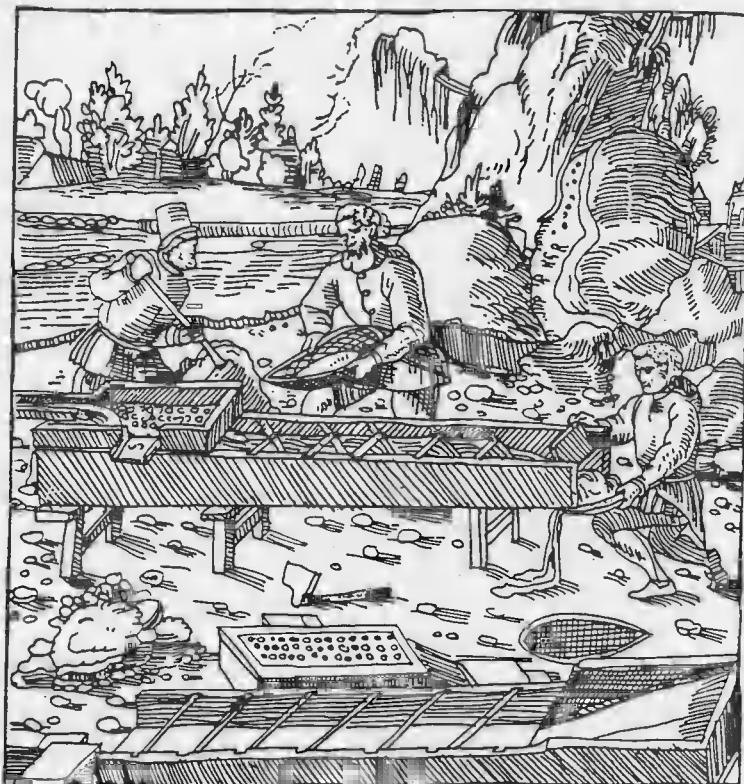
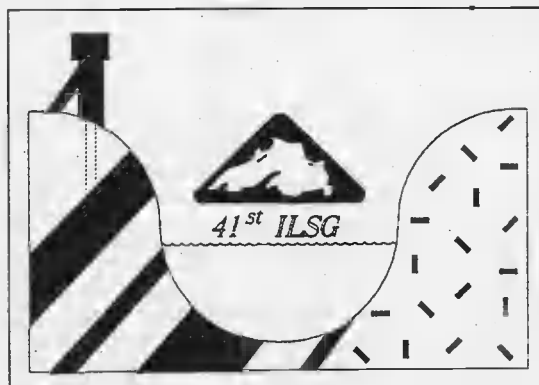

*Kimberlite, Base Metal and Gold Exploration
Using Overburden, Wawa Area*



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Field Trip Guidebook**



Kimberlite, Base Metal and Gold Exploration Using Overburden, Wawa Area

by

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***Frontispiece: Sluicing operation circa 1500 (after Agricola 1556, p.323,
reproduced from the cover of Canadian Mining Journal, February, 1975)***

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KIMBERLITE, BASE METAL AND GOLD EXPLORATION USING OVERBURDEN, WAWA AREA

Background Information

Introduction

Wawa is located 220 km north of Sault Ste. Marie, Ontario, east of Lake Superior (Figure 1). Wawa, accessed by Highway 17, Highway 101 or scheduled air service, sits on the Michipicoten greenstone belt which has been mined for iron and gold since 1866 (Gledhill 1927).

History of Quaternary Geology Mapping, Wawa Area

Surficial materials of the Wawa area were first delineated at a regional scale by Boissoneau (1966, 1968). A more detailed engineering and terrain geology map was compiled by Gartner and McQuay (1979). The purpose of this map was to provide a guide for engineering and resource planning functions. Frey (1987) defined and described several glacial outwash systems and glacial landforms.

Recently, the Ontario Geological Survey (OGS) initiated 2 Quaternary geology projects. The first project involved 2 summer field seasons in 1990 and 1991. The second project involved a field visit in the fall of 1993 and a summer field season in 1994.

WAWA QUATERNARY GEOLOGY PROJECT

The area mapped and sampled during the summers of 1990 and 1991 includes the 1:50 000, NTS 42 C/2 Hawk Junction map sheet (84°30'W and 85°00'W; 48°00'N and 48°15'N), the northern half of the 1:50 000, NTS 42 C/1 Manitowik Lake map sheet and the southern half of the 1:50 000, NTS 42 C/8 Franz map sheet (84°00'W and 84°30'W; 48°07'30"N and 48°22'30"N; Figure 2). This area was chosen in order to cover as much of the Michipicoten greenstone belt as possible in 2 field seasons.

The purpose of the first OGS Quaternary geology project was to: a) compliment OGS bedrock mapping and related projects focused over the Michipicoten greenstone belt (Sage 1994); b) define the types, distribution, physical and geochemical properties of overburden materials; c) define the Quaternary history of the region; and d) apply this knowledge towards exploration, environmental and land use applications. Quaternary geology mapping and an overburden materials sampling program were initiated to meet these goals (Morris 1990, 1991, 1992a, 1992b).

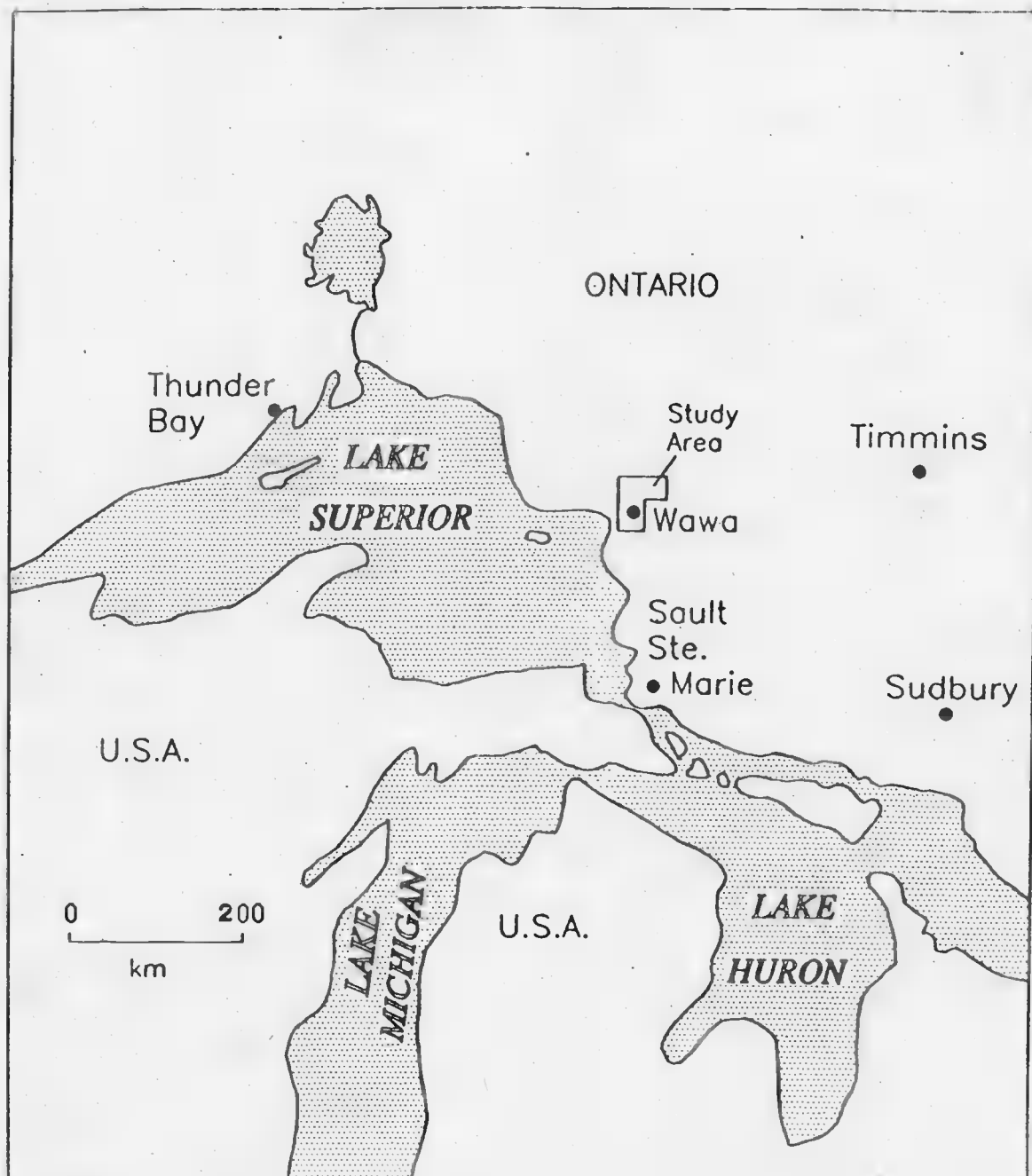
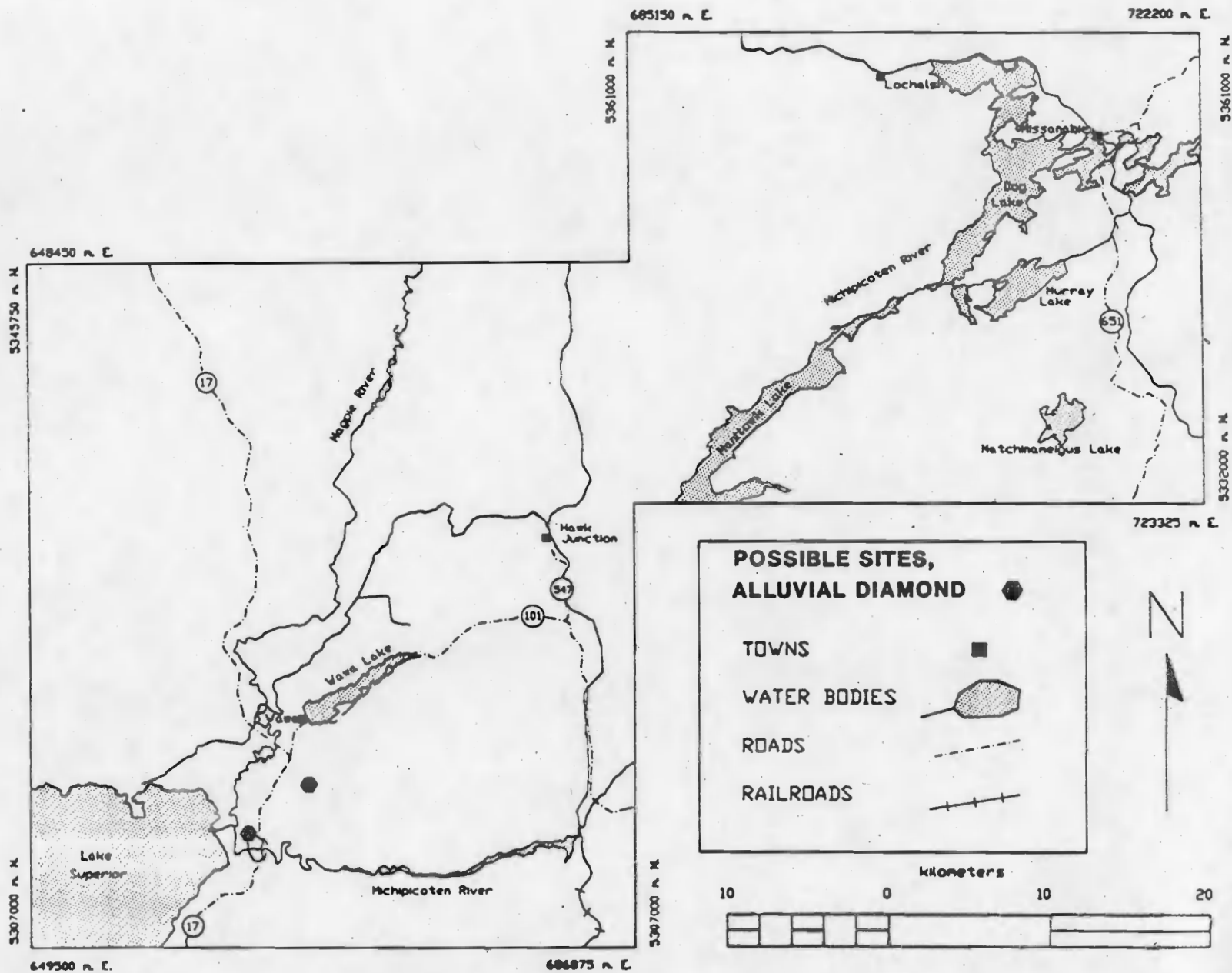


Figure 1: Study area location

Figure 2: Area covered by Ontario Geological Survey mapping and overburden sampling projects, summers of 1990, 1991 and 1994.



MICHIPICOTEN RIVER- WAWA QUATERNARY GEOLOGY PROJECT

Two diamonds, and possibly a third, were recovered from the Michipicoten River-Wawa area (Figure 2) by C. Clement (local prospector) during the summer of 1991. The exact location of the discovery site could not be positively identified. It is thought, however, that the diamonds were collected from either older alluvium (sand and gravel) in a point bar of the Dead River, near the Michipicoten River and/or modern alluvium (sand and gravel) associated with Wawa Creek. This discovery was reported to the OGS in the fall of 1993.

Two of the 3 diamonds were loaned to the OGS and then forwarded to the Royal Ontario Museum, Department of Mineralogy, for confirmation. The stones were identified as industrial grade diamonds with carat weights of 1.05 and 1.13.

A focused sampling program was subsequently initiated by the OGS in September of 1993, in order to establish authenticity of the diamond find. Ten, 25 kg samples were collected from the reported discovery sites: 5 modern alluvium samples from Wawa Creek and 5 older alluvium samples from a point bar associated with the Dead River. Kimberlite indicator minerals recovered from this sampling program verified that the 2 industrial grade diamonds could have been recovered from the Dead River site (Morris et al. 1994).

As a follow-up to these preliminary discoveries, the OGS undertook a regional sampling program in the Michipicoten River-Wawa area in the summer of 1994 (Figure 2). The area from the first OGS Quaternary mapping project was included. In addition, the mapping and sampling of Quaternary materials was extended to include the northern third of the 1:50 000 scale N/15 Michipicoten Harbour NTS map sheet (84°00'W and 85°00'W; 47°07'30"N and 48°00'N).

The area was considered optimal for kimberlite exploration as: a) it includes the area where 2 industrial grade diamonds and associated heavy minerals were recovered; b) bedrock and overburden geology is well understood (Morris 1990, 1991, 1992a, 1992b; Sage 1994); and c) the area includes the northern contact of the Kapuskasing structural zone, a bedrock zone thought to be a favourable host for kimberlite.

This study's purpose was to: 1) provide regional information on the types and distribution of kimberlite heavy mineral indicators (KIM) found within overburden in the Michipicoten River-Wawa area. In addition to the KIM's, visible gold grains were also identified in the heavy mineral assemblage; 2) characterize the way heavy minerals are transported through modern fluvial systems by evaluating variations in concentration and wear on gold grains with distance from a known point source; 3) determine the types, distribution, physical and geochemical properties of overburden

materials within the Michipicoten River valley area; and 4) determine the Quaternary history of the Michipicoten River valley area.

Physiography

TOPOGRAPHY

Topography of the area is described as moderate to undulating by Boissoneau (1966, 1968) and moderately to severely rugged by Gartner and McQuay (1979). Locally this landscape can be flat, although relief in some areas achieves 198 m.

DRAINAGE BASIN CHARACTERISTICS

The study area is located south of the Great Lakes-Hudson Bay regional drainage divide and all water within the study area flows south to the Lake Superior basin. Three major drainage basins cross the study area. These include, from west to east: the Dore', Magpie and Michipicoten rivers (the Michipicoten being the largest). The orientation of many of the major rivers and lakes within drainage basins is controlled by bedrock structural features such as deformation zones (e.g. Emily Bay, Dog Lake and McKewen Lake deformation zones) (Heather and Buck 1988).

Water flow in the upper reaches of each of the major drainage basins is relatively slow due to low stream gradients. As a result, alluvium is poorly sorted in their northern (upstream) reaches. In addition, drainage within the Magpie and Michipicoten rivers is now largely controlled by hydro electric dams.

CLIMATE AND VEGETATION

In the Wawa area, Lake Superior has a moderating effect on the climate in a belt 60 to 91 km inland from the Lake Superior shore. Cooler, more moist shoreline conditions prevail during the summer months which result in more frequent cloud or fog cover. This reduces local evaporation rates and slightly modifies temperature and precipitation. July has the warmest monthly mean temperature (15.6° C) while January has the coldest (-14.1° C). The yearly temperature average based on the monthly mean is 2.0° C. The wettest month is September (113.8 mm) while the driest month is February (55.9 mm). The monthly precipitation average is 78.8 mm.

The area east of Wawa (towards Chapleau) is classified as a subarctic continental climate. July has the warmest monthly mean temperature (17.0° C) while January has the coldest (-16° C). The yearly temperature average based on the monthly mean is 1.3° C. The wettest month is September (116.9 mm) while the driest month is March (48.9 mm). The monthly precipitation average based on the total yearly precipitation is 75.1 mm.

In the Wawa area the St. Lawrence vegetation assemblage is present largely due to the moderating effect of the local climate by Lake Superior (Rupert 1979). This vegetation assemblage is at its northern limit in the Wawa area and includes maples, white and yellow birch, red and white pine, jackpine, hemlock, cedar and spruce. A low crown density and thick development of underbrush are characteristic of the assemblage in the Wawa area. East towards Chapleau, the vegetation is dominated by conifers, more typical of Boreal forest.

Regional Geology

Bedrock Geology

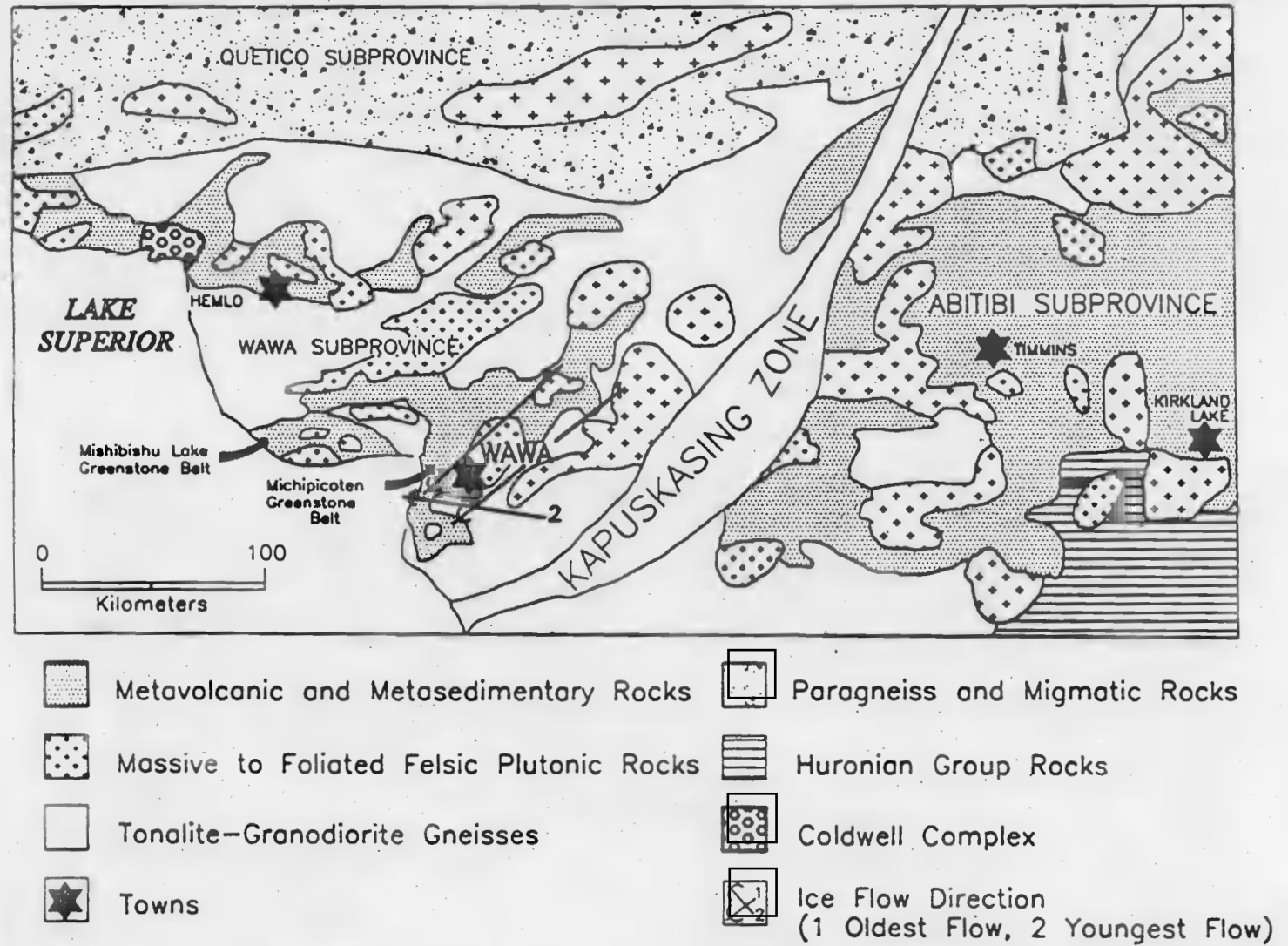
The Michipicoten River-Wawa area lies within the Wawa subprovince of the Superior Province of the Canadian Shield. The study area straddles much of the Michipicoten greenstone belt. This belt extends inland 150 km, to the northeast, from the Lake Superior shore with an average width of 38 km. This greenstone belt consists largely of supracrustal rocks of Archean age. Younger Archean granitic rocks surround the greenstone belt (Figure 3).

The Kapuskasing structural zone extends east from the shore of Lake Superior and then northeast through Kapuskasing into the Hudson Bay Lowland (Figure 3). The northern margin of this zone is traced through Wawa, Hawk, Manitowik and Dog lakes. This structure is significant as it consists of fractured crustal material that may host kimberlite rock (Boland and Ellis 1989). Structures associated with this zone include northeast striking Proterozoic lamprophyre dykes formed by alkalic magma emplacement (Sage 1994).

The Precambrian geology of the area, and related studies, are summarized by Sage (1994). There are 4 major sedimentary and metavolcanic rock types recognized within the Michipicoten greenstone belt. These are: 1) intermediate to mafic metavolcanic rocks; 2) intermediate to felsic volcanic rocks; 3) clastic metasedimentary rocks; and 4) chemical metasedimentary rocks (Figure 4).

Intermediate to mafic metavolcanic rock is exposed throughout most of the greenstone belt. The intermediate to felsic metavolcanic rocks are less widespread and are restricted to belts and blocks scattered across the greenstone belt. The intermediate to mafic and felsic metavolcanic rocks were deposited during 2 major, and a third minor, volcanic cycles. The materials derived from the 2 major volcanic cycles range in composition from tholeiitic basalt to calc-alkalic felsic volcanics (Thurstun 1986). Materials derived from the third minor volcanic cycle represent basaltic to peridotitic komatiite volcanism followed by calc-alkalic felsic volcanism (Sage and Heather 1991).

Figure 3: Regional bedrock geology (modified from Sage and Heather 1991).



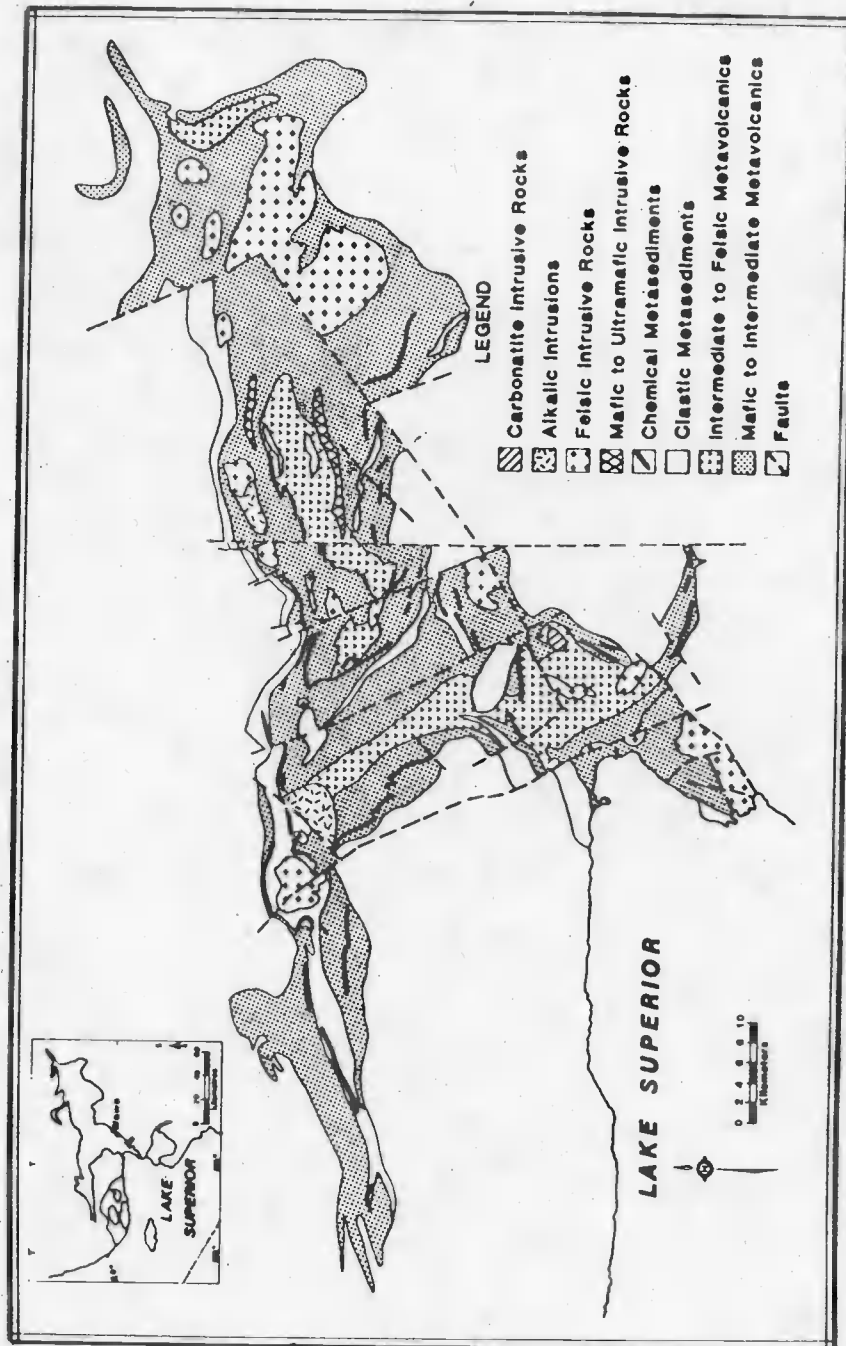


Figure 4: Precambrian geology of the Michipicoten greenstone belt (from Sage 1994)

Metasedimentary rocks are more common in the western part of the study area than they are in the east. They were deposited within a marine alluvial fan depositional environment and were subsequently buried by a shallow braided stream environment (Neale 1981; Thomas 1984). The metasedimentary rocks consist of either conglomerate, wacke, and siltstone or argillite (Sage and Heather 1991).

Iron formation is the dominant chemical metasedimentary rock found within the greenstone belt and is most commonly found in the southwestern, central and northeastern parts of the study area. The iron formation consists of 5 facies which include, from base to surface: a) siderite (carbonate facies); b) pyrite (sulphide facies); c) chert-magnetite wacke (oxide facies); and d) argillite-pyrite-graphite. Occasionally, calcite substitutes for siderite and represents the fifth facies (Sage and Heather 1991). The origin of the iron formation is summarized by Sage and Heather (1991).

Intermediate to mafic intrusions consisting of peridotite to quartz diorite occur predominantly within the central part of the greenstone belt. They vary in age and are fine- to coarse-grained.

Several stocks are scattered across the greenstone belt. These stocks range in composition from trondhjemite to granodiorite to granite. All are younger than the surrounding supracrustal rocks and may have been emplaced at the same time as the granitoid rocks external to the greenstone belt.

Surrounding the supracrustal rocks are felsic intrusive rocks that range from tonalite and trondhjemite to granite (Sage and Heather 1991). External granitoid rocks on the south side of the greenstone belt are older than the external granitoid rocks on the north side.

Quaternary Geology

TIME FRAME

Overburden materials throughout the Michipicoten River-Wawa area were deposited during the last glaciation. The Wawa area has likely been covered by glacial ice since the Early Wisconsin which occurred about 115 000 years ago. Bedrock features, materials and landforms associated with this advance include: a) ice flow indicators (straie, grooves, whalebacks, chattermarks); b) enhancement of bedrock structure (structure parallel to ice flow is enhanced, structure perpendicular to ice flow is not); and c) thin till over bedrock (subglacial till).

A radiocarbon date of 9210 ± 100 years BP (GSC 1851) from a basal organic sediment in Alfies Lake (south of Wawa) provides a minimum date of deglaciation of the Wawa area (Saarnisto 1974). However, Mothersill (1988) argued that radiocarbon dating of material from within the Lake Superior basin is potentially contaminated with old carbon. Using palaeomagnetic dating, Mothersill concluded that the Lake Superior basin had been deglaciated by 8200 years BP. This is in agreement with data compiled by Mahanic and Teller (1985).

The types and distribution of Quaternary materials and features are summarized in the Quaternary Geology maps, back pocket.

ICE ADVANCE

Ice Flow Indicators

Striations, glacial grooves, chattermarks and ice moulded bedrock knobs are preserved on smooth, unweathered bedrock surfaces. Striations are the most common glacial erosion feature and are found throughout the study area.

The orientation of these glacial erosion features varies between 165° to 263° with a mean of 214° . Most of the striae variation is due to deflection of regional flow by bedrock highlands.

Cross-cutting striae have been observed in only 4 places. In all cases, the location of these sites are within major west trending bedrock controlled valleys. At the 4 sites striae formed by the regional ice flow (mean of 214°) are cross-cut by a younger set of striae (mean of 266°). The younger set of striae are orientated parallel to the orientation of the bedrock controlled valleys within which they were observed.

The older set of striae represents flow that was largely unaffected by bedrock topography. The younger set of striae represents flow controlled by bedrock topography, commonly in the westerly orientated valleys. This occurred due to ice sheet thinning during the latter stages of glaciation.

Material

Subglacial Till

A thin, discontinuous till was deposited over the area by ice associated with the last glaciation. This till was derived from the debris rich base of the ice as it advanced. This interpretation of the subglacial origin of the till is based upon morphology, structural characteristics and pebble composition. This till's thickness varies from non-existent over bedrock highs to 1.0 to 1.5 m thick in bedrock lows. Bedrock outcrops are commonly associated with this unit and the material can be

described as a thin, discontinuous veneer.

The unweathered exposures of this till are usually structureless and massive. Occasionally faint shear were observed in sections located up-ice of bedrock ridges. When dry, the material is very hard. A more detailed discussion regarding subglacial till as a media for drift prospecting is contained in the notes for Site # 3, "Field Trip" section.

ICE RETREAT

Bedrock Features

The 2 bedrock features associated with ice retreat in the Wawa area are the potholes and "P" forms. Both features are formed by sediment rich glacial meltwater under high pressure. Potholes are not widely recognized throughout the Wawa area. They are circular features that can extend 1 to 3 m below the rock surface and are formed by the circular rotation of boulders within swirling water under high pressure at the base of the ice. The boulders are analogous to a dentist's drill, whereby the boulders literally drill into the rock. Grinders, as these boulders are called, can sometimes be found in the bottom of the hole.

"P" forms were observed only within the Magpie valley and the Wawa Lake basin. Characteristic "P" forms include furrows, comma form and sichelwannen (Sharp and Shaw 1989, Kor et al. 1991). Although "P" forms are commonly restricted to valley floors, they were observed on valley sides 65 m above the Magpie River. They are aligned oblique to valley orientation suggesting that glacial meltwater flow did not necessarily follow bedrock controlled depressions. Straie exist within "P" forms suggesting that glacial ice was let back down onto the bedrock surface after glacial meltwater was expelled.

Materials and Related Landforms

The distribution of materials and related landform indicate that the ice margin retreated to the north in the western part of the region and to the northeast in the eastern part. The bulk of overburden materials were deposited within bedrock controlled valleys where glacial meltwater was concentrated.

Flow Till and Related Landforms

A second type of till was deposited during ice recession. This till is thicker (>1 m) than the subglacial till. It is commonly associated with west trending moraines, or is found in isolated patches commonly located at the headwaters of outwash systems or around the periphery of former glacial lake basins. Bedrock outcrops are rarely associated with this till type.

The material comprising this till type was derived from the subglacial (base), englacial (middle) or supraglacial (surface) positions of the glacier and deposited as "flows". Because of the flow-like structure associated with these tills, they are commonly referred to as flow tills.

Glaciofluvial Materials and Landform

Glaciofluvial deposits are subdivided into 2 units: ice-contact stratified drift and glaciofluvial outwash. The sides of ice-contact stratified drift deposits are commonly steep due to deposition of the sediments against ice walls. Deposits consist of a wide variety of materials ranging from sandy silt to boulders. Related landform consist of eskers and moraines.

Glaciofluvial outwash deposits commonly have gentle slopes as outwash was deposited in front of but proximal to the ice margin. Kettles are associated with several outwash deposits as glacial ice blocks buried by outwash melted. Materials comprising the outwash range from sand to coarse boulders.

Within the western part of the area glacial meltwater flowed freely downslope from the ice margin toward the Lake Superior basin. Associated with this free-flow of water there are several well defined meltwater channels situated within the bedrock controlled valleys (Figure 5).

In the eastern part of the area, glacial meltwater was commonly trapped in glacial lakes which formed between bedrock controlled topographic highs and the ice margin. Meltwater flow from these lakes occurred either through channels which opened between the lake and ice margin or topographic lows situated around the rim of the ice-controlled lake basin.

Smaller glaciofluvial deposits are associated with bedrock depressions where blocks of ice, detached from the glacier, melted *in-situ*. Where meltwater was dispersed onto open space from concentrated channel flow leading from this wasting ice, small, fan-shaped bodies of aggregate were deposited.

Glaciolacustrine Materials and Landform

Glaciolacustrine materials consist of fine- and coarse-grained sediments. The fine-grained sediments consist of horizontally bedded couplets of varved silt and clay deposited within deep (quiet) water. They are exposed at surface along the shores of Dingman Bay on Manitowik Lake and Localsh Bay on Dog Lake. They were also observed at the base of a deltaic section associated with the Magpie River.

Coarse-grained material occurs where the western, free-flowing glaciofluvial systems empty into the Lake Superior basin and

in shallow glacial lakes formed between the ice margin and the eastern bedrock highlands. In these lakes coarse-grained sediments formed deltas and sheet sand deposits. Where rivers have cut through deltaic deposits, in response to lake level lowering in the Lake Superior basin, magnificent terraces have developed in the Dore', Magpie and Michipicoten river valleys. More detailed discussion of the lake level history in the Lake Superior basin is contained in the description at Site # 8.

Flow Till, Glaciofluvial and Glaciolacustrine Materials as Media for Drift Prospecting

These materials are not desirable overburden media for local drift prospecting since they: 1) are not widespread throughout the Wawa area; 2) commonly do not give a local signature of the bedrock as material is a blend of both regional and local materials derived from the basal, englacial and supraglacial positions of the icesheet; and 3) undergo several depositional processes that may either concentrate or dilute the indicator signatures. Glaciofluvial materials found in eskers and glaciolacustrine deposits are used successfully to gain a quick, inexpensive regional indicator signature (Baker 1985; Craigie 1993).

RECENT DEPOSITS

Eolian Deposits

Eolian deposits consist of yellow, fine to medium-grained sand. These deposits are not widespread and are commonly located on the down-wind side of glacial lake and glaciofluvial deposits such as the broad outwash plain east of Goudreau. A very thin cover of eolian material exists on the Steephills Falls Dam, Magpie River.

Colluvium

Colluvium consists of light brown to brown, coarse sand and boulders. Well developed colluvium aprons are most commonly associated with terrace scarps within the Magpie River valley.

Older Alluvium

Older alluvium consists of pale brown, fine to coarse sand. Older alluvium is restricted to the lower reaches of the Dore', Magpie and Michipicoten rivers. In the Wawa region, alluvium consists of material derived from the erosion of higher elevation glaciolacustrine deltas within these valleys as lake level dropped within the Lake Superior basin.

Modern Alluvium

Modern alluvium consists primarily of sand and minor quantities of organic rich sand and gravel. Thick deposits of alluvium (>1 m)

are commonly associated with those rivers or streams flowing through glaciofluvial or glaciolacustrine deposits where there is a ready supply of erodable material. Where stream or river flow is over bedrock dominated terrain alluvial sand is scarce, found usually as small pockets within sediment traps (behind or under boulders, steps in the stream bed, or inside curves of streams).

Eolian Deposits, Colluvium, Older Alluvium and Modern Alluvium as Media for Drift Exploration

Eolian deposits, colluvium and older alluvium are not recommended as media for local drift exploration for the same reasons given for flow tills, glaciofluvial and glaciolacustrine deposits. In addition, they have all undergone at least one more cycle of erosion, transportation and deposition which will likely further complicate tracing of any indicator signature back to the source or target.

As modern alluvium is regionally pervasive and is thought to represent a signature of a whole drainage basin it is commonly used as a means for gaining a fast, regional signature for either gold or kimberlite exploration (Gonzaga et al. 1994; Marshall 1986; Maurice 1988, 1991; Morris et al. 1994; Seely and Senden 1994; Sutherland 1982, 1993; Wolf et al. 1975). Commonly, samples are taken at the mouths of drainage basins to provide a regional heavy mineral signature for that drainage basin. The merits of such a sampling program are discussed in the write-up for Site # 7a.

Overburden Sampling Methodologies

Sampling Design

Commonly overburden materials are sampled at 2 different scales; regional and local. Regional scale sampling in Ontario involves the collection of samples from glaciofluvial deposits such as eskers and outwash, glaciolacustrine deposits, modern alluvium and lacustrine deposits. This type of sampling program allows evaluation of a large area relatively quickly and inexpensively. The sample density at this scale varies depending on the commodity being sought, distribution of material being collected and exploration cost.

Local scale sampling is usually done once an anomaly has been identified from the regional scale sampling. Individuals have sampled from a variety of materials and from different soil horizons. The exploration limitations of these materials are discussed in "Material Sampling" and at all "Field Trip" stops. In the Wawa area subglacial till is probably the best material to sample due to it's relatively simple depositional history and a local heavy mineral and geochemical signature. Sample collection sites are based on an artificial grid placed over the anomaly. Grid spacings are commonly 30 to 300 m apart (Craigie 1991).

Material Sampling

Consistently sampling the same overburden material in an overburden sampling program is critical when it comes to interpreting the geochemical and/or heavy mineral data. Often, individuals collect whatever material exists at a prescribed sample point without taking the time to evaluate the site or material being sampled. The different depositional histories of the materials and the different ways and rates at which certain materials weather give different geochemical, and possibly, different heavy mineral signatures. For example, sulphide minerals in a near surface oxidizing environment weather quickly.

Because of this, it is essential to take the time to make some basic sample site and material observations. This can be done quickly and accurately by providing the sampler with a checklist of observations. These observations, if done correctly, may be invaluable during data interpretation.

Appendix B consists of 2 site observation sheets and a list of related term definitions. Although there is always room for improvement, these observation sheets prove useful in providing an outline for some of the fundamental observations that should be made at either a till or sand and gravel sample site (Appendix B, p. 55) or a modern alluvium sample site (Appendix B, p. 57).

For humus geochemical sampling at least 20 gm of organic rich material is required. Ensure that the sample consists primarily of organics, removing as much of the mineral material as possible.

For "B" and "C" horizon geochemical sampling (-63 micron or finer) of a subglacial till, only 200 gm of material is required. Preferably, the unoxidized "C" horizon should be collected, however, this horizon may not always be available or practical to get at as soil pit or section at least 1 m deep is required. A subsample of 50 or more pebbles is worth collecting as the pebbles will give you an excellent signature of the local bedrock. For the "B" or "C" horizon heavy mineral sampling, material should be passed through a 1 cm² steel mesh sieve. A sample of at least 10 kg of the -10 mesh (-2 mm) fraction should be collected.

The types and quantities of materials collected can be streamlined for specific indicators. However, when possible and feasible, collect samples of humus, "B" and "C" horizons, a bulk 10 kg sample of "C" horizon material and pebbles at each sample site. Since much in the way of financial resources is invested in placing a crew in a field area, as wide a variety of material should be sampled as possible while the crew is at the sampling site.

Sampling of modern alluvium or other sand and gravel deposits is commonly done to obtain a heavy mineral concentrate (specific

gravity >3.3). Material should be passed through a 1 cm² steel mesh sieve so that 10 kg of the "finer" material is collected. Pebbles from the coarser fraction should also be sampled. If resources permit, the 10 kg of "finer" material can be further processed in the field through the use of finer meshed sieves and shaking tables. This will reduce the cost of shipping materials from the field, but will potentially increase the field time and hence expense of field programs.

Field Trip

Introduction

The Wawa region was initially settled in 1725, with the establishment of a fur trading post at the mouth of the Michipicoten River. In the late 1890's a gold rush was accompanied by the establishment of the Wawa townsite. Attention, however, quickly focused on an iron ore discovery, the future development of which became the town's main industry.

Between 1900 and 1922, iron was mined from an open pit at the Helen Iron Range and gold from deposits around Wawa. Mining ceased until the 1930's when in 1938, mining of siderite for iron began from the Helen Iron Range. Operations continue to the present. Gold prospecting flourished during the 1930's but decreased during World War II. Recently a renewed interest has developed for the exploration and mining of gold (Sage and Heather 1991).

In 1978, the OGS initiated a systematic bedrock geology mapping program of the Wawa area which was completed in 1988. During the summers of 1990 and 1991, a regional Quaternary mapping program was completed to compliment the bedrock mapping and provide Quaternary geology information for mineral exploration, environmental and land use applications. With the announcement of the alluvial diamond discovery in the Michipicoten River area in the fall of 1993, the OGS extended its mapping and overburden sampling program to the Michipicoten River valley.

From these Quaternary mapping projects an understanding of overburden types, their distribution, and physical and geochemical properties has been established. The purpose of this guidebook and related field trip is to review what these local overburden materials are and how they can be used most effectively for mineral exploration.

Site #1; Introductory Overview Site

Appendix A: Algoma Ore Division, Helen Mine

This first stop overlooks abandoned open pit workings on the Helen Iron Range from which a hematite-goethite gossan above the siderite and sulphide facies iron formation was removed. Extractive operations between 1900 and 1918 produced an estimated 2,780,236 tons of ore. Operations did not resume until 1939 when open pit mining of the unweathered siderite began. Underground mining of siderite began in 1949 and continues to the present. An estimated 83,711,391 tons of siderite have been produced up until 1986; reserves as of 1984 were estimated at 58,246,000 tons (Sage and Heather 1991).

On a clear day, this site provides a spectacular overview of the Wawa area. The Wawa townsite, Citadel Gold Mines and the Lake Superior basin can be seen to the southwest. Directly south is Wawa Lake which occupies a linear bedrock controlled valley 1 km wide by 8 km long, and 20-35 m deep. During deglaciation, this valley was connected to higher lake levels within the Lake Superior basin. The west end of this basin closed as a barrier bar, on which Wawa is built, formed during regression of lake levels.

At the east end of the lake, one can see where water was forced through a narrow bedrock controlled constriction to form a delta in Glacial Lake Minong. To the north is a spectacular view of the defoliated zone where the impressive terraces of the Magpie River can be seen.

At this site a summary of the area's cultural and economic history, vegetation, climate, bedrock and Quaternary geology in addition to the physiography will be reviewed. Much of this information is provided in the "Background Information" section of this guidebook.

Drive to Site #2.

As we pass through Wawa the road rises onto a pronounced, raised surface. The eastern part of Wawa is built entirely on sand and minor gravels of a barrier beach bar that sealed the southwest end of the Wawa Lake basin during the middle-Minong Lake stage. The barrier beach was modified by a combination of shoreline wave cutting and fluvial terrace development of the Magpie River. The western half of the town occupies a prominent terrace/beach surface. There is an arcuate escarpment edge that limits urban development. Three steep escarpments are traceable across town.

Site #2: Pothole, Mafic and Volcanic Rock and Lamprophyre Dike.

Appendix A: South side of Highway 101, about 10 km east of Wawa.

This site features a pothole, mafic volcanic rock and a lamprophyre dyke. At this location the ice margin retreated north-northeast and east from around this bedrock high. Debris-charged meltwater from this wasting ice created a delta at the Glacial Lake Minong level within the Lake Superior basin. Remnants of this delta are visible below; a site we will visit later.

At this site, meltwater was forced through this narrow opening in the bedrock under great hydrostatic pressure. This is demonstrated by the formation of a scour pool and pothole. As water was forced up and through this narrow bedrock constriction, it scoured the ground on the upflow side of the constriction, leaving what is now Ghost Lake. Within this constriction, the circular rotation of water rotated "grinders" that literally drilled a hole into the bedrock surface. As ice continued to waste eastward from this site, this meltwater channel was abandoned and flow was directed south through the Firesand Creek meltwater channel, to the east (Figure 5).

There are excellent exposures of pillowed mafic volcanic bedrock and a lamprophyre dyke. The dyke has an elevated radiation level. There are several of these dykes which likely radiate outwards from a carbonatite to the south. Little is known about the mineralogy of these dykes and their possible association to kimberlite.

Drive to Site #3

As we proceed east, the landscape opens up and becomes flat. This feature is a glaciofluvial outwash plain, with glacial drainage south through the Firesand Creek meltwater channel to the Michipicoten River valley (Figure 5). Highway 101 crosses several terraces which are the result of downcutting of the outwash surface by rivers as the base (lake) level in the Lake Superior basin dropped. During its eastward retreat across this valley, the glacier likely stopped several times. The best evidence for this is a moraine composed of ice-contact stratified drift which is orientated perpendicular to the valley axis. The highway cuts through this feature: we will examine the materials of this moraine at Site # 5.

At the turnoff to Hawk Junction, note the depression on the west side of Highway 547. This circular depression is a kettle which formed when an ice block, after being detached from the main ice body, was buried by outwash and subsequently melted. These circular depressions, when filled with water, look similar to circular lakes associated with kimberlite. The ice sitting in this valley continued to force water west and south through the Firesand Creek meltwater channel but now also forced water south through the

Grant Lake meltwater channel (Figure 5).

In route to the town of Hawk Junction Highway 547 has been built on fine sand associated with the distal edges of a glaciofluvial fan. To the north the road crosses several cycles of fine- and coarse-grained sand. Each of these cycles represents proximal (coarse sand, boulders) and distal (fine sand) facies of glaciofluvial fans associated with stillstands of the ice margin during northward retreat up the McVeigh Creek valley.

Site #3: Lodgement Till Section

Appendix A: West of Hawk Junction

At this site a section through lodgement till is examined and discussed (Figure 6). The site is located on the up-ice side of a prominent bedrock high. Here, a relatively thick lodgement (subglacial) till has been deposited.

The section consists of a black (10 YR 2/1 m), 10 cm thick humus layer containing abundant decomposed roots and leaf matter. The lower contact is wavy and clear. The underlying "Ae" horizon consists of 13 cm of light grey silt (10 YR 7/2 m). This material appears massive when wet but platy and loose when dry. The lower contact is wavy and diffuse. The "B" horizon consists of 25 cm of reddish brown (10 YR 4/4 m), thick sandy silt. This material is massive and slightly compact. Subangular clasts, up to 9 cm in diameter, are common. The lower contact is wavy and diffuse. The "C" horizon consists of dark yellowish brown (10 YR 4/4m), > 50 cm thick, silty sand. This material is very fissile, platy and compact. Angular to subangular clasts are abundant.

In general, clast abundance within subglacial till ranges from rare to common, with clasts usually concentrated near the bedrock contact. Till pebble lithology determinations indicate that clasts collected from this till facies tend to have local origin. Pebbles from subglacial till collected over the greenstone belt consisted of 29.8% granitic clasts and 69.2% clasts derived from the supracrustal rocks. Pebbles from till collected over the granitic terrane consisted of 70% granite clasts and 30% clasts derived from the greenstone belt.

SOIL WEATHERING

Soil horizons are produced due to the weathering of overburden materials and subsequent translocation of weathered products through the soil profile. This commonly leads to the development of humus, "A", "B" and "C" horizons.

Soil profile studies have demonstrated geochemical differences between the oxidized "B" horizon and unoxidized "C" horizon (Coker and DiLabio 1989; Shilts and Kettles 1990; Law et al. 1991).

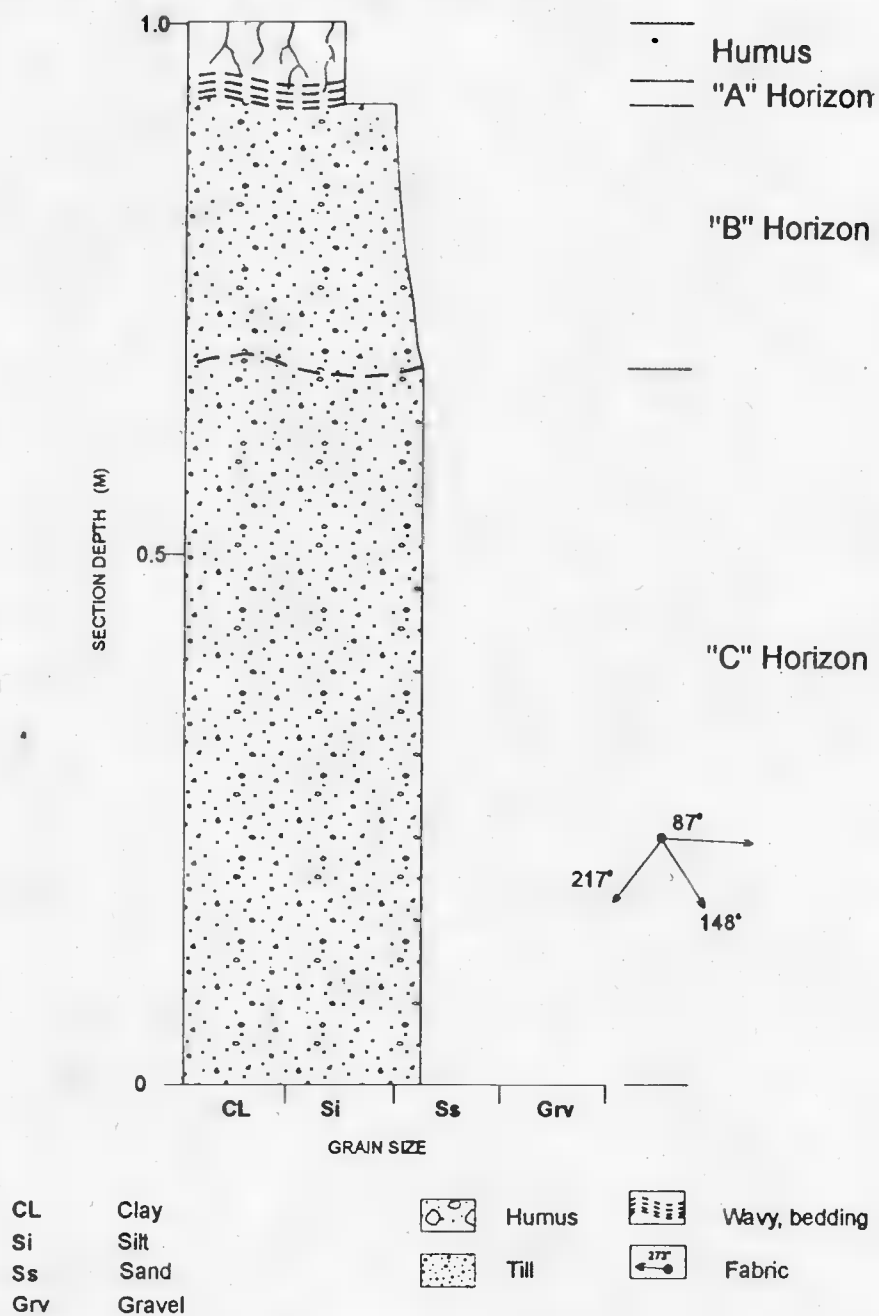


Figure 6: Lodgement till section. See text for description.

Commonly, the chalcophile elements such as copper, lead, zinc, cobalt and nickel are leached out of the "B" horizon due to the breakdown of the host sulphide mineral. Chromium is not as susceptible to leaching-out of the "B" horizon as it is commonly hosted in more resistant chromite.

A relationship exists between the clay percentage of a soil horizon and the metallic element abundance within that horizon. Clay has a high element adsorption capacity due to the large clay mineral surface area and related charge. Shilts and Kettles (1990) demonstrated that the clay fraction (<2 micron) yields significantly higher metallic element values than the silt and clay size (<63 micron) fraction of the same sample. This is due to the dilution of the metal rich clay fraction by the metal poor silt fraction.

The clay mineral distribution with depth in soil profiles is largely dependant upon the local leaching conditions and depth of the soil profile. Leaching conditions can be broken down into extensive, moderate and negligible categories with the extensive and negligible leaching conditions producing uniform grain size and geochemistry throughout the profile. Intermediate leaching conditions can provide variable grain size and geochemistry through the soil profile (Birkland 1974).

Most of the till deposits in the Wawa area are thin and consist largely of a "B" horizon. The degree of leaching is assumed to be intermediate to extensive given the climatic conditions and vegetation type.

The geochemistry of some composite soil profiles from the Wawa area indicate that lead, zinc, arsenic and antimony are concentrated in the humus layer relative to the other soil horizons. This may be due to anthropogenic reasons and may not be due to a local bedrock source as the related "B" horizon geochemistry does not indicate any anomalous geochemical values.

The "A" horizon has the typical platy structure and light colour of an "Ae" horizon (Agriculture Canada 1977). The "Ae" horizon of the Wawa area is characteristically depleted of metallic elements as clay from this horizon has been eluviated into the "B" horizon. The "B" horizon commonly has a sharp upper contact with the "Ae" horizon. The "B" horizon is typically enriched with element illuviated from the "Ae" horizon.

The occurrence of a "C" horizon in the subglacial till is rare. Where observed, the "B-C" horizon contact is diffuse with no accumulation of clay at the contact. The geochemistry data indicates that an enrichment of metallic elements within the "C" horizon does not occur.

SUBGLACIAL TILL AS A MEDIA FOR DRIFT PROSPECTING

Till derived from a mineral deposit has properties that make it unique from surrounding tills. These unique properties could include specific clast types or geochemical or heavy mineral signatures. The unique property is referred to as the indicator. The bedrock from which these unique properties were derived is called the target. The indicator is usually concentrated at or near the target (the head) and decreases exponentially down ice (the tail; Kazycki and Shilts 1989, Peltoniemi 1985, Szabo et al. 1975, Shilts 1976).

Recognition of variables which control material dispersal were defined during the first OGS Quaternary project in the Wawa area. This was done through examining the regional and local distribution of clasts within till.

On a regional scale, the rate of ice flow will control the relative distance of material transport. Faster flowing ice will pass over a surface many more times relative to slower moving ice and therefore incorporate and disperse more target material. Studies have demonstrated that ice streams within ice sheets transport materials farther than the surrounding ice (Dyke and Morris 1989).

One of the more important observations made from the regional clast data was that ice flow over the Wawa area was relatively uniform. This is reflected in the relative uniform concentration and dispersal distance of clasts from related bedrock types. This is not to imply that the broad dispersal of material on to or off of different bedrock terranes is everywhere equal. There are local factors which can control local distance of transport; bedrock topography being one of prime importance.

Some of the more important controls of mineral dispersal were determined from several semi-regional studies in the Wawa area. These semi-regional studies involved collection of till samples in a down ice direction from a chosen target. Indicators within the till were clasts which had been eroded from the target. Although several studies were completed only 3 are presented here (Figure 7).

Some of the more important controls recognized are: a) target size (Figures 8, 9); b) topography (Figure 10); c) relative hardness of materials (Figure 9); and d) relative rate of ice flow. The semi-regional studies indicate that distance of transport was consistently less than 8 km and commonly less than 5 km. Source areas, or targets, for these studies had width perpendicular to ice flow of 4 km or greater.

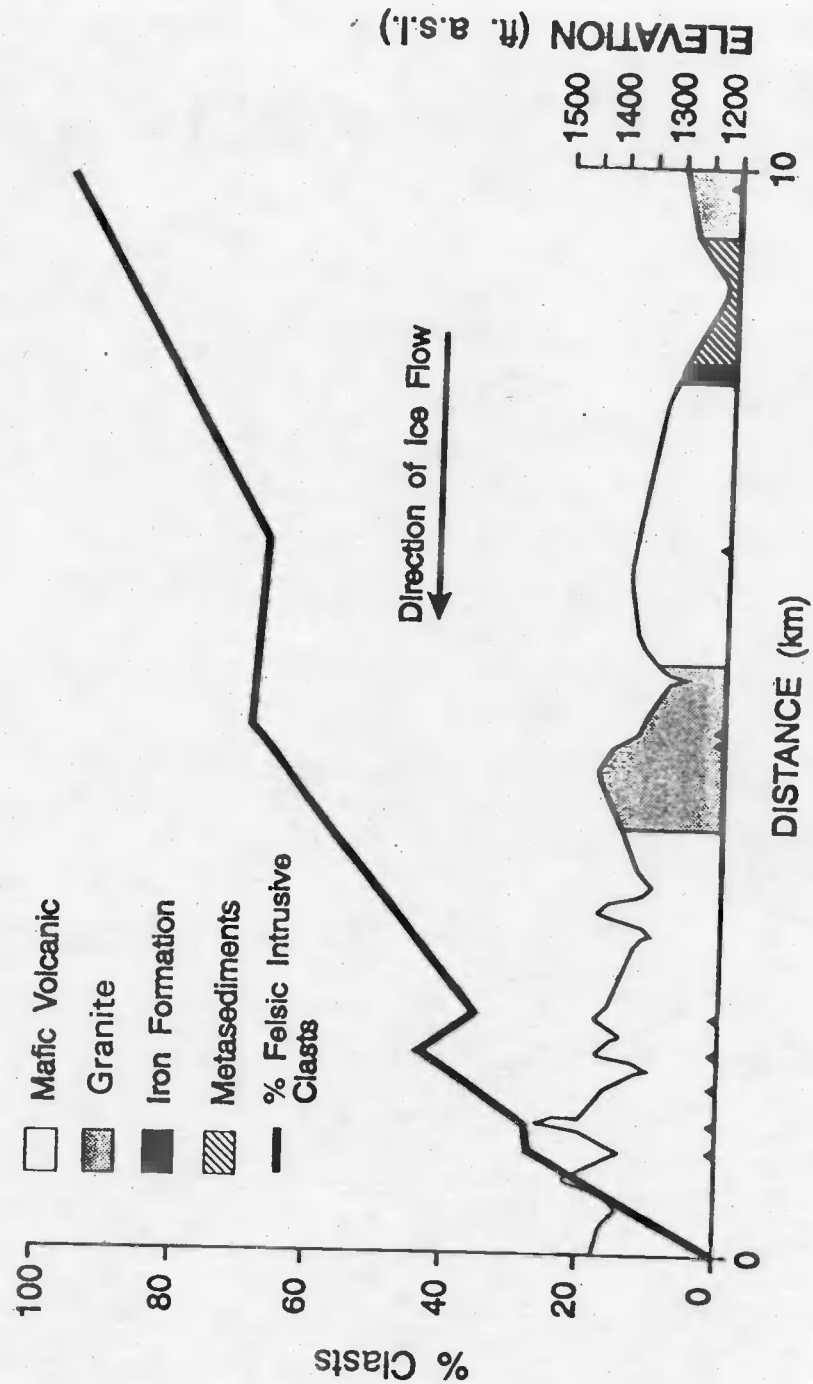


Figure 8: Mall Lake dispersal (small, local target). Ice flow has dispersed granitic clasts southwest of granitic terrane over the greenstone belt. The percentage of granitic clasts decreases exponentially, as expected, until the ice crossed a small granitic stock. The percentage of granitic clasts increases at this point then disappears to 0% within 4 km downice of the stock.

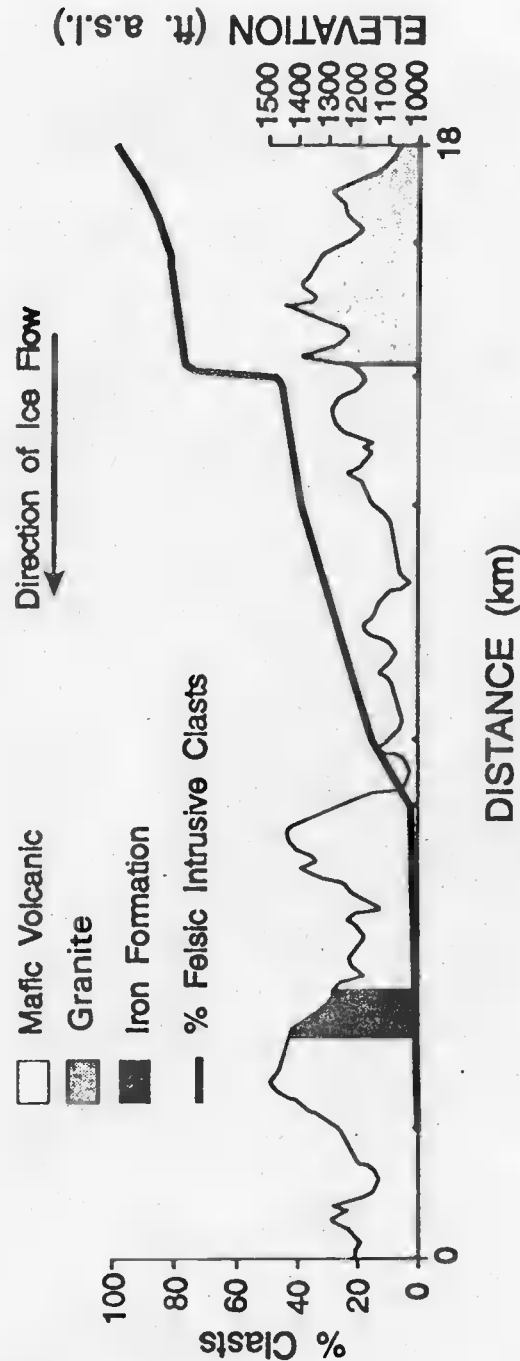


Figure 9: Wawa Lake dispersal (larger, regional target). Granitic clasts were dispersed southwest onto the greenstone belt through the Wawa Lake basin off of a granitic terrane. This granitic terrane is a large target with flow into a basin. In addition, the indicator, granitic clasts, is relatively harder than material making-up the greenstone belt. These factors allow for a longer distance of transport, 10 km, than most other sites.

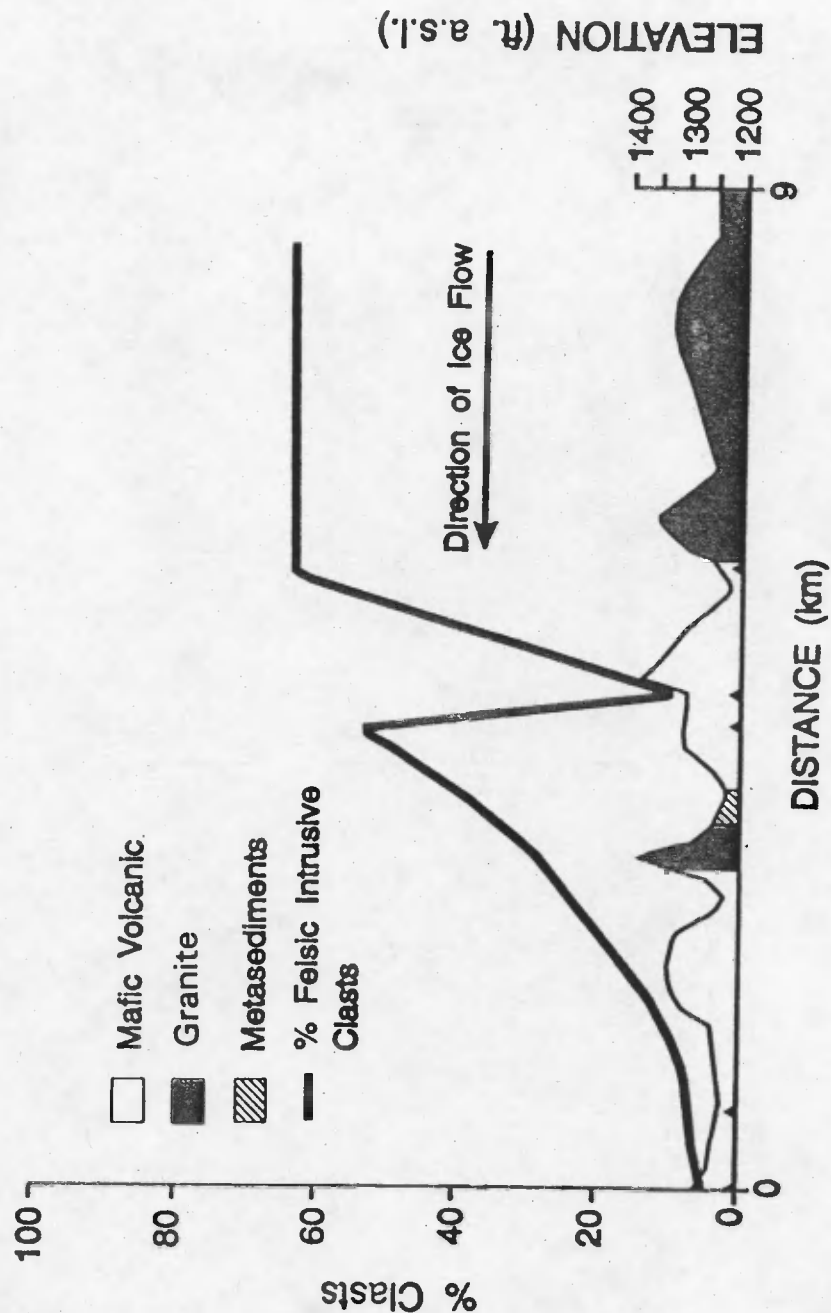


Figure 10: Black Trout Lake dispersal (topographic shadow). The ice dispersed granitic clasts southwest off the granite terrane onto the greenstone belt in a topographically rough area. One sample was collected on the down ice side of a bedrock high, a site protected from the deposition of material from the granitic terrane.

Drive to Site #4.

We head back along Highway 547 to the turnoff to Air Dale, a sea plane base that caters largely to sport fishermen during the summer.

Site #4: Proglacial Outwash Section

Appendix A: Southeast of Hawk Junction

This site is typical of a proglacial outwash deposit (Figure 11). The section exists as material from this site was used for local road construction. The glacier was in close proximity to this site during deposition of the material. This is indicated by the coarseness of the sediments in the lower part of the section indicating a high energy, ice proximal depositional environment. The associated glacial meltwater spilled through the Hawk Lake basin into the Firesand Creek meltwater channel and south into the Grant Lake meltwater channel (Figure 5).

The upper part of the section, Unit 1 (Figure 11), consists of 1.9 m of pale brown (10 YR 6/3 m) cobbly, coarse sand. The material is massive and slightly cemented with calcium carbonate. The lower contact is marked by a 15 cm layer of finely planar, laminated coarse sand (Unit 2). The underlying unit, Unit 3, consists of 3.5 m of pale brown (10 YR 6/3 m) cobbly sand. Faint, planar bedding is best observed after a rain storm event. The beds dip gently west, parallel to Hawk Lake. Clasts are subangular to subrounded and the lower contact is diffuse. The lower unit, Unit 4, consists of >13.7 m of pale brown (10 YR 6/3 m) boulder-rich gravel with a coarse sand matrix. The material is massive and loose with subangular to subrounded boulders.

The material at this site would be useful for a regional heavy mineral or pebble sample. It is not an ideal media for local drift sampling due to the deposit's restricted distribution and more regional material composition. This site, and the fine-grained material we crossed upon entering Hawk Junction, demonstrate the variability in textures of materials associated with glaciofluvial outwash. With distance from the ice margin, material generally becomes better sorted and heavy mineral signatures more concentrated.

Drive to Site #5

Road conditions permitting, we will follow a gravel track west that skirts the outwash plain to the south and the south shore of Hawk Lake.

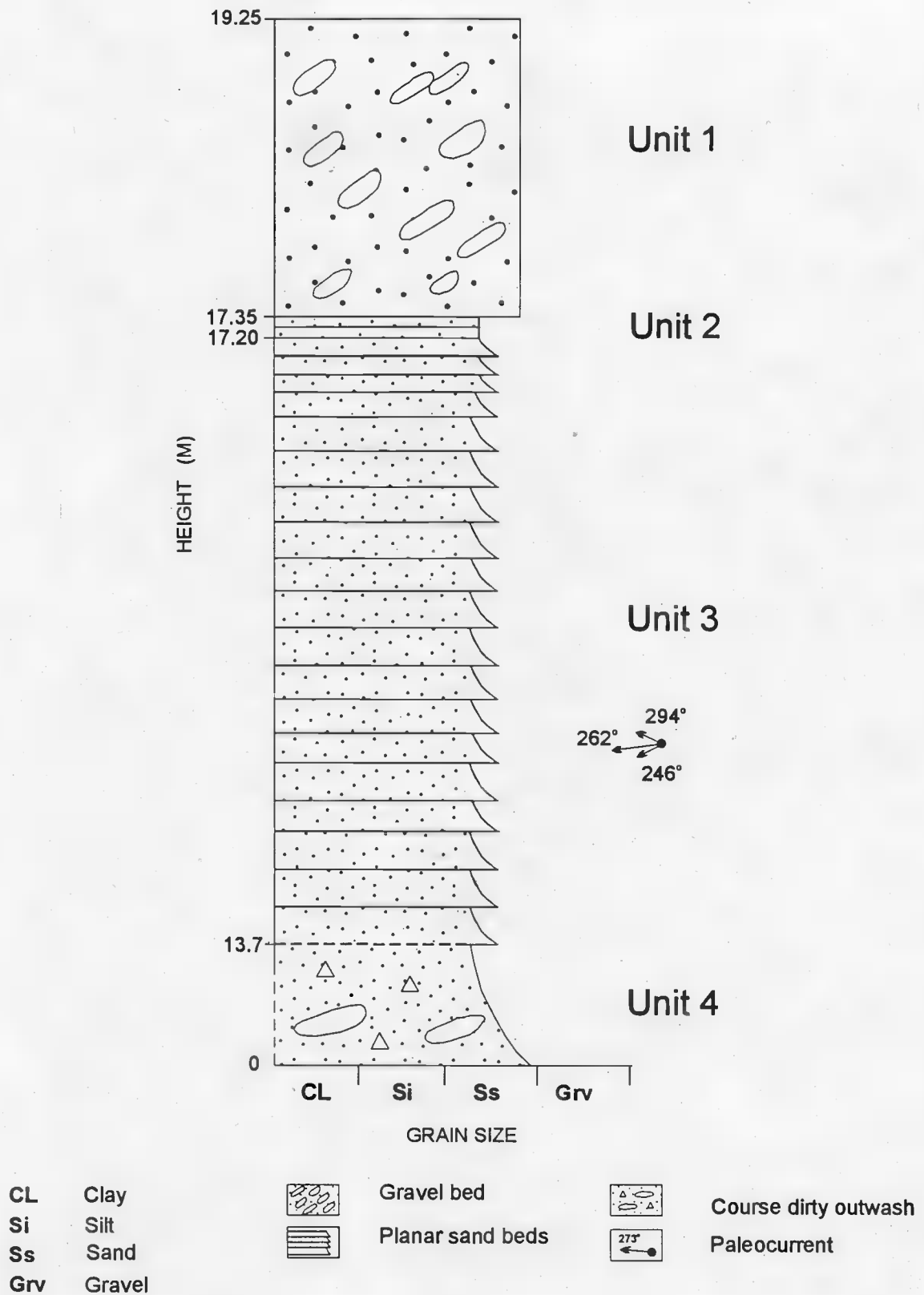


Figure 11: Proglacial outwash section. See text for detailed description and discussion.

Site #5: Moraine and Ice-Contact Stratified Drift

Appendix A: Southwest end of Hawk Lake

At this site we will examine ice-contact stratified drift associated with a recessional moraine (Figure 12). This is the same moraine that we crossed between Sites #2 and #3 while travelling east on Highway 101. The ice sheet existed in a state of equilibrium long enough to deposit the morainic material. Occasional flows of diamicton (flow till) extended out from the ice margin. The meltwater associated with this ice margin flowed westward then south into the Firesand Creek meltwater channel (Figure 5).

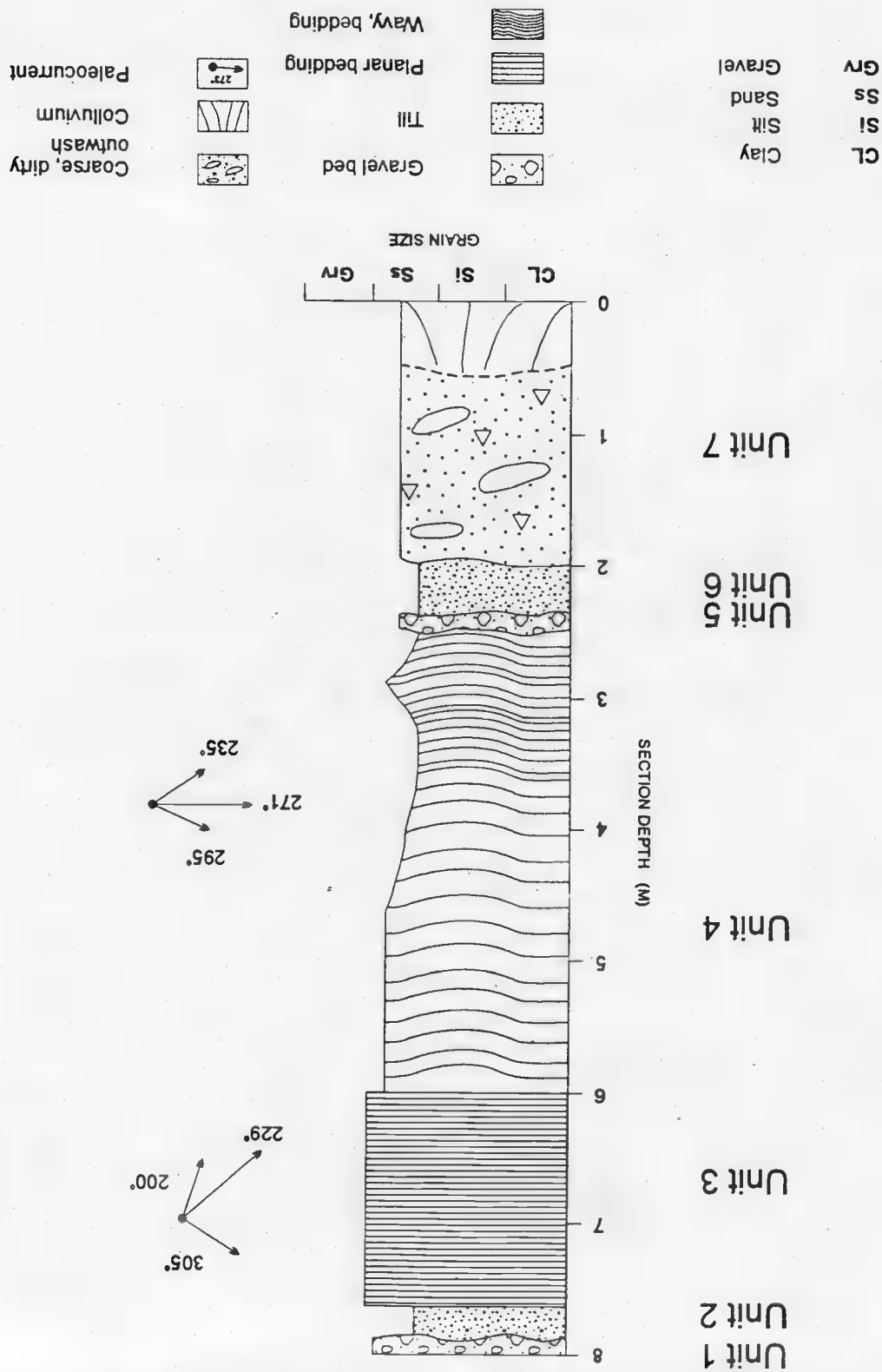
The section consists of 10 cm of an upper unit, Unit 1, of reddish brown (5 YR 4/3 m) cobbly sand. The unit is massive and the cobbles are well rounded, some flat. The lower contact is wavy and sharp. Unit 2 consists of 21 cm of yellowish brown (10 YR 5/4 m), very fine sandy silt. The material is massive, compact and shows no reaction with HCl. Common clast types are of rounded granite and mafic volcanic rock. The lower contact is smooth and wavy. Unit 3 is composed of 1.6 m of dark greyish brown (10 YR 4/3 m), coarse sand. The upper few centimetres are massive with a few large, subangular granite clasts. The massive structure grades to planar bedded sand, with the layers accentuated by darker heavy mineral bands. The lower contact is sharp.

Unit 4 consists of 3.61 m of light yellowish brown (10 YR 6/4 m) sand. The upper 83 cm is coarse sand with planar beds and some ripples which fine downwards to sand which comprises most of the unit (2.17 m). The lower part of the unit consists of 1.44 m of cycles of finer and coarser sand with low and high angled ripples, some with foreset bedding. The lower contact is clear and wavy. Unit 5 consists of 12 cm of dark greyish brown (10 YR 4/2 m) coarse pebbly sand. The material is massive and loose. The pebbles are subangular to subrounded and consist mainly of granitic rock. The lower contact is clear and wavy.

Unit 6 consists of 38 cm of greyish brown (10 YR 5/2 m) silty sand. The material is massive, compact and reacts strongly with HCl. The lower contact is wavy and clear. Unit 7 consists of >5 m of greyish brown (10 YR 5/2 m) coarse, pebbly sand. The material is massive and loose. There are abundant subangular to subrounded clasts.

This lengthy section description emphasises the stratification of materials associated with this type of deposit. The lower part of the section (Units 6 and 7) demonstrate the very close proximity of the site to the ice margin. Unit 6 represents a debris flow off the ice margin, whereas the very coarse Unit 7 represents a high-energy glaciofluvial environment typical of an ice proximal location. The upper units represent either an ice marginal,

Figure 12: Ice contact stratified drift section. See text for description.



perhaps fluctuating setting, or a braided stream environment.

The material associated with this site is not regarded as a prime sampling media for local drift prospecting studies. The materials are derived from both local and distal sources. In addition, the distribution of this material is not widespread, making it difficult to maintain sample continuity. In terms of aggregate potential, the materials are not ideal for roadbed use due to their fine-grained nature. An example of how poor this material is for roadbed construction is demonstrated by the poor road which we just travelled over.

Drive to Site #6

Just east of Site #5 the road takes a sharp bend across the channel where meltwater flowed from the Hawk Lake basin into the Brummer Lake basin before exiting into the Firesand Creek meltwater channel. As we continue east, the road enters onto a broad glaciofluvial outwash plain associated with the Firesand Creek meltwater channel.

Site #6: Minong Delta

Appendix A: North side of Highway 101, 10 km east of Wawa

The road which we have turned onto (Loonskin Lake Road) follows a series of sites which demonstrate features associated with meltwater channels. This site is at the terminus of a meltwater channel. Here, meltwater flowing from ice situated in the Scott Lake basin, empties into Glacial Lake Minong (308 m asl). The materials you see here are associated with a delta which formed in this lake about 9200 years ago.

There are several excellent sections through the lower part of this delta. Material associated with the upper part of this delta is obscured by colluvium. It does not appear, however, that the topset beds of a classic Gilbert-style delta exists at this site.

The lower part of the delta consists of steeply dipping foreset beds composed of poorly sorted, subrounded to subangular cobbly gravel and coarse sand. The bedding has a strong paleocurrent direction of 226°. The clasts are weakly to moderately cemented by calcite and, to a lesser extent, iron oxides, primarily limonite. The origin for the carbonate cement is not well understood. There are 2 potential sources: 1) from abundant syngeneic carbonate alteration (primarily ankerite) of the local early Precambrian metavolcanic bedrock, or; 2) from clasts originating from the Paleozoic carbonates of the Hudson Bay Lowland, found within the material.

This deposit is of limited value for local drift prospecting. The heavy mineral and clast signature is a blend of both local and distal sources. In addition, the regional distribution of this material is restricted to bedrock controlled valleys. The aggregate from this pit has been used for road bed construction.

Drive to Site #7

We proceed along Loonskin Lake Road as it skirts the meltwater channel associated with the Minong Delta. Loonskin Lake Road provides access to the Eleanor Iron Range which was mined from the Sir James Dunn open pit from 1958 to 1967 and produced 1,646,000 tons of siderite. Reserves below the pit floor are estimated at 1,250,000 tons of siderite (Sage and Heather 1991). The Eleanor Iron Range is at the eastern extension of the Helen Iron Range and occurs in a wedge-shaped block bounded on the west and the east by branches of the Mildred Lake Fault and on the south by the Wawa-Hawk-Manitowik lakes fault.

Once we pass the Sir James Dunn open pit, the road passes over the surface of the meltwater channel represented by flat, open stretches of ground covered by sand and gravel.

Site #7: Kame and Kettle (Dead Ice) Topography

A brief stop is made here to view an excellent example of kame and kettle topography. Here, a block of glacial ice became detached from the active ice margin and was subsequently buried by glaciofluvial deposits. Upon melting, depressions and conical hills composed of sand and gravel formed.

Material associated with this deposit is derived from both local and distal sources. The associated heavy mineral and clast signature would be useful for obtaining a regional heavy mineral signature. The aggregate is excellent for roadbed use.

Drive to Site #7A

Loonskin Lake Road eventually splits. The west branch, now blocked, leads to the Lucy Pit developed within the Lucy Iron Range. The Lucy Iron Range is the eastern extension of the Eleanor Iron Range. It is separated from the Eleanor Iron Range by roughly 3500 m of left-lateral faulting. Mining operations were short lived and ceased in 1970 after 3 years of operation. The operation produced 1,073,000 tons of siderite and reserves are estimated at 1,300,000 tons of siderite (Sage and Heather 1991).

We proceed north along the north branch of Loonskin Lake Road as it begins to drop in elevation. The road splits again just south of Scott lake, this is Site #7a.

Site #7A: Modern Alluvium, Ice Margin Deposit

This site provides an excellent opportunity to emphasize the complexity of glaciofluvial systems and associated meltwater channels. As noted, the road falls in elevation from the Lucy Pit turnoff to this site. For glacial meltwater to feed into the Loonskin Lake meltwater channel and the Minong Delta, Site # 6, drainage through the Loonskin Lake channel had to have been blocked. This required the presence of an ice margin at this site. However, as the ice margin receded, an opening occurred between the ice margin and the bedrock controlled high ground. This caused the abandonment of the Loonskin Lake meltwater channel and the establishment of glacial meltwater flow into the Magpie River meltwater channel (Figure 5).

The section on the east side of Loonskin Lake Road exposes material associated with this moraine (Figure 13). Although in contact with the ice margin, the sand and gravel deposited is remarkably clean.

Unit 1 consists of 2.7 m of dark yellowish brown (10 YR 4/3 m) sand (Figure 13). The material is massive and loose and the clasts are rounded. Unit 2 consists of 1.2 m layer of boulders that angle upward through the section. Unit 3 consists of >5 m of dark yellowish brown (10 YR 4/3 m) cobbly sand containing abundant angular clasts and boulders.

As at Site #7, materials associated with this deposit are derived from local and distal sources. Limestone clasts from the Hudson Bay Lowland, for example, have been found here. Therefore the heavy mineral and clast component of this deposit would be useful for obtaining a regional signature. The sand and gravel would be an excellent source for road bed.

SAMPLING MODERN ALLUVIUM

A small, unnamed stream flows north into Scott Lake at this site. As this stream flows through glaciofluvial outwash it is heavily charged with sediment allowing for a modern alluvium sampling demonstration. The sample site consists of a well developed diagonal bar. Site observations are made using the modern alluvium site sampling observation sheet (Appendix B, p.57).

Material is collected from beneath the bar surface and passed through a 1 cm² steel mesh sieve. When enough material (10 kg) has passed through the sieve, excess water is drained from the sample and poured into a sturdy, well labelled plastic bag. The bag is placed in a haversack and the weight is roughly checked by scale. A piece of paper with the sample number is placed in a "baggy" and inserted in with the sample before the bag is sealed.

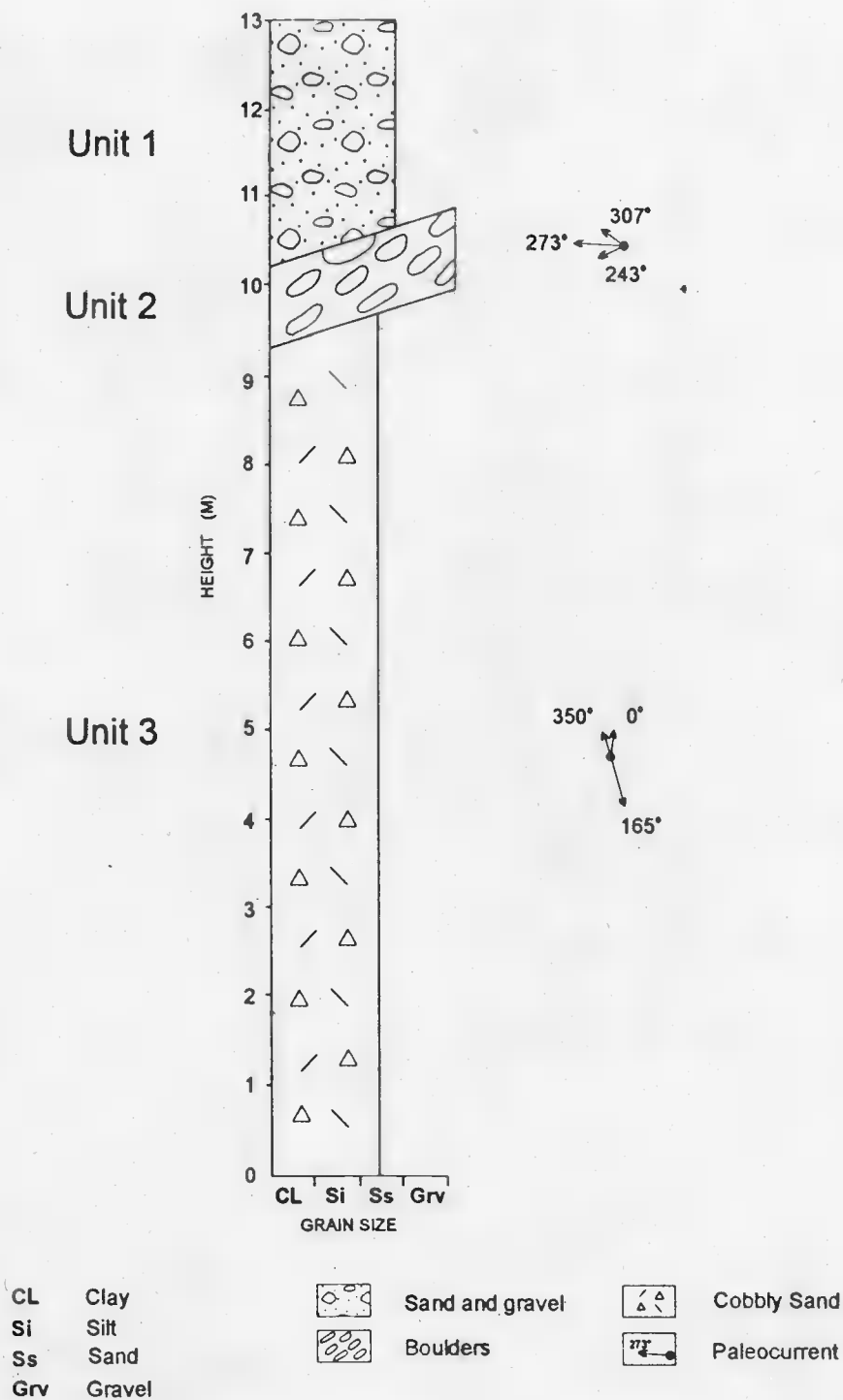


Figure 13: Scott Lake moraine section. See text for detailed description and discussion.

Approximately 50 to 100 clasts are subsampled from the coarse material retained on the screen. In addition, a subsample of the finer grained material ($<1\text{ cm}^2$) is panned and observations of the heavy mineral fraction are made. The panned material is also stored in a labelled "baggy" and put in with the clast sample bag for future reference. Any interesting rock samples associated with the site are also collected and labelled.

The heavy minerals and clasts collected from this site are derived from both the bedrock and overburden through which this stream has passed. When interpreting the data from this sample, it is essential to catalogue what bedrock types and overburden materials exist within the catchment area of the stream. This information will provide a guide as to whether the stream sediment signature is local. Any indicators from this stream may very well have come from a great distance away given that they may have been derived from a large glaciofluvial deposit present in the immediate area.

RESTRICTIONS OF STREAM SEDIMENT SAMPLING

Stream sediment sampling in the Wawa area has demonstrated that a sample collected at the mouth of a drainage basin gives a heavy mineral signature of the overburden (and to a lesser extent the bedrock) over which the stream flows between the sample site and the first significant sediment trap (i.e. a standing body of water such as a lake). Therefore, to maximize the area being "fingerprinted", it is advisable to choose a sample site that maximizes the length of stream between a lake and the sample site (Figure 14).

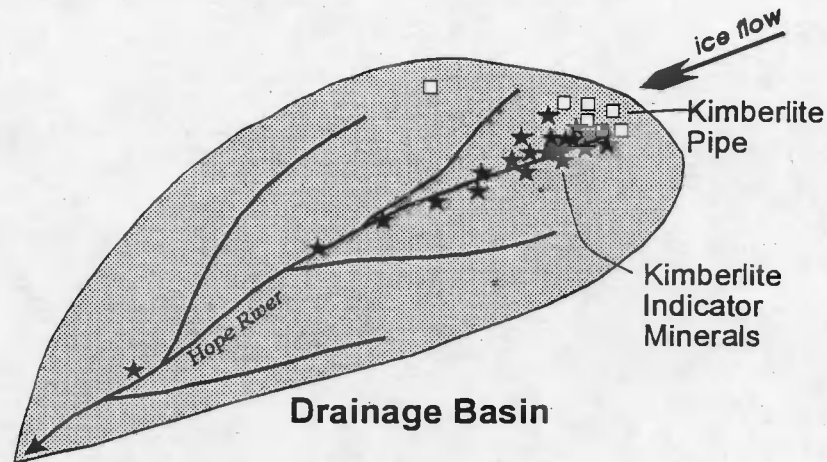
It is also critical to recognize the orientation of the drainage basin being sampled relative to ice flow. The heavy mineral signature of a modern alluvium sample may reflect a deposit farther up the drainage basin or beyond. Glacial erosion of such a target may result in related heavy minerals being transported and deposited within the area of the stream segment that the sample site represents. If the drainage basin being sampled is not aligned in the direction of ice flow, a danger exists in that the heavy mineral signature of that drainage basin may represent a target located up-ice but in the neighbouring (or farther removed) drainage basin (Figure 14). Such a problem was recognized in a sampling program in Brazil (Gonzaga et al. 1994).

Drive to Site #8

We will backtrack south down Loonskin Lake Road to the Sir James Dunn Pit. Here we will follow an abandoned rail bed north to the defoliated zone of the Magpie River drainage basin. The railbed initially cuts through bedrock terrane as it skirts around Lena Lake before veering sharply west towards the Magpie River valley. Just after the sharp turn west, the ground opens up into a

Examples of Kimberlite Indicator Dispersal within Fluvial Drainage Basins

A



B

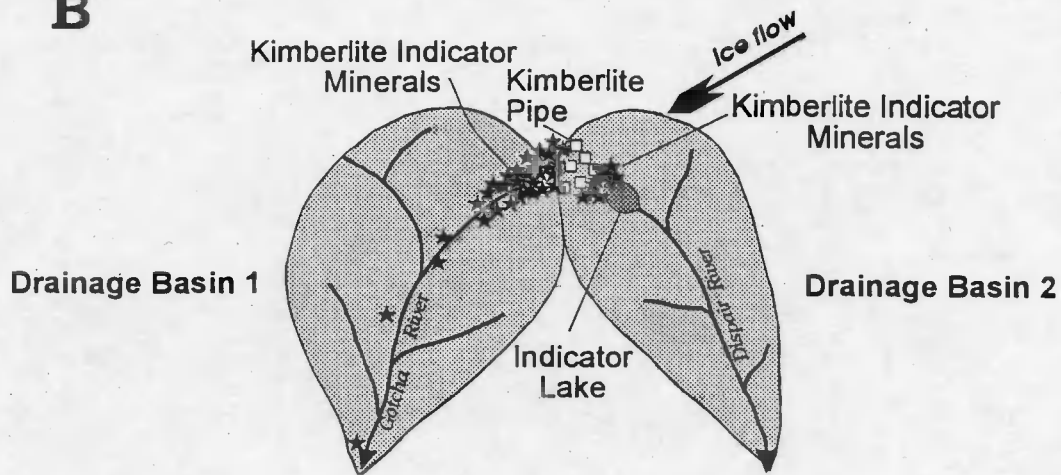


Figure 14: Problems associated with sampling modern alluvium within drainage basins. Part "A" demonstrates the ideal orientation of drainage basin to ice flow. Part "B" demonstrates problems associated with drainage basin orientation perpendicular to ice flow and the effects of a lake on heavy mineral dispersal. See text for details.

remarkable landscape, reminiscent of the midwest prairies or central arctic desert.

The road passes over a broad glaciofluvial deposit which has been fed by a number of meltwater channels issuing from the more rugged, bedrock controlled landscape to the north (Figure 5). As the road swings south, we pass onto the surface of a delta which formed in glacial Lake Minong. The surface elevation of this delta is equivalent to the surface elevation of the delta at Site #6. As we continue south on this road, we will descend over several terrace surfaces which formed as the river cut through the delta in response to lower lake levels in the Lake Superior basin.

Site #8: Mink Lake Glaciofluvial Fan, Straie and "P" Forms

This site overlooks the basin that contains Mink Lake. Around the shores of Mink Lake are several conical hills. These are interpreted to be kames deposited in association with dead ice. North, and immediately in front of the basin, is a smaller basin rimmed with sand. These features demonstrate a process which has occurred throughout the topographically higher areas. Blocks of ice became detached as the ice sheet wasted back. Over time these sediment-rich blocks of ice melted in place leaving kame deposits such as those which rim Mink Lake. In addition, meltwater associated with the wasting of these blocks drained from the basin often leaving small fans composed of coarse sand.

The heavy minerals and clasts associated with these deposits are derived from local and distal sources and therefore give a regional signature. They are not useful for local studies because of the distal component of the material and their erratic and restricted distribution.

Beyond the small fan there is a spectacular view to the northwest of the Magpie River terraces and glaciofluvial sandur surface to the northeast. The terrace surfaces grade to former delta surfaces composed of material transported to the Lake Superior basin by meltwater channels.

Lake levels post date the last retreat of glacial ice from the area. The highest continuous water plain in the Lake Superior basin is associated with Lake Minong which existed within the basin at about 9500 years BP. A drift sill at Nadoway Point, Sault Ste. Marie area, was cut through in 5 or 6 steps reflecting temporary lake levels in the Lake Superior basin. These lakes are referred to as the post-Minong (Dorion-I-IV) levels and terminated with the lowest, Houghton level prior to the isostatic rebound of an outlet at North Bay. The terrace surfaces viewed from this site are all related to the above chronology.

Below the Houghton level there were a series of additional lakes which formed at subsequently lower levels within the Lake Superior basin. Evidence of these lower levels, which include the Nipissing, Algoma, Sault and sub-Sault, are all preserved within the lower reaches of the Magpie and Michipicoten river valleys.

The coarse material on the terrace surfaces northeast of this site does not extend much farther southwest. This coarse material was deposited by a progradation of sandur south onto the terrace surfaces as water levels dropped in the Lake Superior basin. This coarse material is only 1 m thick and overlies up to 33 m of finer grained glaciolacustrine material associated with the bulk of the delta deposit. Once ice receded from the area this supply of coarse material was no longer available. Site #10 will demonstrate this relationship of coarse- and fine-grained materials. North of the Mink Lake basin is an exposed surface of highly polished and striated rock which has also been incised by glacial meltwater forming "P" forms.

Measuring striae orientation is essential when using overburden as an exploration medium. Obviously it is necessary to know the direction from which materials were derived. At this site striae are aligned southwest at 235°. The actual direction of ice flow is determined by looking at the morphology of small scratch marks on the bedrock surface. On the up-ice side of the fracture wall, the wall is steep as it had been plucked by ice freezing onto the rock surface, thereby pulling the rock away. As ice continued to flow over the fracture, the down ice wall was smoothed by abrasion.

Much controversy exists regarding the formation of "P" forms. Some argue that they are the result of strictly glacial erosion while others argue they are caused by glacial meltwater flow under high pressure between the rock surface and ice base. These "P" forms were likely caused by a combination of both glacial ice and glacial meltwater. The presence of striae within the "P" forms indicates that ice was let back down onto the rock surface once meltwater had been evacuated from the base of the ice. The orientation and location of the "P" forms indicates that meltwater under high hydrostatic pressure did not have to follow bedrock controlled channels. The water formed channels within the base of the glacier, ignoring the configuration of the bedrock topography.

Drive to Site #9

We backtrack northeast along the Magpie River road to Site #9, crossing over the coarse surface of at least 2 terraces.

Site #9: Older Alluvium Section

Appendix A: Magpie River Road

This site is optional given the time and number of participants willing to clamber down 33 m of coarse terrace colluvium. Remember, in this case, that what goes down must come back up to the trucks.

This site is situated on the south bank of the Magpie River just upstream from where the river takes a sharp northwest jog around a bedrock outcrop. The section is through a small terrace composed of older alluvium which exists north of and away from the base of the 33 m of coarse terrace colluvium. The origin of the material within this terrace is not derived directly from the ice sheet but consists of reworked material derived from the higher elevation deltas. This terrace surface is graded to a lower lake level within the Lake Superior basin after glaciers had receded from the immediate area.

The bulk of the section consists of light brown fine sand, about 1.5 m thick. The material consists of couplets about 10 to 20 cm thick comprised of light brown sand with foreset beds, capped by 5 cm of darker brown silt. Paleocurrent measured from the fine-grained sand indicates that the direction of flow was upstream!

The couplets of sand and silt suggest that the river flow was cyclic. Cyclicity is likely related to seasonal changes in flow. During the summer months sand was deposited and during the reduced flow of the winter months the deposition of the finer grained silt took place. Obviously, the silt would have to settle through a standing body of water. The upstream flow direction is confusing until the site is put into context with the bedrock obstruction downstream. This site was likely a whirlpool at one point in time as river flow was deflected upstream off of the bedrock obstacle. A modern analogue to this process occurs just downstream from this site.

The heavy minerals and clasts associated with this alluvium deposit would provide a regional signature as the materials are derived from both local and regional sources. As a local indicator this material is a very poor media to use. Not only is the material blended with both locally and distally derived material, but it has gone through several cycles of erosion, transportation and deposition, making it impossible to trace an indicator back to it's source. In addition, the material is restricted to the lower reaches of the area's major rivers, making it impossible to use this material as a regional sampling media.

Drive to Site #10.

We continue to backtrack along the Magpie River Road until the road branches just below a glaciofluvial escarpment. Fine sand winnowed from the coarse aggregate by prevailing northeast winds blowing off Lake Superior is trapped on the southwest side of this bedrock high. As the road bed is made of eolian sand, it may not be possible to get to Site #10 if the road is wet.

Site #10: Glaciolacustrine Section

Appendix A: Magpie River Road

The section at this site shows the complete suite of materials associated with the terraces (Figure 15). This is one of the few sites where the terrace escarpment is not obscured by boulders.

In simple terms, the section consists of 3 main units. The upper unit, Unit 1, consists of 1 m of brown to dark brown (10 YR 4/3 m) coarse sand and boulders. The material is massive and loose. The boulders and clasts consist of a wide variety of lithologies of varying sizes and degrees of roundness. The lower contact is abrupt and smooth.

Unit 2 makes up the bulk of the terrace. The description here is an extremely simplified description of the associated material structures and textures. Essentially, Unit 2 consists of alternating beds of pale brown (10 YR 4/3 m) coarse sand, brown (10 YR 4/3 m) sand and light grey (2.5 YR m) fine sand. Thicknesses of each sandy bed varies between 2 m and 30 cm. Related structures include massive to planar beds in the coarse sand, planar beds to trough cross-bedding in the sand and trough cross-bedded, planar and massive beds in the fine sand. The vertical distribution of sand textures represent fining upward cycles. The lower contact associated with the coarse sand is often smooth and clear. The lower contacts associated with the other sand textures are more gradual or diffuse.

Unit 3, the lowermost unit, consists of horizontally bedded couplets of varved silt and clay. There are at least 25 couplets each about 25 cm thick. The lowest couplet drapes the bedrock surface.

This section represents the progradation of material (Units 1 and 2) over material deposited in deeper water (Unit 3). Clearly, this section indicates that the bulk of material that makes up the terraces is fine-grained and has limited use as an aggregate resource. Samples of the heavy minerals and clasts of this deposit would be useful to define a regional signature. These same materials would not be as useful for local prospecting due to: the local and distal sources for the materials; and the restricted distribution of these deposits to the mouths of major rivers around

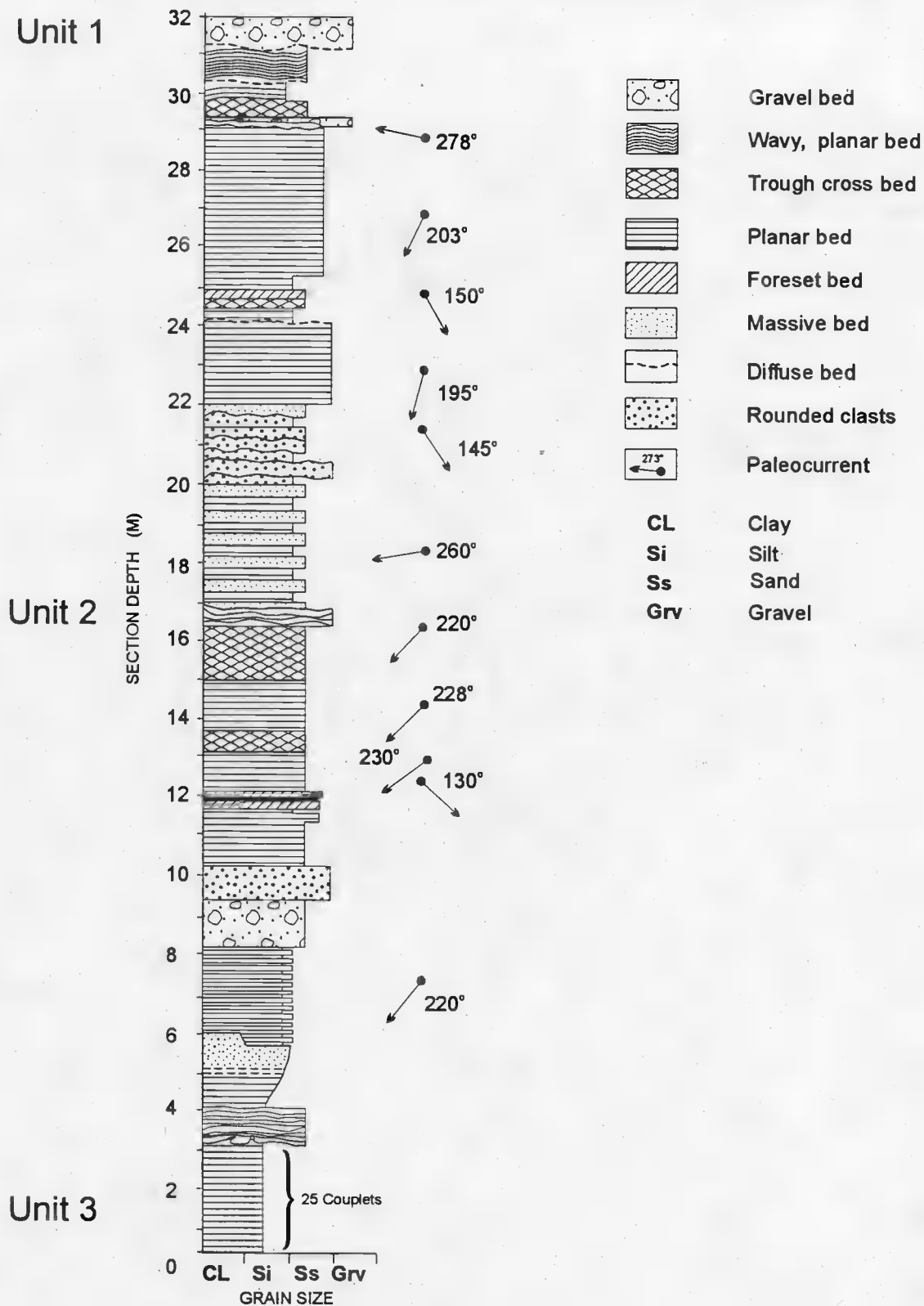


Figure 15: Glaciolacustrine section. See text for description and discussion.

the Lake Superior basin.

Drive to Site #11

We again backtrack to the Magpie River Road and continue north toward Site #11. The road continues across glaciofluvial outwash associated with a remarkable glaciofluvial fan, east of the road. Parallel to the railroad is an elongated lake. This is a scour pool similar to the one discussed at Site #2. Note the lag of boulders on the downflow side of the lake which were literally blasted out of the glaciofluvial outwash surface by water under tremendous hydrostatic pressure.

Site #11: Steephills Falls Moraine

Appendix A: Magpie River Road

This site provides an example of a recessional moraine composed of materials more typically described in the literature. The moraine represents a state of equilibrium between ablation and accumulation of ice within the ice sheet's glacial budget. However, this state of equilibrium was short-lived since the moraines are relatively small and not laterally extensive. There are no sections through this moraine although the moraine is likely composed of flow tills. This assumption is made from observations of sections through recessional moraine elsewhere in the area.

Clast abundance ranges from rare to common with clasts sometimes concentrated within flow structure. Pebble type assemblages determined from flow tills in moraine deposited over greenstone and granitic terranes were compared. Pebble assemblages within flow till associated with moraine deposited on the greenstone belt consisted of 31.6% granitic clasts and 67.8% clasts of greenstone belt origin. Pebble assemblages within flow till of moraine deposited on granitic terrane consist of 34.9% clasts of greenstone belt origin and 61.5% granitic clasts. These pebble type assemblages differ little from the pebble type assemblages associated with subglacial till collected from over granitic and greenstone belt terrane.

The average concentration of Paleozoic clasts within lodgement and flow tills differs little. However, Paleozoic clasts within subglacial till have a more regional, homogeneous distribution throughout the region whereas Paleozoic clasts tend to have a more erratic distribution within moraines; more concentrated within certain moraines over others.

The geochemical, heavy mineral and clast composition of the morainal material at this site may be useful as a regional signature as the moraine is composed of materials derived from local and distal sources. For this reason, the moraine would not be useful as a local sampling media.

Drive to Site #12

The trip continues towards the Steephills Falls Dam. West of the dam, the road crosses several valleys filled with glaciofluvial materials. These are former meltwater channels that fed into the Magpie River valley (Figure 5). Proceeding south, Highway 17 drops below the Lake Minong level north of Wawa and again, the road crosses over several terrace surfaces.

Site #12: Summary Site

Appendix A: Visitors centre, Wawa

This last stop provides an excellent view over the lower reaches of the Magpie River valley. Several of the terraces that trim the valley walls provide a perspective of how high former lake levels were within the Lake Superior basin. The visitors centre is situated on the lowest Glacial Lake Minong terrace surface (294 m).

It is sincerely hoped that this guidebook and related field trip provided an appreciation regarding the use and limitations of overburden in mineral exploration. When done correctly, drift prospecting can be an effective tool to aid mineral exploration.

Summary of Sites:

- 1) Bedrock surface features associated with glacial advance and ice margin retreat were reviewed (Sites #1 and 8). Discussion included the importance of ice flow indicators in establishing ice flow direction, essential for determining material source.
- 2) The need to understand local Quaternary history was discussed (all sites) to determine local ice flow patterns across an area and to determine ice margin retreat patterns and associated meltwater flow. This aids in interpreting the results of any glaciofluvial (Sites #2, 4, 8), glaciolacustrine (Sites #6, 8, 10) or modern alluvium (Site #7, 7a) samples taken.
- 3) The use of subglacial till (Site #3) as the important medium for local drift prospecting was highlighted. The physical characteristics and pedogenic processes that affect geochemical signatures and style of material sampling were reviewed.
- 4) Glacially derived materials and related landforms that provide a more regional signature for drift prospecting were discussed. These included proglacial outwash (Site #4), ice contact stratified drift (Site #5), glaciofluvial outwash (Sites #7, 7a, 8), recessional moraine (Site #11) and glaciolacustrine deposits (Sites #6, 10). The discussion considered the value and limitations of these materials as drift prospecting media.

- 5) The materials and related landforms that have undergone several cycles of erosion, transportation and deposition were investigated. These include modern alluvium (Site #7; 7a), older alluvium (Site #9) and glaciolacustrine deposits (Site #6, 10). The value and limitations of using these materials as sampling media for drift prospecting were also reviewed.

ACKNOWLEDGEMENTS

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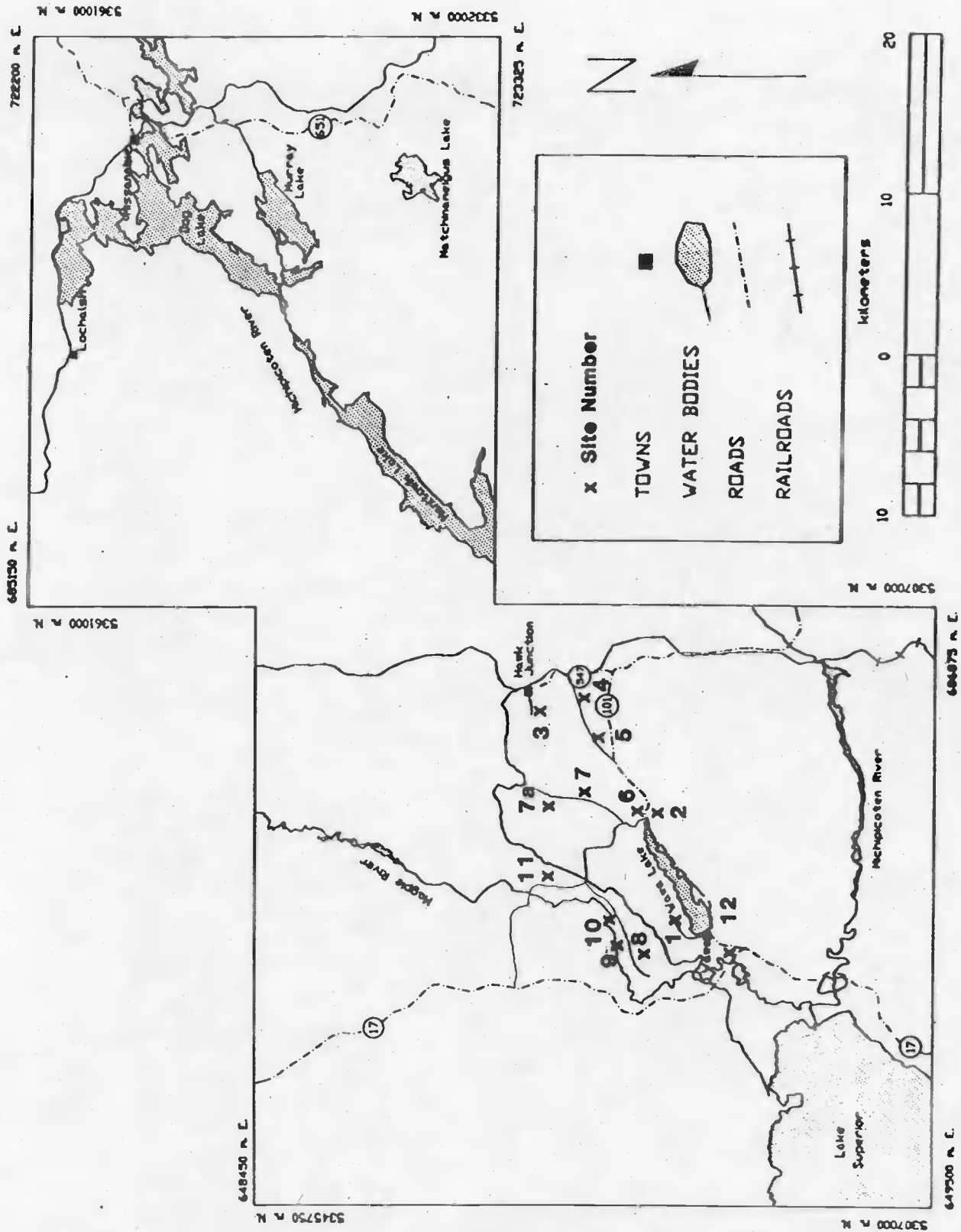
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APPENDIX A

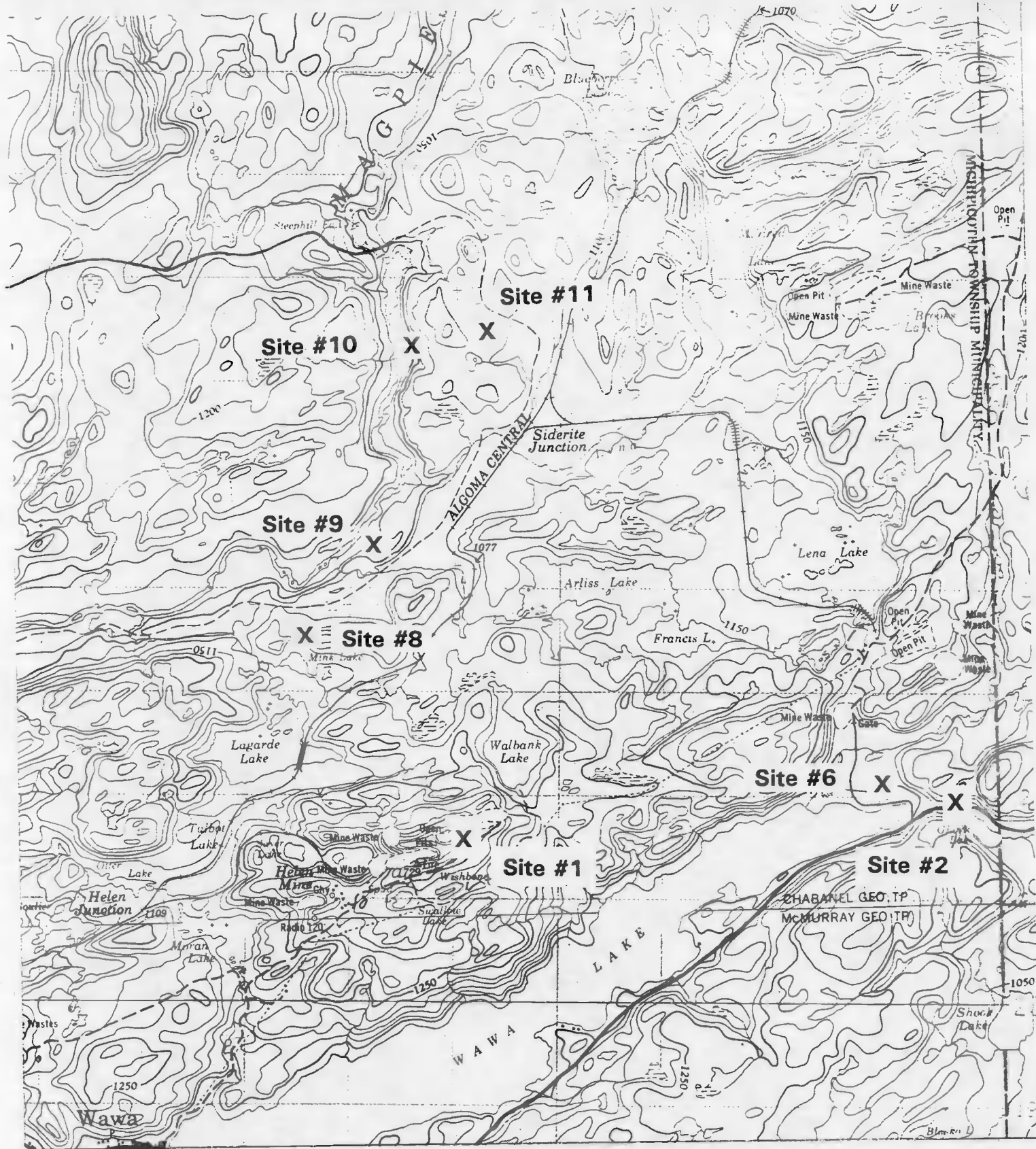
ROUTE MAPS

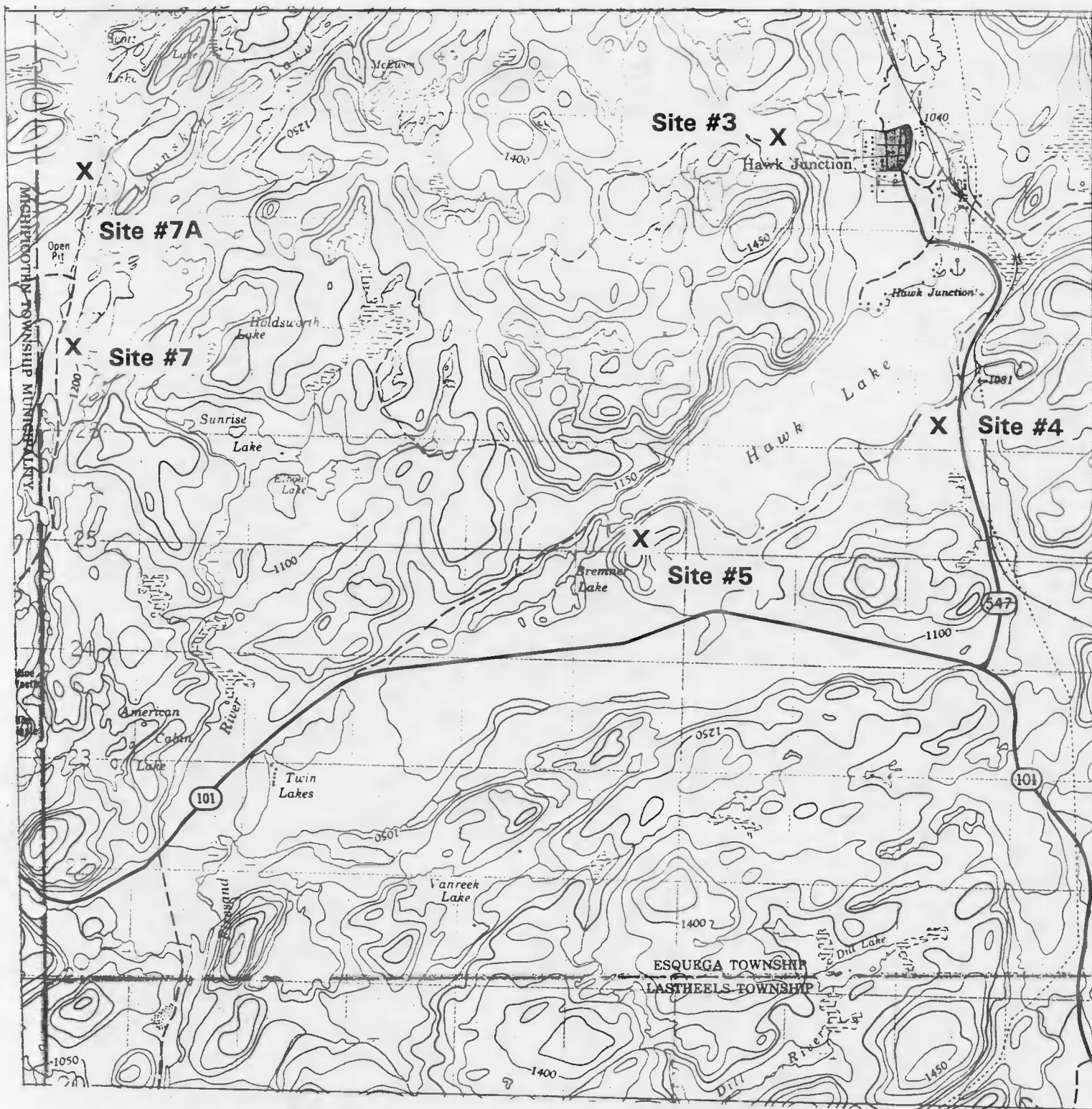
Appendix A consists of: Regional plan of site locations, Appendix A-1

- : Portion of NTS Sheet 42 C/2 (Hawk Junction), illustrating location of site numbers 1, 2, 6, 7, 7A, 8, 9, 10, 11 and route; Appendix A-2.
- : Portion of NTS sheet 42 C/2 (Hawk Junction) illustrating location of site numbers 3, 4, 5 and route, Appendix A-3.
- : Portions of NTS sheets 42 C/2 (Hawk Junction) and 41 N/15 (Michipicoten Harbour) illustrating location of site number 12 and route; Appendix A-4.



Appendix A-1





APPENDIX B

SITE AND MATERIAL OBSERVATION SHEETS

Appendix consists of: Till observation forms, p.55

: Modern alluvium observation forms, p.57

: Field note definitions, p.58 (modified from
Agriculture Canada (1977))

Stop Number:

U.T.M. Ref.:

Air Photo:

Sample Number(s):

- Comment:

Site Description

A) Genetic Material:

B) Surface Expression: apron/ blanket/ fan/ hummocky/ inclined/
level/ rolling/ ridged/ steep/ terraced/ undulating/ veneer/
location:

C) Slope: Inclination-

Aspect-

D) Drainage: Well drained/ Moderately well drained/ Poorly drained

E) Vegetation: Type- Coniferous/ Deciduous/ Mixed/ Scrub/ Grass/
Bog/ Other:

: State- Virgin/ Logged/ Fired/ Stress:

F) Material Thickness: Class 1/ 1A/ 2/ 3/ Other:

Material Description

Horizon: A

B

C

A) Colour:

Munsell Code:

B) Texture

Sand: Coarse/ Medium/ Fine

Silt: Sandy/ Silt/ Clayey

Clay: Silty/ Clay- Organic

C) Structure

Type: Structureless/ Block/
Plate/ Prism/ Flow
Other:

Kind: Massive/ Blocky,
< blocky/ Platy/
Prismatic, Columnar
Flow:

Size:

D) Consistency

Wet- Nonsticky/ Slightly
Sticky/ Sticky

Moist- Loose/ Friable/ Firm

Dry- Loose/ Soft/ Hard

E) Plasticity

-Nonplastic/ Slightly
Plastic/ Plastic

Material Description (Cont) Horizon: A B C

F) Cementation (Yes/ No)
- Weak/ Strong/ Indurated

G) Clasts
- Abundance; Rare/ Few/
 Common/ Abundant
- Size;
- Shape; Rounded/ Subrounded
 Angular/ Subangular
- Striated (Yes/ No);
- Type; Plutonic/ Supra-
 crustal/ Marine

H) Lower Horizon Boundary
- Distinctiveness; Diffuse/
 Gradual/ Clear
- Form; Smooth/ Wavy/ Irreg.

I) Unit Thickness:

COMMENTS/ DIAGRAM(S)

MODERN ALLUVIUM OBSERVATION FORM

General

Stop #:

U.T.M. Reference:

Aerial Photo:

Sample Number(s):

Site Description

A) Material:

B) Surface Expression: apron/ blanket/ fan/ hummocky/ inclined/ level/ rolling/ ridged/ steep/ terraced/ undulating/ veneer

C) Slope: Inclination-

Aspect-

D) Drainage: Strong/ Moderate/ Weak/ Ephemeral

E) Vegetation: Type- Coniferous/ Deciduous/ Mixed/ Grass/ Bog/ Other;

State- Virgin/ Logged/ Fired/ Stress:

Material Description

A) Colour:

Munsell Code:

B) Texture: Sand- Coarse/ Medium/ Fine/ Other:

C) Structure: Structureless/ Current and Wave Ripples/ Cross Bedding/ Climbing Ripple Lamination/ Flaser and Lenticular Bedding/ Graded Bedding/ Rhythmites/ Flow/ Undetermined

D) Bar Form:

Bar Form	Flow Pattern	Growth Pattern		
		Plan	Transverse	Longitudinal
Longitudinal:				
Transverse:				
Point:				
Diagonal:				

E) Clasts: Abundance; Rare/ Few/ Common/ Abundant
Size Range;
Shape; Rounded/ Subrounded/ Angular
Striated; Yes/ No
Types;

FIELD NOTE DEFINITIONS

Stop Number: HJxx/91

- : HJ- Refers to project NTS map sheet.
- : xx- Refers to sample number. Sample numbers run consecutively from 1-n.
- : /91- Refers to the project year.

U.T.M. Reference: This fixes the ground sample point to a location on the NTS topographic map (identified in the stop number).

Aerial Photograph: This number is the aerial photograph number which relates to the sample collection site.

Sample Number: 91FxxLBA

- : 91- Refers to the project year.
- : F - Refers to the NTS map sheet.
- : xx- Refers to the sample number. Sample numbers run consecutively from 1-n. Each sample has it's own number.
- : L - Refers to material type; i.e. till, glaciolacustrine, outwash, lacustrine etc.
- : B - Refers to fraction sampled. B refers to bulk, C refers to clasts only.
- : A- Refers to soil horizon sampled; H, A, B, C.

Genetic Material: This describes the mapping unit and landform type from which the sample is being taken.

Surface Expression: Refers to the lay of the land.

- Apron: A relatively gentle slope at the foot of a steeper slope, and formed from the materials of the steeper slope.
- Blanket: A mantle of unconsolidated materials thick enough to mask minor irregularities in the underlying unit but which still conforms to the general underlying topography.
- Fan: A fan-shaped form that can be likened to the segment of a cone, and possessing a perceptable gradient from the apex to the toe.
- Hummocky: A very complex sequence of slopes extending from somewhat rounded depressions or kettles of various size to irregular to conical knolls or knobs. There is a general lack of concordance between knolls or depressions. Slopes are generally between 5 and 35°.

- Inclined: A sloping, unidirectional surface with a generally constant slope not broken by marked irregularities. Slopes are between 1 and 35°. The form of inclined slopes is not related to the mode of origin of the underlying material.
- Level: A flat, or gently sloping, unidirectional surface with a generally constant slope not broken by marked elevations and depressions. Slopes are generally <1°.
- Rolling: A very regular sequence of moderate slopes extending from rounded, sometimes confined, concave depressions to broad, rounded convexities producing a wave-like pattern of moderate relief. Slope length is often 0.5 km or greater and gradients are <5 %.
- Ridged: A long, narrow elevation of the surface, usually sharp crested, with steep sides. The ridges may be parallel, sub-parallel or intersecting.
- Steep: Erosional slopes, >35°, on both unconsolidated and consolidated materials. The form of a steep erosional slope on unconsolidated materials is not related to the initial mode of origin of the underlying material.
- Terraced: Scarp face and the horizontal or gently inclined surface (tread) above it.
- Undulating: A very regular sequence of gentle slopes that extend from rounded, sometimes confined concavities to broad rounded convexities producing wave-like pattern of low local relief. Slope length is generally <1 km and dominant gradient of slopes from 2-5 %.
- Veneer: Unconsolidated materials too thin to mask the minor irregularities of the underlying unit surface. A veneer will range between 10 cm and 1 m in thickness and will possess no form typical of the material's genesis.

Slope: Describes the slope inclination and aspect.

Drainage: Describes the slopes ability to drain.

- Well drained: Water is removed from the soil readily downward into underlying previous material or laterally as subsurface flow. Soils have a low to intermediate water moisture storage capacity.
- Moderately well drained: Water is removed somewhat slowly in relation to supply. Excess water is removed somewhat slowly due to low perviousness, shallow water table, lack of gradient or some combination of these. Soils have intermediate to high water storage capacities.

- Poorly drained: Water is removed so slowly in relation to supply that the soil remains wet for a comparatively large part of the time the soil is not frozen. Excess water is evident in the soil for a large part of the time.

Vegetation: Refers to the type of vegetation cover, coverage and vegetation state.

- Type: Coniferous- More than 80 % coniferous cover.
Deciduous- More than 80 % deciduous cover.
Mixed- Mix of coniferous and deciduous cover with one or the other <80 % of the cover.
Scrub- <50 % canopy, mixture of open grass or bushland and tree.
Grass- >50 % grass cover.
Bog- >50 % wetland.
- State: Virgin- No evidence of recent cutting or forest fire. Forest is mature.
Logged- Evidence of recent logging activity. Forest area mature cover largely logged.
Fired- Evidence of recent fire. Forest area mature cover largely burned.
Stress- Evidence that vegetation is stressed by environment; i.e. drought, insects etc.

Material Thickness: Refers to the thickness of unconsolidated material over the bedrock surface.

- Class 1: Virtually bare bedrock. Maybe thin drift within undulations of the bedrock surface.
- Class 1A: Thin drift (<1 m) over bedrock. Does not obscure the bedrock topography.
- Class 2: Pockets of drift within bedrock depressions >1 m thick. Bedrock crests are covered by <1 m of drift.
- Class 3: Bedrock surface expression obscured by unconsolidated material >1 m thick.

Colour: Refers to the colour of a specific unit based on the Munsell Soil Colour Chart.

Texture: Refers to the representative grain size of a particular unit.

- Coarse Sand: 25 % or more very coarse or coarse sand, and <50% any other one grade of sand.
- Sand: 25 % or more very coarse or coarse sand and medium sand, and <50 % fine or very fine sand.
- Fine Sand: 50 % or more of fine sand, or <25 % very coarse, coarse or medium sand.
- Sandy Silt: Contains >50 % silt, and <50 % sand.
- Silt: Contains at least 80 % silt and <2 % clay.

- Clayey Silt: Contains >50 % silt, and <50 % clay.
- Silty Clay: >50% clay and <50% silt.
- Clay: Contains at least 40 % clay, <45 % sand and <40 % silt.
- Organic: Contains at least 30 % organic material.

Structure: Refers to the physical characteristics of the unit.

- Type: Structureless- Simply no structure.
 Blocklike- Have distinct blocklike shape consisting of 4 or more sides.
 Platelike- Ped(s) are arranged horizontally to give a platelike structure.
 Prismlike- Peds are longer than wide giving a columnar or peaked shape, the peak towards the top of the ped.
 Flow- There is the presence of flow structure; flow cones, stringers, injections, rip-ups, flames, balls, pillows, dish, planar, crossbedding, trough crossbeds, ripples, flaser, graded.
- Kind: Massive- Refers to structureless type, and indicates homogeneous arrangement of materials.
 Angular- Refers to the blocklike type, where there are just 4 sides to the ped.
 Subangular- Refers to the blocklike type, where there are 5 or more sides.
 Platy- Refers to the platelike type, where the peds are arranged horizontally.
 Prismatic- Refers to the prismlike type, where the peds are rounded or angled at the surface.
 Columnar- Refers to the prismlike type, where the peds are longer than wide and do not have a rounded or angled surface.
 Flow- Indicate the flow regime based on the flow structure type.

Consistency: Refers to the degree and kind of cohesion and adhesion or to the resistance of the soil to deformation or rupture.

- Wet: Nonsticky- After release of pressure, practically no soil material adheres to thumb and finger.
 Slightly sticky- After pressure is applied, the soil material adheres strongly to both the thumb and forefinger, but comes off one or the other rather cleanly. The soil is not appreciably stretched when the digits are separated.
 Sticky- After pressure is applied, the soil material adheres strongly to both the thumb and forefinger and tends to stretch somewhat and pulls apart rather than pulling free from either digit.
- Moist: Loose- Noncoherent soil material.

Friable- The soil material crushes easily under gentle to moderate pressure between the thumb and forefinger and coheres when pressed together.

Firm- The soil material crushes under moderate pressure or greater, but resistance is distinctly noticeable.

- **Dry:** Loose- Noncoherent soil material

Soft- The soil material is weakly resistant to pressure and easily broken between the thumb and forefinger.

Hard- The soil material is moderately resistant or greater to pressure, it can be broken in the hands with moderate to some degree of difficulty.

Plasticity: Is the property of changing shape continuously under the influence of an applied stress and of retaining the new shape after removal of the stress.

- **Nonplastic:** A roll 4 cm long and 4 mm thick cannot be formed.

- **Slightly plastic:** A roll 4 cm long and 2 mm thick can be formed but will not support its own weight.

- **Plastic:** A roll 4 cm long and 2 mm thick can be formed and will support its own weight.

Cementation: Refers to whether or not the soil is cemented and the degree to which the unit is cemented.

Clasts: Describes the type, relative abundance of each type, shape and size of clasts.

- **Abundance:** Rare- <5 % Common- 15- 20 %
 Few- 10 % Abundant- >20 %

- **Size:** State common and largest size.

- **Shape:** Rounded, subrounded, subangular, angular.

- **Striated:** Yes or no

- **Type:** As detailed pebble counts are usually done per sample site, it is only necessary to describe the clasts generally as granitic, volcanic, metamorphosed or sedimentary.

Lower Horizon Boundary: Describes the characteristics of the units lower contact.

- **Distinctiveness:** Diffuse- Vertical change >15 cm
 Gradual- Vertical change within 5 to 15 cm.
 Clear- Vertical change within 2 to 5 cm.
 Abrupt- Vertical change <2 cm.

- **Form:** Smooth- Nearly a plane.

 Wavy- Pockets wider than deep.

 Irregular- Pockets wider than deep.

Unit Thickness: State thickness of each horizon.