends: 1) west-northwest trending folds and faults of the Sault Ste Marie-Elliot Lake area; and 2) east to northeast striking folds and faults of the Sudbury-Manitoulin area (Figure 1.16). These two structural orientations are associated with differing fold styles, metamorphic grade and metamorphic fabric. Changes are most notable across the east-west faults of the Murray fault system. This northeast striking fault zone (Figure 1.16) is the most significant structural feature of the Huronian belt. Since many formations show a significant increase in thickness south of the fault, it is generally interpreted as an inverted growth fault. (i.e. an early listric normal fault, active during sedimentation; which, during a later compressive regime, was converted to a thrust or reverse fault (Card, 1978; Jackson (2001).

The rocks of the Huronian Supergroup have been subjected to several deformational events. This is particularly evident south of the Murray Fault zone. In the Whitefish Falls area (south of the Murray Fault) Young and Nesbitt (1985) conclude that some large-scale folding is related to syn-depositional and/or post-depositional deformation of unconsolidated sediment. Early syndepositional deformation is also indicated by an important unconformity below the Gowganda Formation of the Cobalt Group; and the presence of ragged, slumped contacts and large slump blocks along major faults (Card, 1978; Young, 1983).

Convincing evidence of at least one important pre-Nipissing (2.2 Ga) deformational event, assigned to the Blezardian Orogeny (Stockwell, 1982), is provided by the observation that Nipissing bodies in the Sudbury-Whitefish Falls area transects axial surfaces of major folds (Card, 1978). Jackson (2001) did not observe such relationships in the areas north of the Murray Fault. However, Jackson (2001) points out, as earlier noted by Robertson (1964), that the tendency of Nipissing dikes to occupy structures parallel to the axial plane of the Chiblow Anticline, suggests pre-Nipissing folding. Jackson (2001) also noted evidence of pre-Nipissing faults north of the Murray Fault zone.

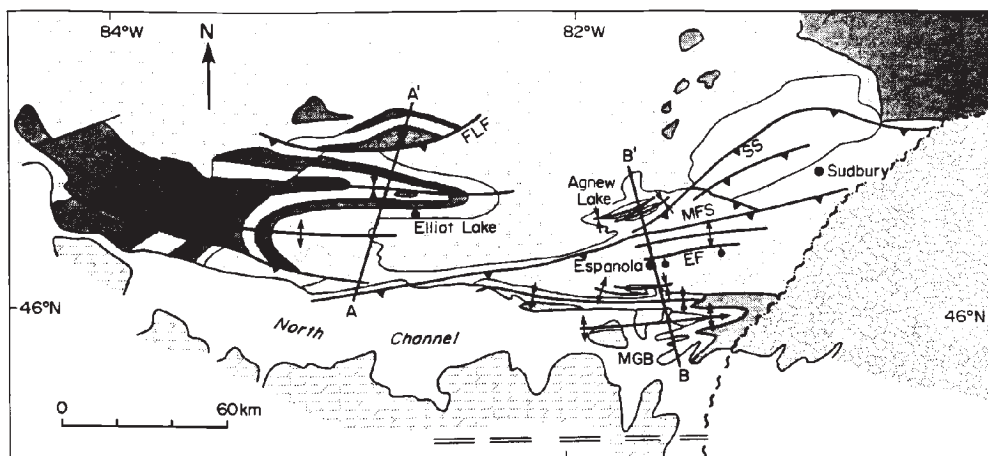
Following emplacement of the Nipissing intrusions but prior to the emplacement of the Sudbury Igneous Complex there was further deformation and regional metamorphism. Rb-Sr isotope studies of Huronian metasediments indicate that prograde metamorphism occurred at about 1.90-1.85 Ga (Fairbairn et al., 1969). This event is probably correlative with the Penokean Orogeny of Michigan-Minnesota (Sims et al., 1989).

After the emplacement of the SIC and the deposition of the Whitewater Group, there is evidence of further deformation and low-grade metamorphism, followed by intrusion of granite plutons at about 1.75 and 1.5 Ga. The post-SIC deformation and retrograde metamorphism was found mainly south of the Murray Fault, especially in the area between the SIC and the Grenville Front. Shanks and Schwerdtner (1991) report that this deformation is characterized by south-dipping thrust faults or deformation zones with northeast-trending foliation and southeast-plunging lineation. The last recognized deformational feature affecting Huronian rocks is the movement along faults, which post-date the diabase dikes of the 1.25 Ga Sudbury swarm (Jackson, 2001).

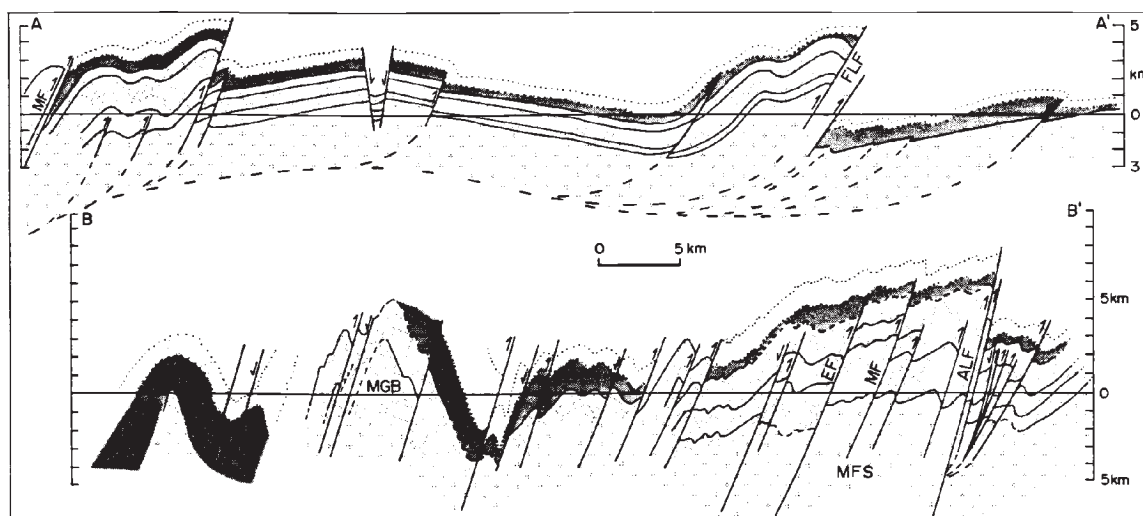
A study of magnetic fabrics, strain patterns, and microstructures in granitoid rocks of the Creighton and Murray plutons and their

Huronian host rocks by Riller (1996) have provided information on the pre-2.2 Ga "Blezardian Orogeny" (Stockwell, 1982). Riller concluded that major folding and amphibolite facies regional metamorphism in the Sudbury area was coeval with the emplacement of the Creighton Pluton and Murray Plutons, which were dated at 2.3 Ga by Frarey et al (1982) and Krogh et al. (1984) and more recently at  $2477 \pm 9$  Ma by Krogh et al. (1996). Large-scale dome-and-basin structures in Archean basement and Huronian cover rocks represent major south-vergent nappes. The Sudbury Structure, a deformed relic of an astrobleme, is superimposed on a major antiformal dome cored by Archean granulite and granitoid rocks and flanked by overturned Huronian strata on the south and several remnant rim synclines of Huronian rocks on the north (Riller, 1996; Bennett et al, 1997).

In the Sault Ste Marie-Elliot Lake area fault and fold structures trend in general west-northwest to northwest direction. Folds are generally upright, open concentric structures with gentle, variably plunging hinges (Figure 1.16). There is only a weak development of minor tectonic structures. The metamorphic grade is subgreenschist (Card, 1978b). The major structural features of the Elliot Lake area include a gently south-dipping homocline south of the Flack Lake Fault, the open fold of the Quirke Lake Syncline and the Chiblow Anticline between the Quirke Lake Syncline and the Murray Fault. Jackson (2001) found no evidence of detachment at or near the basement-cover interface in the Elliot Lake area. He also proposed that the "inverted growth-fault" model as applied by Zolnai et al. (1984) to structural-stratigraphic relationships in the Huronian may, in some cases at least, be interpreted as thrust faults with flats following depositional boundaries, and ramps that cut up through the stratigraphic section. Given the data available, neither model could be rejected for major northwest trending faults in the Sault Ste Marie area (Jackson, 2001). Jackson (1997) points out that the curvature of the Flack Lake



After Zolnai et al. (1984)



#### Legend

- |                                                            |                                                                               |                                               |
|------------------------------------------------------------|-------------------------------------------------------------------------------|-----------------------------------------------|
| Paleozoic rocks                                            | Thrust fault, teeth indicate hanging wall                                     | FLF Flock Lake Fault                          |
| Mesoproterozoic rocks (Grenville Province)                 | Normal fault, spot indicates downthrown side                                  | ALF Agnew Lake Fault                          |
| Cobalt Group rocks                                         | Fault (observed, assumed)                                                     | MF Murray Fault                               |
| Pre-Cobalt Group rocks                                     | Anticline, syncline                                                           | MFS Murray Fault System                       |
| Pre-Cobalt Group rocks derived from Archean basement rocks | Manitoulin Island Discontinuity                                               | SS Sudbury Structure                          |
| Archean basement rocks (Superior Province)                 | Grenville Front Tectonic Zone (traceable on surface, traceable in subsurface) | MGB McGregor Bay                              |
|                                                            | A A' Location of cross sections                                               | EF Unnamed fault 2 km north of Espanola Fault |
|                                                            | B B'                                                                          |                                               |

Figure 1.16: Main structural features of the Huronian Supergroup.

Fault is in the opposite direction to that expected if it is a thrust fault as proposed by Zolnai et al. (1984). In the Sault Ste Marie area the presence of trust faults, as suggested by out-of-sequence units, has been confirmed, in at least one location, by diamond drilling (Assessment files, Sault Ste Marie Resident Geologist's Office).

The Murray fault zone separates the moderately

developed. More than one age of major and minor structures can be discerned south of the Murray Fault (Jackson, 2001).

Metamorphism south of the Murray fault ranges from low greenschist to low amphibolite facies (Figure 1.17). Rocks of higher metamorphic grade occur in two zones or nodes, one along the Murray Fault zone and another northwest of the Grenville Front. Both zones coincide with major

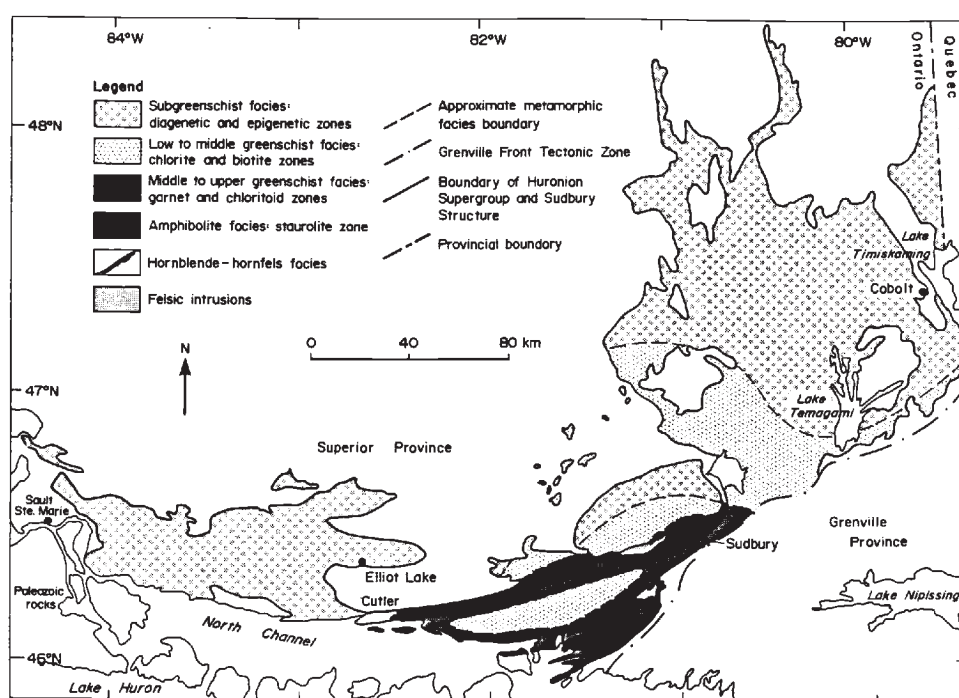


Figure 1.17: Metamorphism of the Huronian Supergroup

from Card (1978b)

deformed, low metamorphic grade rocks to the north from the multi-deformed, higher-grade rocks of the Sudbury-Manitoulin area to the south. In the Sudbury-Manitoulin area is characterized by open to sub-isoclinal, flattened buckle folds with upright to northward overturned axial surfaces. Elongate domes and basin are formed by reversals in plunge. Penetrative axial plane cleavage and steeply plunging rodding or mineral lineations are well

anticlinoria, although in detail, metamorphic isograds transect fold axes (Jackson, 2001). Higher-grade metamorphic nodes do not coincide with the few granitic intrusions that intrude the Huronian rocks south of the Murray fault. The 1.850-1.900 Ga age of metamorphism is much younger than the Creighton-Murray granite (2.45 Ga) and older than the

1.700-1.750 Ga of the Chief Lake and Cutler granites.

Jackson (2001) considers the origin of the high-grade staurolite-biotite assemblages of the McKim Formation in the hanging wall of the Murray Fault as one of the most enigmatic aspects of the tectonic history of the Southern Province. He concludes that geobarometry indicates a relatively low- pressure metamorphism (2-3 kbar) at high temperature. These conditions differ significantly from the 6-7 kbar pressures estimated for the Penokean metamorphism in Minnesota as determined by Holm and Silverstone (1990). He concluded that the high-temperature metamorphism was at or below pressure corresponding to the thickness of the Huronian rock column, thereby precluding crustal thickening as the origin of the metamorphism. Jackson (2001) concluded that a high heat flow regime as developed in areas of crustal extension and related mantle upwelling Jackson (2001). Such a model is compatible with Card's (1964) view that the high-grade metamorphism may be the result of rapid, focused heat flow.

### **Tectonic Models for the Development of the Huronian Basin**

There have been various tectonic models proposed for the early development and later deformation of the Huronian basin. Many reconstructions are essentially modifications of the model put forth by Deitz and Holden (1966) which stated that the Huronian Supergroup represents a rift and passive margin sequence that was compressed, partly tectonically buried and metamorphosed during a collision with the Superior craton and another mass which overrode its southern edge. Zolnai et al. (1984), Bennett et al. (1991) accept the essential aspects of the Dietz and Holden (1966) model. They propose that rifting and continental break-up was coeval with Huronian volcanism (2.45 Ga) and that the much later deformation was equivalent to the Penokean Orogeny (1.860-1.835 Ga). This model does not attempt

to account for the multiple deformation events affecting Huronian rocks and the origin of the Nipissing magmatic event.

Young (1982) proposed that the Huronian Supergroup was deposited in an aulocogen, an easterly trending fault bounded trough, which opened towards an ocean in the area now occupied by the Grenville Province. Sims et al. (1980, 1981) concluded that the Huronian Supergroup, the Marquette Range Supergroup and Animikie rocks were deposited as intra-continental, fault controlled basins developed along a major, late Archean structure, the Great Lakes Tectonic Zone.

More recently, Roscoe and Card (1992), noting the close stratigraphic correlation between the Early Proterozoic sequences of the Wyoming craton and the Huronian Supergroup, proposed that the Superior and Wyoming cratons are rifted portions of what was once a single continental land mass. They suggest the direction of the Matachewan-Hearst dike swarm (2.45 Ga) indicates an east-west tensional regime, which resulted in, a Huronian basin elongated in a north-south direction. On this larger craton the Huronian sediment was deposited in a southward deepening intracratonic basin. Roscoe and Card (1992) propose that it was during the Nipissing igneous event (2.2 Ga) that successful rifting of the Superior Province took place with the eventual drifting of part of the missing Superior Province to its present location as Wyoming craton. They attribute pre-Nipissing folding to the Blezardian Orogeny of Stockwell (1982) and the later more important deformation to be coeval with the Penokean Orogeny of Michigan, Wisconsin and Minnesota (Roscoe and Card, 1992).

Jackson (2001) supports the model of Roscoe and Card (1992) since the high heat flow, which he considers necessary to give the observed features of the high-grade metamorphic rocks, would be a necessary effect of mantle upwelling during continental break-up. He also interprets some of the early high-strain deformation as being consistent with a Nipissing age break-up of the Superior craton.



## ILSG Field Trip No. 1 - Day 1

### The Elliot Lake Transect

On the first day of this field trip we will examine many of the excellent rock exposures of one of the Earth's most well-known and most completely studied stratigraphic sequences. The rocks of the Elliot Lake transect display clearly visible evidence of the nature of the climate and atmosphere of the Earth more than 2 billion years – of course not all Earth scientists agree as to what this evidence tells us.

### Stop Descriptions and Road Log

From Sault Ste Marie, Ontario proceed east on Highway 17 for 162 km (101 mi) to the intersection of Highway 17 and Highway 108, then 29 km (18 mi) north on Highway 108 to Elliot Lake.

At Elliot Lake continue north past Hillside Drive South and the first few stoplights to Hillside Drive North. Turn left (west) onto Hillside Drive North.

Continue west on Hillside Drive North for about 1 km (0.6 mi) to Spruce Street. Turn right (North) on Spruce Street to Valley Crescent continue on Valley Crescent to Balsam Place and stop at the cul-de-sac. When collecting samples please exercise care to avoid damaging any vehicles parked nearby.

17 – 372751E, 5138695N (All coordinates in the Elliot Lake are within UTM zone 17; NAD 83 which is essentially equivalent to NAD WGS84).

#### **STOP 1.1: McKim Formation and Nipissing Diabase**

Outcrops are argillite/slate and grey sandstone of the McKim Formation on the east side of the

cul-de-sac. Note the deflection of the axial plane cleavage in the mudstone units. The movement of adjacent beds inferred from the deflection of the cleavage indicates the south limb of a syncline. A gabbroic dike is separated from the sedimentary rocks by a zone of sheared and fractured rocks. The McKim Formation is missing on the north limb of the syncline.

Return to Hillside Drive North and continue west for about 1 km to Spine Road. Turn right (west) onto Spine Road to Lawrence Avenue at the west end of Spine Road.

14.9 km = 9.3 mi. 17-370462E, 5137991N

#### **STOP 1.2: Radioactive quartz-pebble conglomerate of the Matinenda Formation.**

The low outcrops on north side of Spine Road are grey, buff and dark-grey arkose and radioactive, pyritic, quartz-pebble conglomerate of the Matinenda Formation. Pebble units are about 20-30 cm thick and dip about 10 degrees to the north. Pebbles in this outcrop are about 1-2 cm across and are generally much smaller than the typical pebbles in the ore zones of the Elliot Lake mines. Ruzicka and LeCheminant, (1984) report the radioactive conglomerate contains

“rare-earth-element-bearing uranothorite (?), large zircons, a Ti-U-Si-Fe phase (brannerite?), chalcopryrite and chromite. The distribution of radioactive minerals in the conglomerate displays layering thus indicating a detrital origin of these grains”

The dark-grey areas in the radioactive beds are due to the presence of minor amounts radioactive carbon generally known in the Elliot Lake area as “thucolite” but also referred

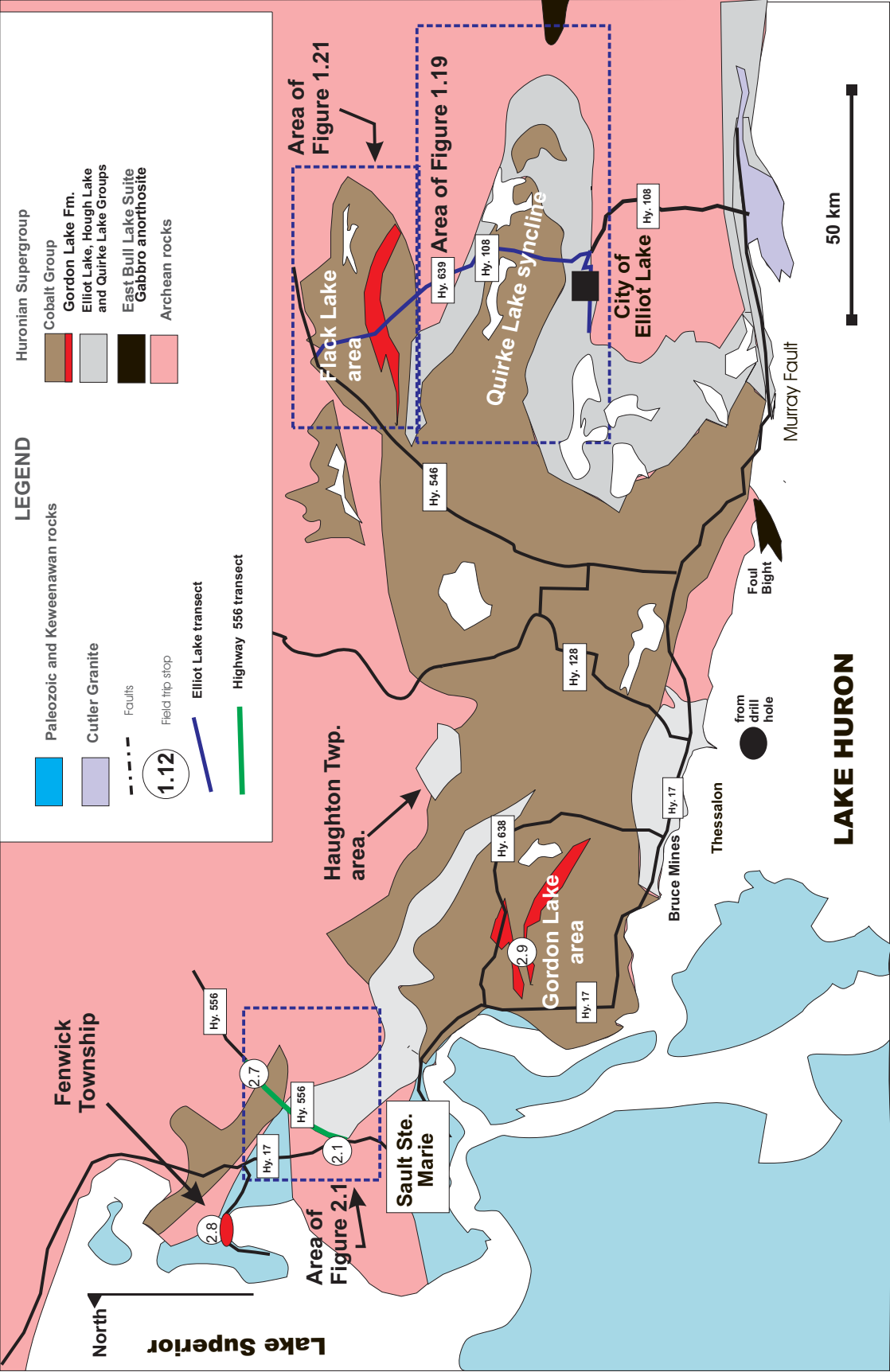


Figure 1.18: Index map for included geological maps and some areas mentioned in the text.



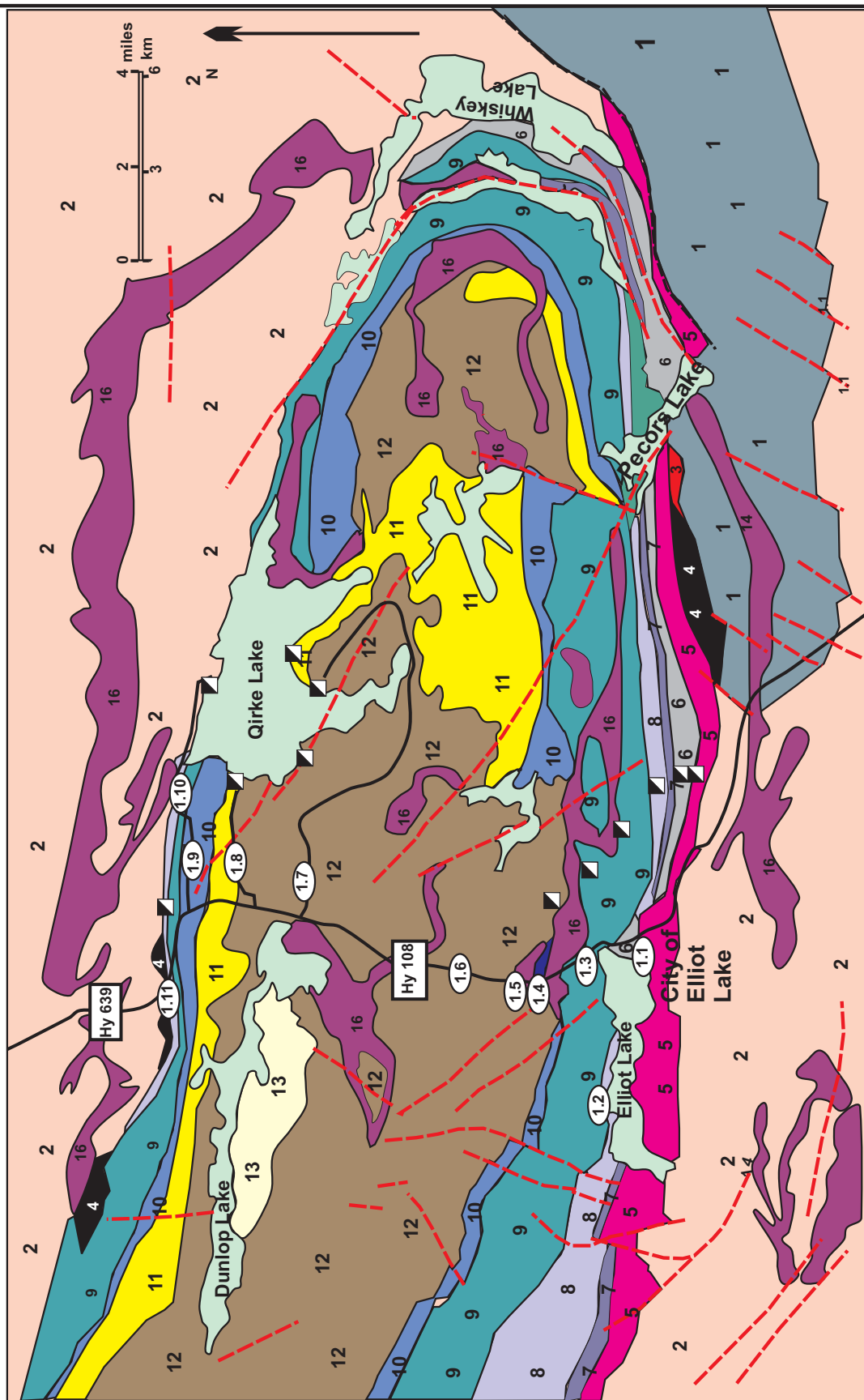


Figure 1.19: Geological map of the Quirke Lake Syncline.

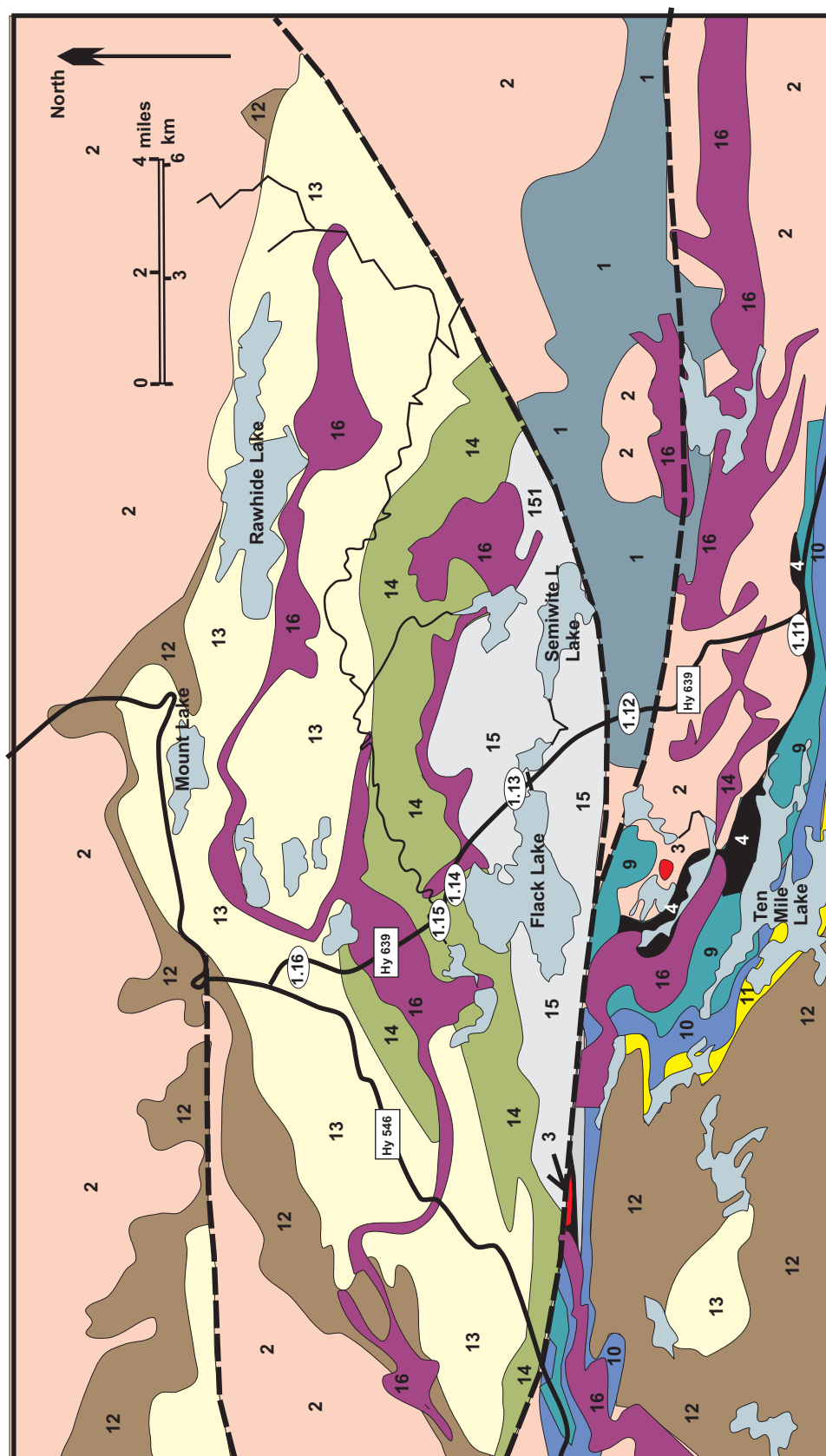


Figure 1.2.1: A geological map of the Flack Lake area.

to a hydrocarbon kerogen. Ruzicka and LeCheminant, (1983) note that several generations of carbon occur in the conglomerates of the Matinenda Formation. The earliest generation occurs as layers concordant with the bedding or a component of the matrix and appears to have been deposited in areas of quiescent sedimentation during the last phase of an upward fining sedimentary cycle.



Figure 1.22: Trough cross-bedding in the Mississagi Fm. Stop 1.3.

Later generations are probably remobilized phases of the first generation of carbon. The carbonaceous matter in the Elliot Lake ores is comparable in occurrence and composition to similar hydrocarbon in the Witwatersrand gold reefs; interestingly Ruzicka and LeCheminant (1984) report elevated gold content (1000 - 2000 ppb) in the carbonaceous matter of the Elliot Lake ore beds. The radioactive carbon at this site is reported to be auriferous, although the gold content is not available.

In 1955 Rio Algom Mines Limited completed a diamond drill hole about 30 m south of this location. The logs of this hole indicate that the radioactive beds exposed here are about 35 meters above the Archean basement rocks.

Diamond drilling has indicated that there are no ore-grade units in this area.

Grab samples collected by the author in 1982 returned up to 0.80 lbs U<sub>3</sub>O<sub>8</sub> /ton and 0.78 lbs ThO<sub>2</sub>/ton. A continuous chip sample returned 0.31 lbs U<sub>3</sub>O<sub>8</sub>/ton and 0.53 lbs ThO<sub>2</sub>/ton.

Return to Highway 108 and proceed north on Highway 108. Reset odometer at Stanleigh Road. About 1.5 km north of Hillside Drive North).

1.0 km = 0.63 mi. 17 - 371717E, 5140426N

### ***STOP 1.3: Mississagi Formation, Hough Lake Group.***

One-meter thick beds of grey subarkose of the Mississagi Formation on the west side of the highway display the rusty staining on the face of the outcrop reflecting the minor pyrite content along the foreset beds of trough cross-beds (Figure 1.22). The paleocurrent direction (from the west) can be best observed on the upper surface of the outcrop. – **Please exercise caution when walking on smooth, wet rock surfaces** - The grey colour of these sandstones and the presence of apparently detrital pyrite

is held by most geoscientists to indicate of the very low partial pressure of free oxygen of the atmosphere during the deposition of the Mississagi Formation.

1.4 km - 0.9 mi. 17-371652E, 5140948N

### ***STOP 1.4: Nipissing Diabase (Gabbro) altered Mississagi Formation, Bruce Formation.***

A sill-like body of Nipissing gabbro/diabase is exposed on the east side of Highway 108. Rhythmic, compositional layering is visible on the vertical face of the road-cut. Near the north end of the Nipissing outcrop face note the relatively planar, striated, surface is truncated by more irregular surface that has been interpreted

as the result of erosion by high-pressure, waterborne sediment, presumably as a result of melting of an adjacent Pleistocene ice sheet. North of gabbro sill, the upper portion of the Mississagi Formation is exposed along the east side of the highway. The distinctly pinkish hue of the sandstone is probably due to the formation of albite by hydrothermal fluids activated by the adjacent intrusion. Further evidence of hydrothermal activity is seen by dark-green to black chlorite deposited along fractures.

Continue northward on foot for a few tens of meters. Here (17-371668, 5141245) the Mississagi Formation is overlain by diamictite of the Bruce Formation at the base of the Quirke Lake Group. The dispersed megaclasts of the Bruce Formation are predominantly grey granitic rocks with smaller mafic clasts of predominantly Huronian volcanic rocks of the Thessalon Formation. The abundant matrix of the conglomerate is dark-grey to black. Sand-sized quartz grains have a glassy, black appearance, a reflection of the dark matrix behind the clear quartz. There is no evidence of significant disconformity at the base of the Bruce Formation.

Proceed by vehicle to near the top of the hill.

1.8 km = 1.4 mi. 17-371621E, 5142684N

### ***STOP 1.5: Espanola Formation and Nipissing diabase sills.***

The base of the Espanola Formation is a green, laminated unit about a meter or so thick. Laminated silty limestones and minor thin, chert beds of the Bruce Limestone member, Espanola Formation, overlie this unit. At this location the proximity of Nipissing gabbro intrusions has led to the development of calc-silicate minerals including: grossularite garnet, idocrase (vesuvianite), diopside, and wollastonite typical of a skarn (Robertson, 1968). Wollastonite (identified by X-ray diffraction) is found just

below the north-dipping diabase sill near the north end of the exposure, where it occurs as sub-parallel groups of pale-grey to white prismatic crystals about one mm wide and up to a centimeter long. X-ray diffraction analysis has determined that the pink coating on joint surface is apophyllite ( $\text{KFCa}_4[\text{Si}_8\text{O}_{20}]\cdot 8\text{H}_2\text{O}$ ) an uncommon mineral, sometimes found in amygdules in basalts, but is also associated with calc-silicates (Figure 1.23). Young (1991) states

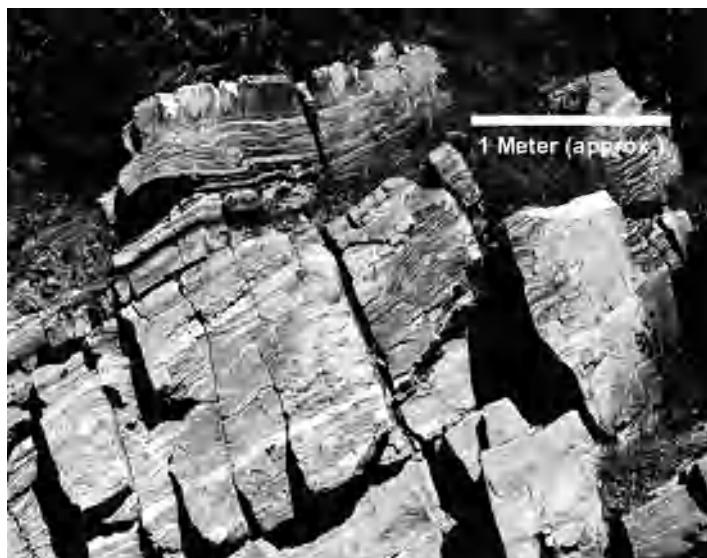


Figure 1.23: Espanola Formation with calc-silicate minerals. Stop 1.5

that the small scale thrust faults and folds in the limestone on the west side of the highway is probably the result of slumping during early tectonic activity.

The upper, ferruginous dolostone-bearing member of the Espanola Formation and the overlying Serpent Formation are not present at this location but are well represented on the north limb of the syncline. Since the Serpent Formation is missing we can infer that the ferruginous dolostone was removed during a period of pre-Gowganda erosion.

Continuing north the basal units of the Gowganda Formation are visible in road-cuts along the highway.

2.0-2.5 km = 1.3-1.6 mile. Gowganda Formation diamictite.

Megaclasts of pink granite, grey granite and granitic gneiss and mafic rocks are widely distributed in a dark green matrix. Most geologists now consider at least some of the diamictites in the Gowganda Formation to be tillites, although a debris-flow origin, either glaciogenic or as submarine debris flows is a more reasonable interpretation at specific localities. Roscoe, (1969) places the appearance of free oxygen in the atmosphere (“oxyatmoverison”) as coinciding with the appearance of the reddish hue of hematite just above the base of the Gowganda Formation a short distance north of STOP 1-5.

3.8 km. = 2.4 mi. 17- 371841E,  
5143180N

### **STOP 1.6: Stratified Gowganda Formation.**

Park just south of the rock-cut on east side of the highway.

This is an impressive exposure though a stratified sequence of diamictites, clast-supported conglomerates and sandstones of the Gowganda Formation. The base of the sequence at the extreme southern end of the exposure on the west side of Highway 108 consists of massive diamictite overlain by a thin unit of laminated mudstone-siltstone with a few small dropstones. About a meter of stratified Gowganda overlies the siltstone. Distinct beds of diamictite, sandstone, pebbly sandstone and clast supported polymictic conglomerate are present. Some conglomerate units display normal and reverse grading suggestive of debris flows. The rocks displayed here may be interpreted to represent a depositional environment proximal to retreating glacial margin.

Note the predominance of red and pink granitic clasts, in marked contrast to the pale grey clasts of the Bruce and Livingstone Creek Formations seen earlier. There is also a significant proportion of black pebble to cobble-sized clasts

(Figure 1.24). The mineral assemblage and metamorphic grade of the few of the mafic clasts examined by the writer many years ago indicated that the clasts were probably from Huronian basaltic flows.

4.7 km. = 2.9 mi. Pink sandstones and diamictite of the Gowganda Formation.

6.7 km = 4.2 mi. Diamictite with large boulder, Gowganda Formation.

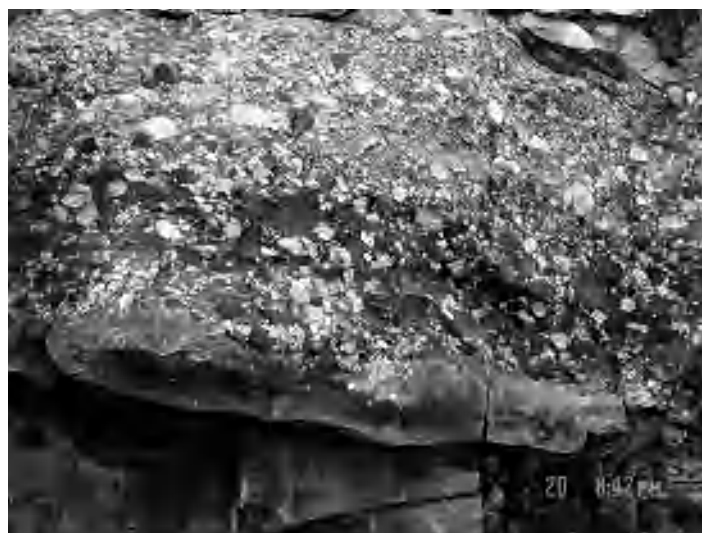


Figure 1.24: Crudely stratified conglomerate of the Gowganda Fm. with mafic volcanic clasts. Stop 6.

8.2 km. = 5.0 mi. Stanrock Mine Road. Reset odometer. Turn east onto Stanrock Road -  
**Optional Stop**

2.2 km = 1.4 mi. 17-374911E, 5147007N

### **Stop 1.7: Laminated varvite?**

Laminated siltstone/mudstone of the Gowganda Formation on the north side of the road. This unit has been interpreted as varves found as deposits from Pleistocene glacial lakes. Return to Highway 108.

Set odometer to 0 at Stanleigh Road and Highway 108.

3 km = 1.9 mi. Denison Mine Road - Turn east. Reset odometer to 000 km.

1.5 km. = mi. 17 -375102E, 5150499N

### ***Stop 1.8: Gowganda Formation Serpent disconformity***

The Serpent Formation is not present in the south limb of the Quirke Lake Syncline and the Blind River Sault Ste Marie area where it was probably removed during a period of pre-Gowganda erosion. At this location, on the south side of the road, well-sorted sandstone of the Serpent Formation is overlain by polymictic conglomerate of the Gowganda Formation. The contact is sharp but irregular. Evidence of a sub-Gowganda disconformity at this location is given by the presence of pebble and cobbles of the Serpent Formation near the base of the Gowganda Formation.

Return to Highway 108. Reset odometer at Highway 108 and Denison Mine Road.

0.5 km = 0.3 mi. Disseminated carbonate in sandstone of the Serpent Formation on east side of Highway 108.

1.1 km = 0.68 mi. Road to Quirke Lake and former Panel Mine. Reset odometer to 0. Turn east onto Panel Mine road.

1.5 km = 0.9 mi. 17-375258E, 51511331N

### ***Stop 1.9: Espanola Limestone Member of the Espanola Formation.***

Rock-cut in ferruginous dolomite and siltstone of the Espanola Limestone Member of the Espanola Formation. The Espanola Limestone Member is the uppermost of the three members of the Espanola Formation recognized in the Elliot Lake area (Robertson, 1968). It is characterized by intercalated siltstone and reddish-brown weathering, ferruginous dolostone beds containing 3-4% FeO. Intraformational breccia, ripple marks, small-scale cross-bedding, and various soft sediment features are present but faintly visible on the south outcrop. Near the east end of the outcrop a grey clastic dike crosses the stratification at a high angle.

4.1 km = 2.5 mi. 17 – 377379E, 5152019N

### ***Stop 1.10: Ramsay Lake Formation overlain by Pecors Formation.***

Diamictites of the Ramsay Lake Formation contain cobbles of grey granitic rocks, mafic clasts of Huronian volcanic rocks and Archean felsic volcanic clasts in an abundant dark-grey to black sandy matrix. The Ramsay Lake Formation is overlain by dark laminated siltstone and mudstone (argillite) of the Pecors Formation. The latter contains a few dropstones (Figure 1.25). Note: the Matinenda Formation of the Elliot Lake Group, expected between the basement and the Ramsay Lake Formation, is truncated by the Ramsay Lake Formation in this area. The Matinenda Formation does occur in the mine workings down-dip from this location.

Continue east to the end of the Panel Mine road. This is the rehabilitated area of the former Panel Mine. There is little evidence of the uranium mine and mill complex that was on this site until 1993.

Return to Highway 108. Reset Odometer. Continue north on Highway 108. Tailings dam of the Quirke Mine is visible west of the Highway.

Highway 108 ends and Highway 639 begins.

1.0 km = 0.6 mi. Diamictite of the Bruce Formation is exposed west of the Highway.

1.5 km = 0.9 mi. Outcrops of Mississagi Formation are exposed along Highway 639. Note the yellowish colour characteristic of the Mississagi Formation where it lies directly on the Archean granitic basement (Robertson, 1968).

2.5 km = 1.6 mi. 17 – 371508E, 5152302N

### ***STOP 1.11: Huronian volcanic rocks of the Thessalon Formation (Dollyberry belt).***

A gated road leads west from Highway 639 leads to one of the Quirke Mine tailings dams. Park near the gate and walk a short distance along a rough road from the gate to the base of the tailings dam.

Note the very dark-green to black, flattened, chlorite amygdules characteristic of the Huronian mafic volcanic rocks between Sault Ste. Marie and the Elliot Lake area. Cross the stream and proceeding northward a short distance along a rough road to the crest to the low hill. The Huronian volcanics at this location (17 – 371428E, 5152342N) include transitional



Figure 1.25: Dropstone in laminated argillite of the Pecors Formation. Stop 10.

alkalic types, hawaiite and mugearite (unpublished analyses in the authors files). The eastward trending, south dipping unconformity between the Archean granitic basement rocks and Huronian volcanic is visible near the crest of the hill. There appears to be no visible paleosol development at this location. Near the west end of the outcrop, a thin, quartz-pebble conglomerate/breccia unit, comprised mainly of angular, quartz-clasts, overlies the granitic rocks at the base of the volcanic unit. Scattered, isolated, mainly cobble-sized clasts of quartz can also be found along the unconformity.

Some visitors to this site have proposed that the contact between the Archean and Huronian volcanics is not an unconformity, but a fault contact. However, during a visit to the Stanleigh Mine in 1990, the writer along with Rob Henderson, Mine Geologist and Dr. Larry Jensen of the Ontario Geological Survey

observed identical scattered, quartz pebbles were found along the contact of the Huronian volcanic rocks where they overlie Archean mafic volcanic rocks in the haulage drift of the Stanleigh Mine on the south limb of the Quirke Lake Syncline. The writer proposes that these quartz cobbles are lag deposits left behind while the finer sediment was washed off the surface.

A few kilometers west of this location, occurrences of this conglomerate unit contain more rounded quartz, and are commonly overlain by a thin arkosic unit. Quartz-pebble conglomerate, which locally contain significant pyrite as well as uranium, occur sporadically at the base of the Huronian volcanic sequence of the Quirke Lake Syncline and westward to the Sault Ste. Marie area. The conglomerate at this location occupies the same stratigraphic position as the radioactive, quartz-pebble conglomerate.

Return to vehicle, set odometer to 0 and continue north on Highway 639.

0.2 km = 0.1 mi. Archean outcrops cut by diabase outcrops along the highway.

6.8 km = 4.3 mi. 17 – 368530E, 515773N

### ***STOP 1.12. Archean metavolcanics with pillow structures.***

Archean mafic metavolcanics displaying well-developed pillow structures are exposed, on north sloping outcrop, the east side of highway (Figure 1.25). Pillows are deformed, but facing directions can easily be determined. Small amygdules are concentrated near the upper surface of many pillows.

7.7 km = 4.9 mi. Flack Lake fault occupies a valley near this point.

8.2 km = 5.2 mi. Outcrops of hematite-stained sandstone of the Bar River Formation.

8.8 km = 5.6 mi. Entrance to Mississagi Provincial Park.

9.1 km = 5.7 mi. Pale grey sandstone of the Bar River Formation with herringbone cross-bedding.

9.8 km = 6.2 mi. Christman Lake.

17 – 366863E, 5160228N

10.2 km - 6.5 mi.

17 –366742E, 5160652N

**STOP 1.13: Bar River Formation.**

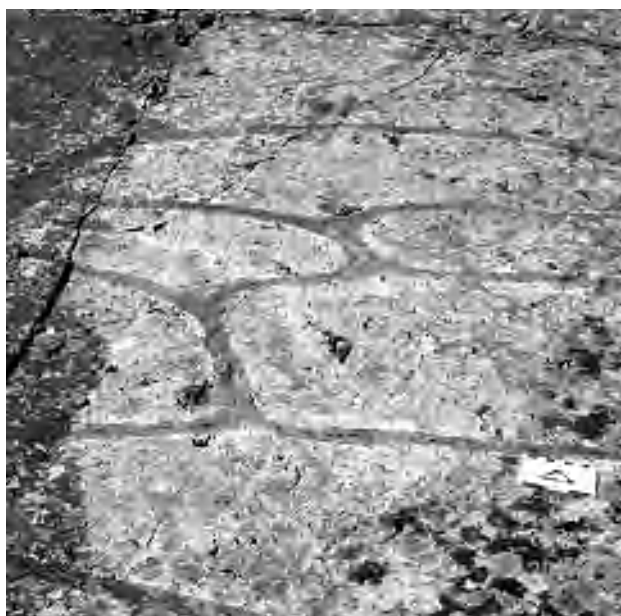


Figure 1.26: Pillow structures in mafic metavolcanics. Stop 1.12.

Sandstones of the Bar River Formation display ripple marks, mud cracks and sinuous structures, which have been described as possible worm casts. Comparison with desiccation structures in the Gordon Lake Formation led Young (1969)

to suggest that these features are the result of the transportation of consolidated desiccation fracture fillings.

13.6 km = 8.6 mi. 17 – 364395E, 5162758N

**STOP 1.14: Red beds of the Gordon Lake Formation**

Laminated, maroon buff siltstone and chert with reduction spots in the upper part of the Gordon Lake Formation. This is another red-bed occurrence within the Cobalt Group.

14.9 km = 9.4 mi. 17 – 363062E, 5163194N

**STOP 1.15: Gordon Lake Formation.**

Siltstones and sandstones of the Gordon Lake Formation display ripple marks, desiccation cracks, cross bedding and a late cleavage . Note: the presence of pyrite in contrast to hematitic nature of the Gordon Lake Formation near the top of the formation.

19.3 km = 12.20 mi. 17 – 361771E, 5166967N

**STOP 1.16: Lorrain Formation**

White to pale pink quartz arenite of the upper portion of the Lorrain Formation is exposed on the east side of the highway.

21.0 km = 13.3 mi. At Little White River Road (Highway 546) – End of Field Trip

Return to Sault Ste Marie.

22.8 km 17.8 mi. Junction with Little White River road (Highway 546.)

**End of Day one field trip.**

## ILSG Field Trip No. 1

### Day 2 - Part 1

#### Huronian Stratigraphy along Highway 556 and correlation with the Chocoday Group of the Marquette area.

On Day 2 we will examine some of the Huronian rocks of the area north of Sault Ste Marie where we will see important differences in the stratigraphy and structural relationships when compared to the sequence in the Quirke Lake Syncline of Day 1. The transect along Highway 556 will show that all three formations of the Quirke Lake Group are missing and correlation with formations of the Hough Lake Group is problematical. Also, there is a significant unconformity at the base of the Gowganda Formation.

We will spend part of Day 2 examining a dolostone unit in Fenwick Township near the north shore of Goulais Bay, and a dolostone-bearing unit in the Gordon Lake Formation, southeast of Sault Ste Marie. Those familiar with the Kona Formation of the Chocoday Group in the Marquette Range Supergroup will notice the correspondence in lithology and stratigraphy.

#### Road Log and Stop Descriptions (Refer to Figures 2.1 and 2.2)

IMPORTANT: When observing roadside rock-cuts, be especially careful to park your vehicle well away from the pavement and exercise the necessary caution when crossing the road. Where stops are located on or near blind turns, park in a safe place and walk to the rock exposure.

GPS datum is NAD 83 = WGS 84. UTM Zone 17.

000 km - Second Line and Highway 17 N. Continuing north on Highway 17.

13.3 km. = 8.2 mi. Intersection of Highway 17 and Highway 566. Reset odometer to 0. Proceed east on Highway 556.

5.6 km. = 3.5 mi. Fractured altered Archean rocks. The Archean granitic rocks north of the

Island Lake fault in this area are locally chloritized and albitized micro-breccia. The lack of such alteration in the Huronian rocks south of the fault suggests that the alteration pre-dates Huronian sedimentation (Delio Tortosa personal communication, 2005).

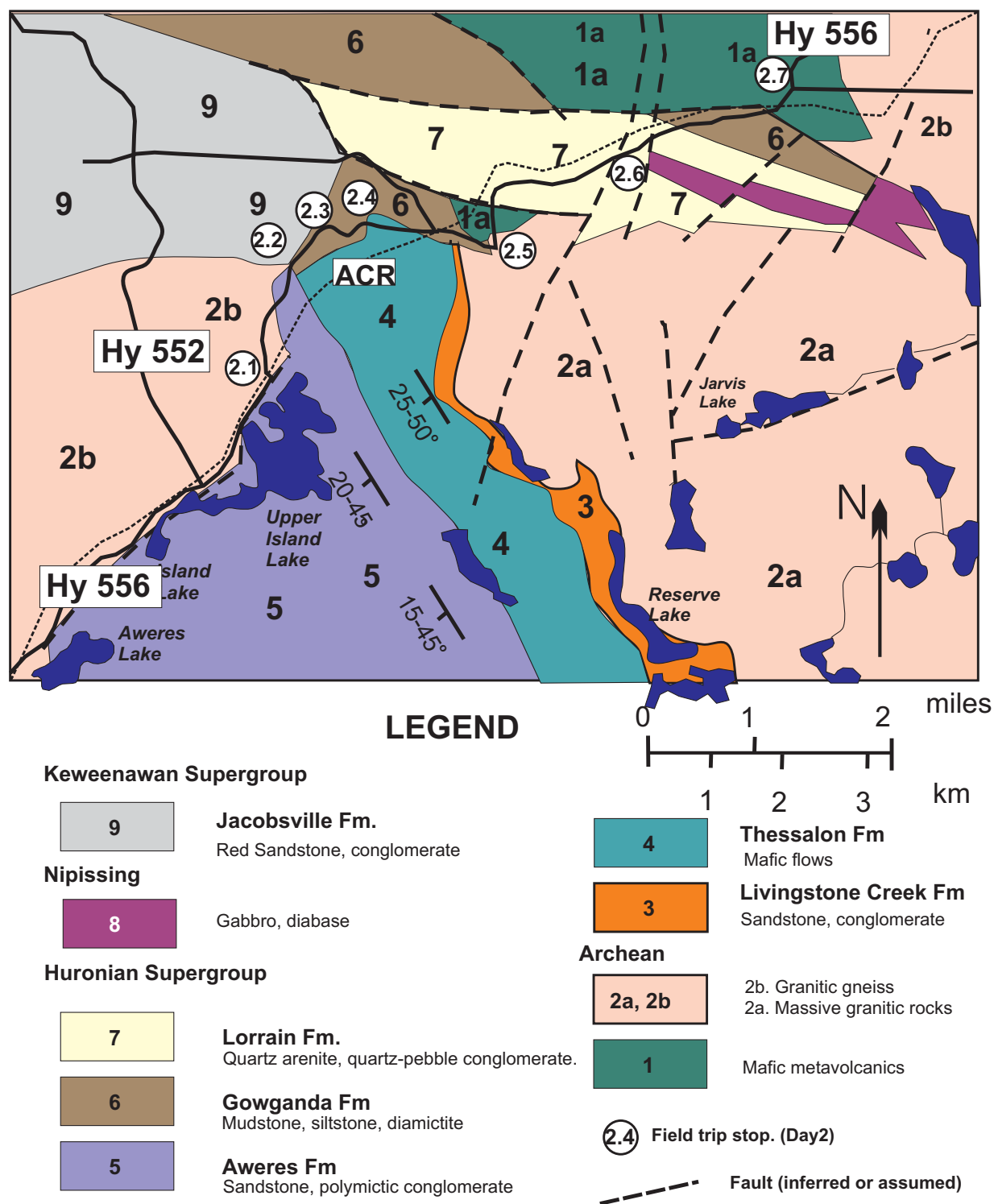
#### STOP 2.1: Island Lake Fault Zone

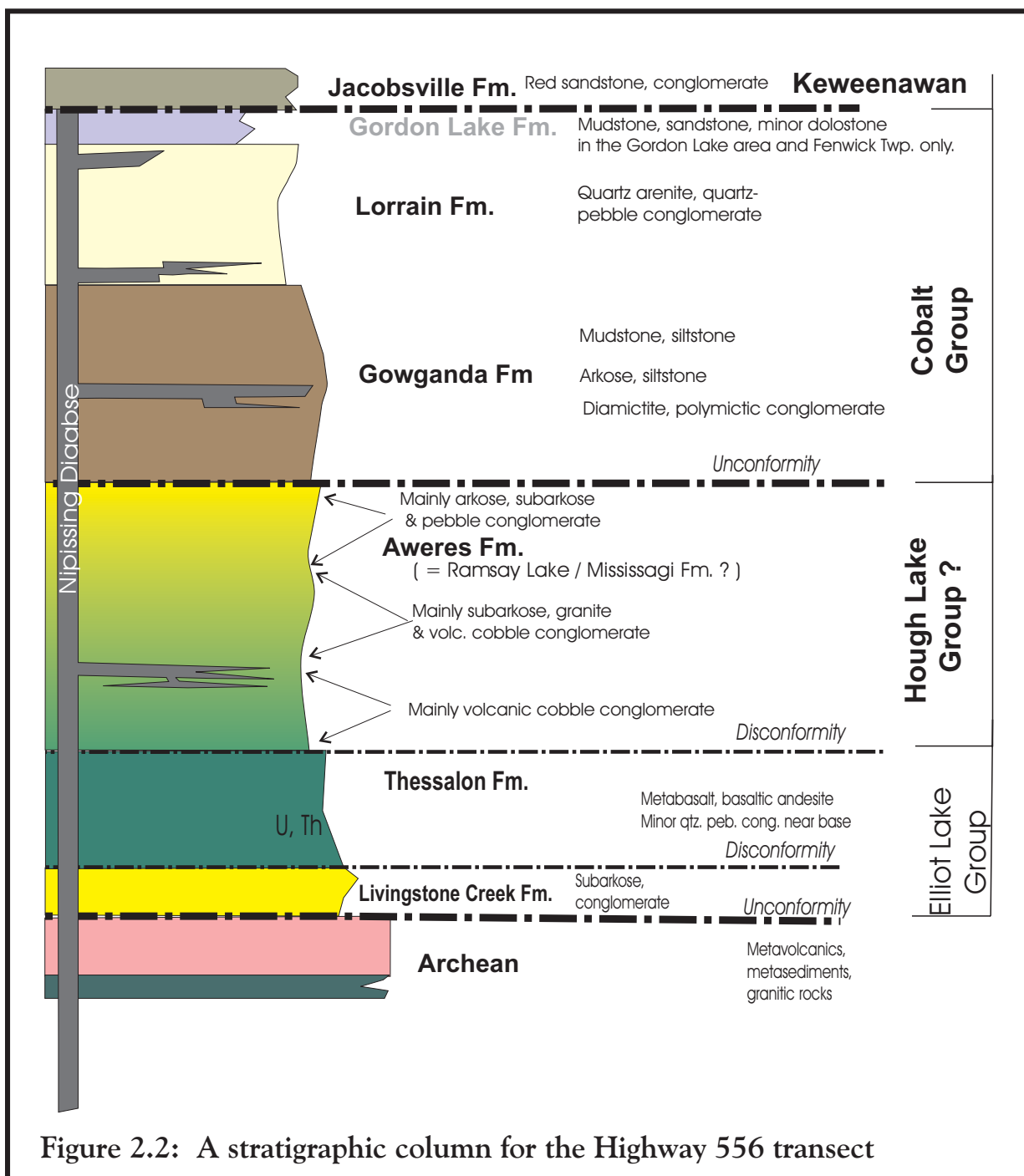
Rocks of the Island Lake Fault Zone separating the Archean rocks on the north from Huronian rocks on the south are exposed along Highway 638 near Lower Island Lake. Rocks within the fault zone are highly sheared and brecciated. Pink rock in the shear zone is a Keweenaw felsic intrusion (felsite).

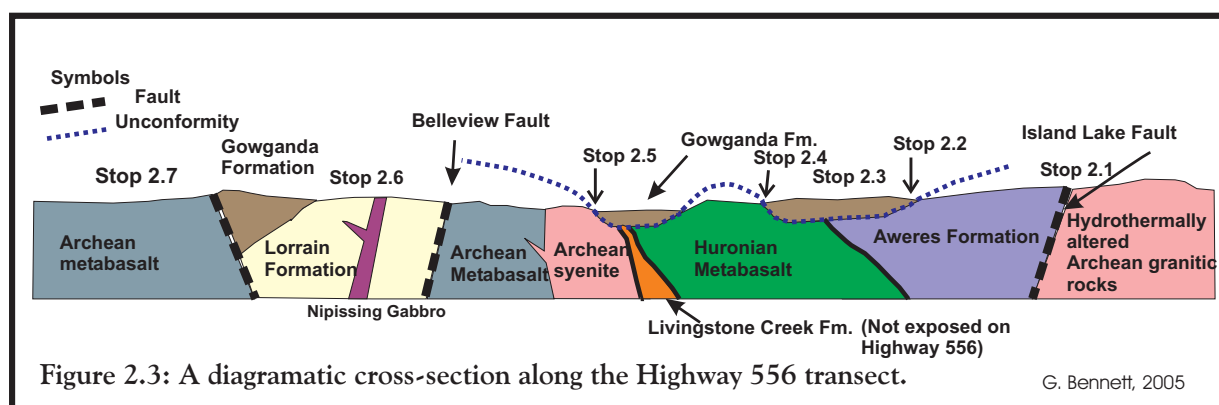
6.4 km. = 4.9 mi. - Railroad crossing

8.1 km. = 5.0 mi. 16-709788E, 5175568N

Park on shoulder just west the outcrops.







## **STOP 2.2: Gowganda Formation unconformably overlying Conglomerate of the Aweres Formation.**

On south side of highway an almost black, volcanic pebble to cobble, clast-supported conglomerate of the Aweres Formation is overlain by massive, grey, pebbly wacke of the Gowganda Formation. The contact is abrupt and visible in outcrops along both sides of the



Figure 2.6: Polymictic conglomerate of the Aweres Formation, Aweres Twp.

highway at this location (Figure 2.4). The entire Quirke Lake Group is missing in this area (Figures 1.3, 2.2). It is possible that tectonic activity north of this area, such as that which produced the Kapuskasing structure may be responsible for the uplift and erosion of some of the sub-Gowganda rocks in this area.

The lithology of the Aweres Formation seen here is identical to the lowermost part of the Aweres Formation as seen directly overlying the Thessalon Formation in the Jarvis Township a few kilometres southeast of this point. The proportion of volcanic clasts within the Aweres formation decreases as the proportion of granitic clasts and sandstone increases with stratigraphic height (Figure 1.14) (Bennett et al., 1975).

The Aweres Formation seems to have been deposited as alluvial fans along the valley walls of a down-dropping fault block (rift valley?). The surrounding plateau of Huronian volcanic rocks were eventually eroded to the underlying Archean basement.

The Aweres Formation is probably stratigraphically equivalent to the Mississagi Formation. At the north boundary of the Garden River Indian Reserve, about 12 km southeast of this area, the writer noted a southward transition from Aweres-type conglomerate to the sandstones of the Mississagi Formation (Bennett and Sawiuk, 1979).

9.2 km = 5.6 mi. 16 - 710458E; 5176230N

## **STOP 2.3: Drop-stones of the Gowganda Formation**

The vertical face of an outcrop of laminated argillite of the Gowganda Formation on the south side of the highway contains a few pebble-size dropstones. (Figure 2.5). The juxtaposition of pebble to boulder-sized clasts, normally indicative of a high-energy environment, with laminated mudstone of a low energy environment is unusual. Dropstones are the important indicators of paloclimate because, in Precambrian rocks, dropstones can only be explained as a rain of coarse sediment from floating ice onto silt and mud of a relatively still lake bottom or sea floor. It is the presence of dropstones at within stratified, fine-grained metasediment of Gowganda Formation (also the Bruce and Ramsay Lake Formations) which points to the glaciogenic origin of Huronian matrix supported conglomerates. A very impressive occurrence of dropstones is found in a cliff of Gowganda Formation about 50 meters west of Highway 129 about 30 km north of the intersection of Highway 129 and Highway 17.

9.5 km. = 6.9 mi. 16 - 710962 E, 5176196 N

**STOP 2.4: Contact between Gowganda Formation and Huronian metabasalt of the Thessalon Formation**

Park on south shoulder just west of outcrop. Pebbly wacke and matrix supported, polymictic conglomerate with abundant granite clasts (Gowganda Formation) show an abrupt contact with the dark-grey Huronian basalt flows to the east. The contact between the volcanics and the Gowganda conglomerate strikes 135 dips 65 W. Faint bedding (?) in Gowganda Formation is essentially parallel to the contact with the volcanic rocks. There is minor fracturing parallel to the contact in the volcanics but no significant deformation is noticeable in the conglomerate near the contact. The writer (eventually) concluded that the contact is an unconformity (Figure 2.3).

The Huronian volcanics (Thessalon Formation) contains clots of altered plagioclase crystals (glomeroporphyritic texture). Whole rock chemical analyses of the basaltic flows in this area show the elevated soda similar to that of spilite. Albite, clinozoisite, actinolite and some (original) clinopyroxene are the essential minerals.

10.8 km. - Railroad trestle.

11.3 km. = 7.2 mi. 16- 712648E, 5176124N. Sharp Corner – watch for traffic. You may park on the level area south of the Highway if your vehicle has a relatively high road clearance.

**STOP 2.5: Archean granitic rocks and Gowganda Formation.**

The easternmost, high rock-cut is of pink, coarse-grained Archean syenite to syenodiorite. Two mafic dikes intrude the

granitic rocks. About 15 meters of overburden separates the granitic rocks from an outcrop of grey pebbly wacke assigned to the Gowganda Formation. The east end of the outcrop (nearest the syenitic rocks) contains angular blocks of reddish the syenite/syenodiorite suggesting an unconformable relationship rather than a fault. The unconformity crosses pre-Gowganda rocks that dip from 10° to 30° west.

12.6 km. - 7.9 mi - Quartzite of the Lorrain Formation. Fractured reddish quartzite

14.9 km. = 9.2 mi. 16- 714951E, 5177887N

**STOP 2: 6: Jasper Pebble Conglomerate Member of the Lorrain Formation.**

This striking rock is a pebbly sandstone and quartz pebble conglomerate known locally as “puddingstone”. The abundant pebbles of variously coloured jasper presumably had a provenance in Archean iron formation, which is well represented in the Superior Province to the north. This member is in about the stratigraphic middle of the Lorrain Formation (Frarey 1977). At this point the dip of the bedding here is vertical or nearly so. A possible axial plane cleavage is visible, suggesting the rocks lie on the south limb of an anticlinal structure.

16.4 km. = 10.25 mi - Northland Lake Road.

17.6 km. = 10.9 mi (Optional)

**STOP 2.7: Outcrop of Archean metavolcanic rocks.**

Fine to medium-grained amphibolite is part of the hornfels zone near the granitic plutons.

End of road log for Highway 556.



Figure 2.8: Dolostone and chert. Fenwick Township, ON.



Figure 2.10: Jasper-pebble conglomerate member of the Lorrain Formation. Stop 2.6.



Figure 2.7: Dolostone of the Kona Formation. Highway 63, Marquette area, MI.



Figure 2.9: Dolostone nodules and lenses (dark areas) in the Gordon Lake Formation. Near Highway 638, Gordon Lake area, ON.

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Return to Highway 17. At intersection of Highway 17 and Highway 556 reset odometer to 0.

Continue north on Highway 17 to Highway 552 (about 13 km).

Turn left (west) onto Highway 552.

5.5 km = 3.4 mi. Goulais Mission Road.  
Turn right onto Goulais Mission Road.

11.4 km = 7.1 mi. Private road of Case Construction Company. **Permission must be obtained from Case Construction before continuing.**

We will continue to the end of the road as indicated by a locked gate. A short walk (> 100m) in a southwest direction will bring us to a small hill we refer to as the “dolostone knob”.

***STOP 2.8: Outcrops of Dolostone at the Dolostone Knob.***

Thinly bedded and laminated dolostone and chert are found along the steep sides of an outcrop knob. Some laminated silty sections may be stromatolitic bedding.

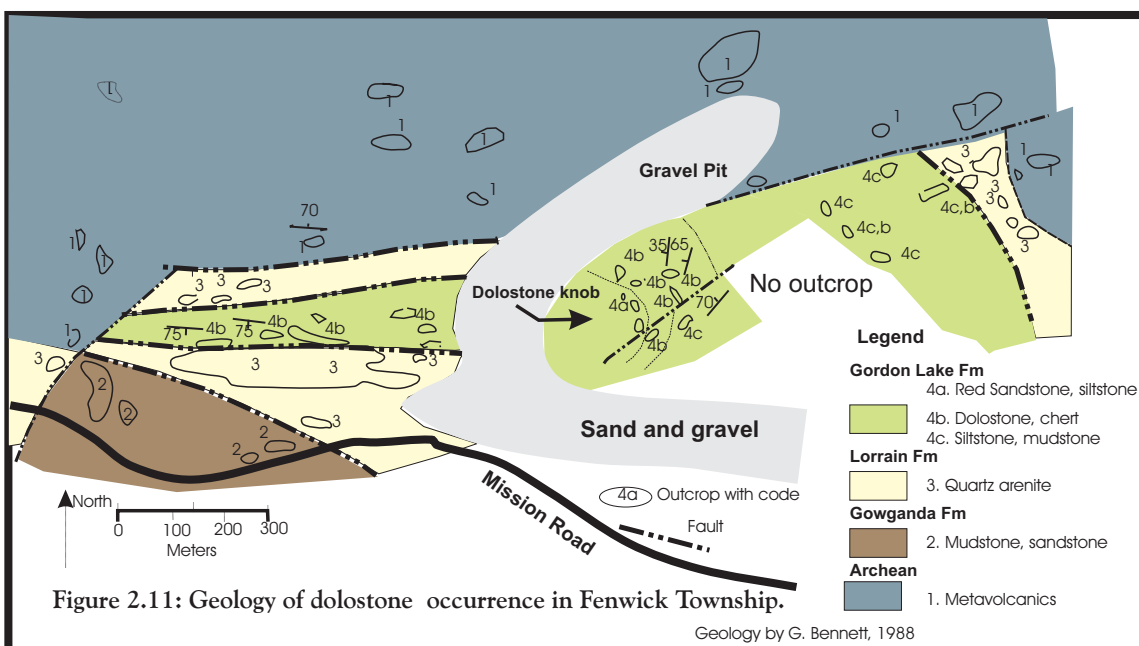
***STOP 2.9: This stop will be visited as time allows.***

This stop is located near Highway 638. Directions and a stop description are included in the supplementary road log for Highway 638.

## Geological Features and Correlation of a Dolostone Unit in Fenwick Township, Northeast of Sault Ste Marie, Ontario

Born (1987) described, a previously unrecognized occurrence of dolostone and associated clastic rocks in Fenwick Township, approximately 20 miles (30 km) northwest of Sault Ste. In the spring and fall of 1988 the writer mapped the known extent of the dolostone, and some of the surrounding rocks, was mapped by at a scale of about 1:8000 (Bennett et al, 1990). Mr. Paul Morra of Sault Ste Marie provided a stadia survey of selected areas.

millimeters to at least 1 m thick. The metachert beds have a similar thickness range but form less than 25 percent of the visible section (Figure 2.8). No clearly identifiable stromatolitic structures were observed but irregular and wavy, closely spaced laminae of brownish chert, suggestive of algal mats, were noted. Pale grey, clastic dolostone and oolitic dolostone appear to be the main rock types in the upper part of the carbonate unit. A few lenses, up to 50 cm wide, of coarse, pink barite are found within dolostone on the south side of the knob.



The general geological setting of the dolostone units in Fenwick Township is shown on Figure 2.11. The best exposures of the dolostone unit are found in the area indicated on the figure as the "dolostone knob". In the area of the dolostone knob, the lowermost third of the dolostone sequence consists mainly of very fine-grained, pale pink to reddish pink dolostone with intercalated grey to pink metachert. Individual dolostone beds are from a few

At the western side of the knob, the clastic dolostone is directly overlain by deep-red sandstone, and red to pink laminated siltstone. The dolostone unit is underlain by green and maroon siltstone and argillite.

The southern contact between the Lorrain quartz arenites and the dolostone is not exposed but lies within an east-trending, narrow, linear,

recessive zone about 10 m wide, and is inferred to be a fault.

### Correlation with the Gordon Lake Formation

Red siltstone and sandstone, purple and green siltstones, chert and dolostone of Fenwick Township have been assigned to the Gordon Lake Formation of the Huronian Supergroup (Bennett et al, 1990). This correlation is indicated by the juxtaposition of the dolostone and associated rocks with the Lorrain Formation (Although this is likely a fault contact). The reddish hues of the associated sandstones indicate they are stratigraphically superior to the Serpent Formation (Roscoe (1969). Most importantly, nodules and continuous beds of dolostone have been identified in the Gordon Lake Formation of the Gordon Lake area (Jackson, 2001; Hofmann et al 1980).

During a discussion (in 1988) of the problematic correlation of the dolostone units with Mr. Ken Hatfield of Lake Superior State University, the latter suggested a correlation with the Kona Dolomite of the Marquette, Michigan area (Figure 2.7).

### Correlation with the Chocoday Group of Michigan

There has been a long-standing debate as to stratigraphic and temporal equivalence of the Huronian rocks of Ontario and the Middle Precambrian rocks of the Lake Superior region of Michigan (Young, 1983) The

lithological and stratigraphic similarities of the Chocoday Group (and equivalent groups further west) and the Cobalt Group have been pointed out by many authors (Figure 2.12). At the time, this correlation was not widely accepted because previous radiometric dating of rocks considered to underlie the Chocoday Group was seen as providing evidence that the Chocoday Group is significantly younger than the Huronian Supergroup of Ontario (Young, 1983). However, Vallini et al (2005) have successfully dated hydrothermal xenotime in the Kona Formation and detrital zircons in the underlying Mesnard Formation thereby constraining the

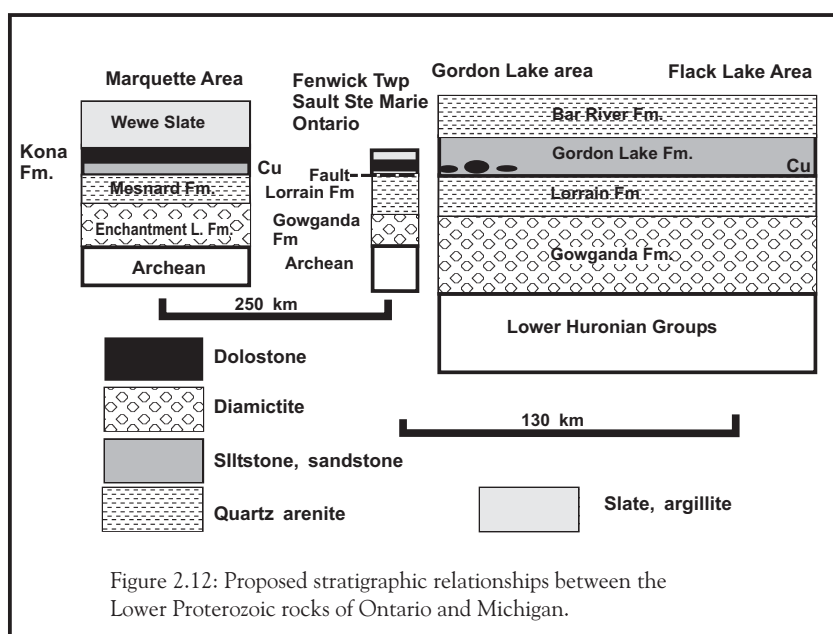


Figure 2.12: Proposed stratigraphic relationships between the Lower Proterozoic rocks of Ontario and Michigan.

timing of deposition of the Chocoday Group between 2300-2200 Ma thus proving a correlation with the Huronian Supergroup of Ontario.

There seems little doubt now that the Cobalt Group rocks of the Huronian Supergroup are stratigraphically equivalent to the Chocoday Group of the Marquette Range Supergroup of Michigan and to correlative units further west.

## Supplimentary Road Log for Highway 638

Highway 638 extends north from Highway 17 at Echo Bay and continues in a broad loop to rejoin Highway 17 at Bruce Mines (Figure 1.18).

Only STOP 2-9 of this road log is part of the Day 2 sequence. Stops preceded by "S" are supplementary or optional stops. A few of these stops may be made if time allows. The remaining outcrop descriptions are abstracted from a previous guidebook (Bennett et al, 1997) for the general interest of the reader.

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### Road Log and Outcrop Descriptions.

0 km = 0 mi. The Husky Service Station on Highway 17 near the eastern limits of the City of Sault Ste. Marie.

17.8 km = 11.1 mi. Junction of Highway 638 and Highway 17 in the Town of Echo Bay.

Reset odometer. Continue along Highway 638.

5.4 km = 3.4 mi. Outcrops of pink weathering sandstone of the Lorrain Formation.

10.6 km = 6.6 mi. Large road cuts on both sides of highway. The west limit of the outcrop area is at NAD 83 (WGS 84) 17-273278E, 5015292N.

#### ***STOP S1-1: Lowermost Gordon Lake Formation***

The sandstones and minor mudstone exposed in the rock cuts are either the lower units of the Gordon Lake Formation or the uppermost rocks of the underlying Lorrain Formation.

A few small, ground-level rock exposures on the north side of the road near the western limit of the northern rock-cut exhibit ancient mud-cracks as polygonal patterns of apple-green mudstone and pink sandstone.

Ripple-marks and laminated, red siltstone can be seen at about midpoint on the north outcrop. Small-scale (less than 20 cm) cross-bedding is well developed in pale grey and pink sandstone on the eastern portion of the southern road-cut but can be observed in most of the sandstone of the road-cut.

A large portion the sandstone is "bleached" almost white in contrast to the pink colour dominant in much of the outcrop. Note that the boundary between the pink and pale-grey sandstone clearly crosses the stratification in the rocks. That the bleaching (reduction) is the later event can be seen near the eastern limit of the road-cut. There the pale-grey sandstone is cut by dark red, hematite staining for several meters on both sides of steeply dipping, northeast striking fractures in the sandstone. A wide zone of reduction can be seen on both sides of the oxidized fractures. A hypothesis consistent with these observations is that chemically active fluids passing upward through the fractures first reduced the red hematite in the pink feldspar of the sandstone over a broad area along the fracture and in doing so became enriched in ferrous iron. Some time later, the system became oxidizing resulting in the precipitation of the much less soluble ferric iron as hematite adjacent to the fracture zone. These later fluids may have been oxygenated groundwater percolating downward from the surface encountering the ascending  $\text{Fe}^{+2}$  bearing reducing fluids that had scavenged iron from the underlying rocks.

A mafic dike about 10 cm wide intrudes the sandstone near the fracture zone. The dike occupies a fracture with a strike (direction) and dip similar to that of the hematite-filled (reddened) fractures. This suggests that hot magma was in the vicinity when the fractures existed and thus may have provided the thermal energy to drive the fluids through the fracture system.

10.9 km = 6.7 mi. East end of outcrop at 17-273416E, 5150243N.

11.6 km = 7.2 mi 17 – 274165E, 5150594N

**STOP 2.9: Dolostone nodules and discontinuous dolostone beds in the Gordon Lake Formation.**

NOTE: The outcrop at this location is on private property. To protect the rights of the property owner the exact location of the outcrop will not be provided here.

Outcrops of buff coloured siltstone and sandstone contain deeply recessed, discontinuous beds and scattered dark-brown to black dolostone. Jackson (1994) states:

“Buff brown to black weathering siliceous dolostone nodules are common throughout the lowermost Gordon Lake Formation. The nodules are commonly amoeboid and concentrically zoned with carbonate-rich core and dark hematitic-rich rinds. A large number of the amoeboid forms are, however, asymmetrically zoned with the hematitic rind being concentrated, or better developed, towards the stratigraphic top of the amoeboid forms suggesting at least local upward flow of fluids. In red to deep maroon siltstones, the carbonate-rich nodules are very pale pink to white, reflecting

the widespread reduction and/or removal of iron from these volumes of the rock”

Return to Highway 638.

23.2 km = 14.4 MI. Village of Leeburn - Corner and general store.

25.0 km = 15.3 mi. East side of road.

Dark grey-green mudstone and siltstone of the Gowganda Formation. Thin-bedded to very thick bedded with some thin beds of pink siltstone.

25.3 km = 15.8 mi. Dark grey siltstone with smooth, striated outcrop surface due to most recent (Pleistocene) glaciation.

26.4 km = 16.4 mi. Nipissing granophyre and diabase, fractured and cut by calcite and iron carbonate veinlets.

30.7 km = 19.1 mi. Stop Sign at the village of Ophir.

32.7 km = 19.7 mi. West side of highway.

**STOP S1-2: Mudstone overlying matrix-supported conglomerate (diamictite) of the Gowganda Formation.**

Matrix supported conglomerate consist of pebbles and bounders dispersed in a fine matrix so that the pebble and boulder sized clasts are supported by the matrix, not each other. Such conglomerates cannot be formed by the transport and deposition of clay to boulder-sized clasts by water or wind. Matrix supported conglomerates usually imply deposition from mudflows or directly from ice as glacial till.

32.9 km = 20.4 mi. West side of Highway.

**STOP S1-3:** Dropstones in laminated siltstone and mudstone of the Gowganda Formation.

A few granitic pebbles lie within dark grey laminated siltstone. It is generally agreed that the only process that can allow the juxtaposition of pebbles or boulder-sized clasts in stratified, fine-grained sediment is the release of stones by melting icebergs onto the sea bed or lake bottom.

33.6 km = 20.9 mi. Large gravel pit with high rock face on east side of the highway. A short unsurfaced road leads to the gravel pit.

***STOP S1-4: Diamictite of the Gowganda Formation.***

The high rock face is worn smooth by rushing water charged with abrasive sand etc. Vertical channels in the rock face suggest the erosive effect of sand-charged water under the extreme pressure of an overlying ice sheet.

The northern section of the outcrop is matrix-supported conglomerate of the Gowganda Formation. A diabase dike (probably of Nipissing age) intrudes the southern part of the outcrop. The dike is about 20 meters wide (estimated).

36.2 km = 22.5 miles Rock Lake Road.

39.8 km = 24.7 mi.

***STOP S1-5: Jasper pebble conglomerate of the Lorrain Formation ("Pudding Stone").***

Outcrops of pale-grey quartz arenite and jasper-quartz pebble conglomerate are found at east side of the highway. It is assumed that the jasper pebbles were derived from Archean banded iron formation, which is well represented in the Batchawana greenstone belt about 130 km northwest of these outcrops. The jasper-pebble conglomerate member (Frarey, 1977) of the Lorrain Formation is a minor but persistent unit. It has been found near the middle of the Lorrain Formation from the Sault Ste Marie area in the west to the Quebec border in the east. Although the high concentration of red, maroon and pink jasper presents a striking appearance it has a limited commercial use as a decorative stone because of its extreme hardness.

42.8 km = 26.6 Outcrops of Lorrain Formation sandstone on west side of highway.

At least two faults show hematization in the fracture zone. A pebble unit is seen to be displaced along one of the fault.

44.1 km = 27.4 mi. Bridge at Rydal Bank.

52.7 km = 32.7 mi Junction of Highway 628 and Highway 17 at Bruce Mines.

**End of road log for Highway 638.**

**Supplementary Road Log for parts of Highway 17 and Highway 129  
between Sault Ste Marie and Highway 108**

Most of the outcrops included in this section are not included in the ILSG 2006 field trip. Stops indicated as supplementary are preceded by the letter "S". They are included to allow those interested to visit them if traveling in the area at some future date. UTM coordinates have been provided for some locations.

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Proceed east along Highway 17 from Sault Ste. Marie.

The road log starts at the intersection of Highway 638 and Highway 17 East in the Town of Echo Bay

0.0 km = 0.0 miles - Highway 638 at Echo Bay  
- continue east on Highway 17.

8.8 km = 5.5 miles - At sign for Calabogie Road UTM 16- 725322E, 5144204 N,.

**STOP S2.1: Sub-Jacobsville unconformity**

Outcrop on west side of Highway 17. The most southerly outcrop is white and grey quartzite (quartz arenite) of the white orthoquartzite member (Frarey, 1977) of the Lorrain Formation quartzite is overlain by a sedimentary breccia of the Keweenaw, Jacobsville Formation. The conglomerate is comprised of angular clasts of Lorrain quartzite up to 60 cm across in a red siltstone matrix. The contact is irregular. No stratification was observed.

25.0 km = 15.5 mi.

**STOP S2.2: Lower red quartzite member of the Lorrain Formation.**

On the north side of Highway 17 steeply dipping beds of the lower red siltstone member of the Lorrain Formation reveal well preserved oscillation ripples on a large south facing surface.

Note: the differing ripple directions and local interference ripples. This impressive outcrop is known locally as the "Ripple Rock".

26.8 km = 16.6 mi.

**STOP S2.3: Purple siltstone member of the Lorrain Formation.**

Dark red to purple siltstone and sandstone constitute true red-beds in the Huronian (Frarey, 1977). These hematite-rich rocks display the reduction along fractures typical of red beds, and a good indicator of deposition in an oxidizing environment. The bedding is faint, but locally distinct, striking 140° and dipping 10° south.

27.7 km = 17.2 mi. Lake Huron Drive in the town of Desbarats.

28.0 km = 17.4 mi. 17- 5136434N, 275510E,

**STOP S2.4: Basal Arkose Member of Lorrain Formation.**

Large outcrops of pink, medium-grained, rather massive arkose beds with hematite-rich spots about one centimeter across. Pale laminations in outcrop on south side of the road indicate shallow dips of about 10° west. The unit is about 1700 feet thick in this area (Frarey, 1977).

40.5 km = 25.0 mi.

**STOP S2.5: Bruce Mines Copper Vein.**

In a rock-cut on the north side of Highway 17, in the town of Bruce Mines, is a 3 m wide quartz vein in Nipissing diabase. The vein contains small amounts of chalcopryrite, chalcocite, bornite and malachite. It is one of the few remaining remnants of the copper mineralization that once made this town known throughout the mining world. Mining began here in 1846 and continued to 1875, making Bruce Mines the first mining town in Canada. **Please do not take samples from this outcrop.**

About 75 meters north of this outcrop there is a reconstruction of a copper mining operation of that period built on one of the original mine workings, known as the "Simpson Shaft".

42.6 km = 26.5 mi.

Entrance to the quarry of Ontario Trap Rock (R.W. Tomlinson Limited). The quarrying of trap rock (Nipissing diabase) at Bruce Mines resumed in 1990. A predecessor near Lake Huron operated during the First World War.

45.3 km = 28.1 mi. 17-289512E, 5129999N

### ***STOP S2.6: Low outcrops of Mississagi Formation.***

Medium-sand to grit-sized, grey, subarkose with thin quartz-pebble beds and prominent planar cross-bedding are well exposed along the north side of the highway. Rusty staining on the outcrop reflects minor detrital (?) pyrite along the foreset beds. Black chert pebbles in pebbly beds, minor pyrite and meter scale bedding are common features of the Mississagi Formation. Roscoe, (1969) concluded that the drab colour and presence of detrital pyrite in Huronian sandstones and conglomerates is evidence of the reducing nature of the early Huronian atmosphere.

45.4 km = 28.2 mi. Waltonen Road near east end of the outcrop area.

60.6 km = 37.6 mi. 17 - 303650E, 5126650N  
Intersection of Highway 17 and Highway 129.

### ***Stop S2.7: Thessalon Formation tholeiitic basalt.***

Dark green, fine to medium grained basalt is exposed on the east side of Highway 129 just north of the intersection with Highway 17. This tholeiitic basalt forms the top of the Thessalon Formation in the Thessalon area and is typical of the thicker tholeiitic sequences which make up the upper parts of the Thessalon Formation in the Sault Ste. Marie and Aberdeen Township areas. The rocks consist of albite, chlorite, epidote, clinozoisite, leucoxene and minor quartz and oxides. The metabasalt contains amygdules of albite, quartz, epidote, calcite and

chlorite. The relatively small, monomineralic chlorite amygdules ("chlorite buttons") are characteristic of the mafic volcanics of the Thessalon Formation between Sault Ste. Marie and Elliot Lake.

Glacial striae and chatter marks are well developed on the outcrop surface.

Proceeding north on Highway 129. Reset odometer to 00 at Intersection of Highway 17 and Highway 129.

1.0 km = 0.62 mi.

### ***STOP S2.8: Outcrop of Matinenda Formation on east side of Highway 129.***

This fine-grained, pale pink to greenish grey, subarkose which directly overlies the Thessalon Formation in the Thessalon area has been correlated with the Matinenda Formation of the Elliot Lake Group (Bennett et al., 1991). Faint outlines of trough cross-bedding, visible on the upper surface of the outcrop, indicate paleocurrent directions from the northwest. The greenish (sericitic) units and the trough cross-beds are typical of the Matinenda Formation, but the fine grain size is not. At Thessalon Point about 4 km southwest of this location these rocks contain thin quartz pebble conglomerate units, but the pyrite and radioactivity, characteristic of the Matinenda Formation of the Elliot Lake area, is lacking.

23.0 km = 14.9 miles The village of Warncliffe

29.1 km = 18.4 miles north end of Appleby Lake.

30.3 km = 19.4 miles

UTM 17, 5 145 009N, 320 904E

### ***STOP S2.9: Laminated siltstone of the Gowganda Formation with dropstones.***

West of Highway 129. Proceed up steep slope to cliff face located a few tens of meters into the bush.

Vertical joint faces in laminated siltstones-mudstone of the Gowganda Formation form an impressive cliff just west of Highway 129. The bedding comprises regular and remarkably continuous mudstone-siltstone

couplets from 0.5 to 2 cm thick. The grey siltstone unit at the base of each couplet grades up to a darker mudstone which is in sharp contact with the siltstone base of the overlying couplet. The sequence closely resembles varves of Pleistocene glacial lakes. A few pink, discontinuous, fine, sandstone beds are also present. Widely scattered through the sequence are pebble to boulder-sized “drop stones”, predominantly of Archean granitic rocks. In the absence of volcanic activity within the Gowganda Formation, the only plausible source of the drop stones is the presence of floating ice which released its rock load during melting. This outcrop, and many others of a less spectacular nature, provide some of the best evidence for a cool climate during Gowganda deposition more than 2 Ga..

Church and Young, (1972) interpret the laminated unit as a varved sequence. They also note the presence of small sedimentary clasts, lithologically similar to the enclosing rocks. They interpret the clasts of sedimentary rocks as having been derived from the ablation of sediment on the upper surface of the glacier.

30.9 km = 19.5 miles. Intersection with Highway 554. Return to Thessalon along Highway 129.

30.9 km = 19.5 miles. Intersection of Highway 17 and Highway 129 at Thessalon.

Reset odometer to 0.0

7.3 km - 4.6 miles. 17 - 306085E, 5126967N. Green Lane. Cross the railway tracks (with care) and immediately turn left then south to short section of unpaved road between private properties. Outcrops of Thessalon Formation felsic metavolcanics lie at the end of the road.

### ***STOP S2.10: Rhyolite of the Thessalon Formation.***

Volcanics are fine grained, grey to pink and maroon rhyolite consisting of a fine grained mosaic of albite, k-feldspar, and quartz with minor green pleochroic biotite. Amygdules are filled with quartz, biotite and stilpnomelane. Collapsed vesicles are also present. Local iron staining and darker chloritic areas indicate the presence of iron sulfides.

Return to Highway 17 Reset Odometer.

3 km = 1.9 Pine Ridge Road

Proceeding east on Highway 17 from Pine Ridge Road

Reset odometer to 0.

13.5 km = 8.4 mi. Melwell Road

14.1 km = 8.7 mi. 17-321874E, 5129338N – Outcrop with prominent white quartz veins near crest of hill .

### ***STOP S3.1: Mineralized quartz vein breccia.***

Quartz-carbonate veins and vein breccia cut pebbly siltstone of the Gowganda Formation on the south side of Highway 17. The vein and mineral assemblage (quartz-carbonate-pyrite-chalcopryrite-hematite) are typical of many in such occurrences the area between Sault Ste. Marie and Sudbury. The extensive brecciation suggests surface venting with resulting hydrothermal boiling, adiabatic cooling with coincident brecciation and mineral deposition. Some sections of the vein system show well-developed mineral zoning and pre-vein alteration. Minerals identified include: quartz, iron-carbonate (ankerite?), pink calcite, chalcopryrite and specular hematite. The lack of pyrite and the late deposition of hematite, indicates a sulfur deficient hydrothermal fluid.

47.6 km = 29.6 mi. Town of Blind River

66.7 km = 41.4 mi. Pronto Road. 17 – 367425E, 5117509N

Access to granitic paleosol and a remnant of radioactive quartz-pebble conglomerate of the former Pronto Mine.

At the time of writing (2006) the Pronto Mine site is currently not open to the public. Those planning to visit this site should contact the

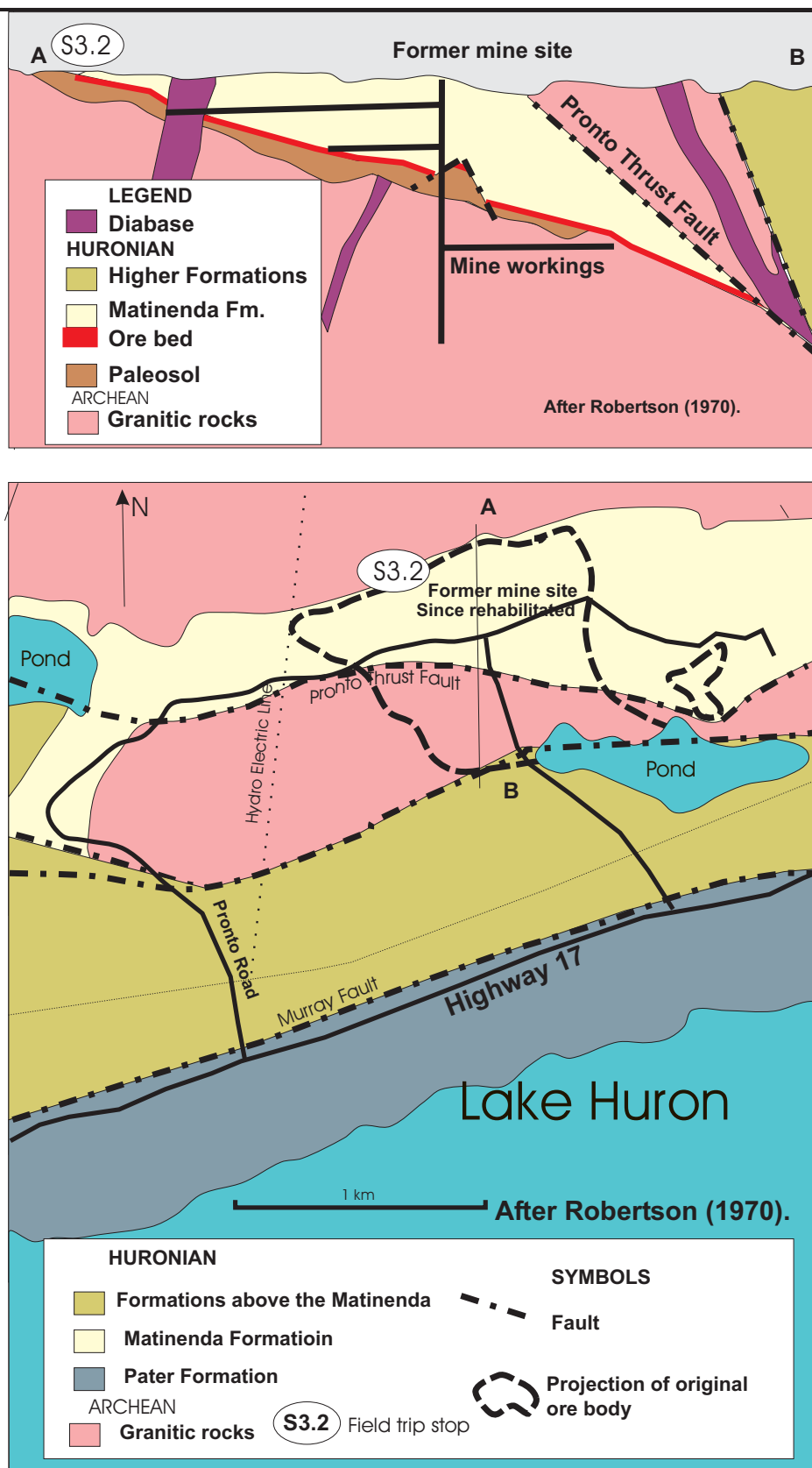


Figure 2.13. Plan and section of the geology of the (former) Pronto Mine area.

District Geologist office of the Ministry of Northern Development and Mines at Sault Ste Marie, Ontario (705 - 945-6931) to learn of the site status and the phone number of a contact person with the authority to grant permission to access the property.

Turn north onto the Pronto road and continue until prevented by a gravel barrier from proceeding further. Continue on foot past the barrier to the west end of a beaver pond just north of the road. Proceed along a trail across the west outlet of the pond, then around the north end of the pond and up a steep hill. Turn left (to the north) on a gravel road at the top of the hill. Continue to an area of outcrop and gravel which marks the former open slope of the Pronto mine at 17-367804, 5119019. If not accompanied by a guide, please do not attempt to access this site without a GPS receiver or compass as well as suitable footwear and clothing.

### **STOP S3.2: Pronto Mine Location**

This property is currently (2006) undergoing restoration to a condition as closely as possible to its original state.

The Pronto Mine of Rio Algom Limited, the first operating uranium mine of the Algoma District, produced 2.1 million tonnes of ore between 1955 and 1960. (Figure 2.13).

This is one of the few locations where exposures of uraniferous quartz pebble conglomerate of the Matinenda Formation can be found on surface in the Elliot Lake-Blind River area. In the depression south of the road, a few remnants of rusty-weathering outcrops of radioactive, pyritic, quartz-pebble conglomerate of the Matinenda Formation mark the base of the ore bed of the Pronto Mine. The conglomerate lies directly upon yellowish, sericitic paleosol developed on Archean granitic basement. Visitors are requested not to take samples of the conglomerate.

Proceeding in a general northerly direction, some features of the original granitic rocks,

displayed as dikes and irregular bodies of aplite and pegmatite, can be recognized in the paleosol (saprolite). Continuing up the southward sloping outcrop the yellowish colour of the paleosol can be seen to take on a pinkish and reddish hue normal to the Archean granitic rocks of the area. Continuing north and west to near the highest point on the outcrop area one can discern the faint outline of core-stones in the original granitic rocks.

11.6 km = 7.2 mi Highway 108 to Elliot Lake

Return to Highway 17. Continue east along Highway 17 to Highway 108 to Elliot Lake. Continue eastward for a few hundred meters past Highway 108 to an outcrop just south of Highway 17.

Continue for about 100 m past the intersection of Highway 17 and Highway 108.

Low outcrops a few tens of meters south of Highway 17. (Refer to Figure XXX).

### **STOP S3.3: McKim Formation - *Staurolite (pseudomorph) schist*.**

This outcrop, which lies a few hundred meters south of the Murray Fault Zone, displays the higher metamorphic grade and deformation common to rocks south of the fault. At this location argillaceous units of the McKim Formation contain pale prismatic crystals of staurolite that have undergone retrograde metamorphism to sericite-quartz aggregates. A few pseudomorphs show the characteristic cruciform twinning of staurolite. The growth of large staurolite crystals in the originally more argillaceous upper portions of the beds has resulted in "reverse graded bedding" in a few places.

Return to the intersection of Highway 17 and Highway 108. Proceed north along Highway 108 to the Town of Elliot Lake.

Continue north on Highway 108 to the City of Elliot Lake.

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