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**Ontario Geological Survey
Open File Report 6211**

**Surficial Geology of the
Bruce Peninsula,
Southern Ontario**

2007



ONTARIO GEOLOGICAL SURVEY

Open File Report 6211

Surficial Geology of the Bruce Peninsula, Southern Ontario

by

W.R. Cowan and D.R. Sharpe

2007

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Contents

Abstract	ix
Introduction	1
Previous Work	2
Physiography and Drainage	4
Bedrock Geology	5
Paleozoic Geology	5
Economic Geology	9
Karst Development	9
Surficial Geology	10
Bedrock Topography and Drift Thickness	10
Directional Indicators in Glaciated Terrain	10
Surficial Materials and Features	12
Till Deposits	12
Glaciofluvial Ice-Contact Deposits	14
Glaciofluvial Outwash	15
Glaciolacustrine and Postglacial Lacustrine Deposits	16
Deep-Water Deposits	16
Shallow-Water Deposits	17
Abandoned Shoreline Features and Deposits	17
Eolian Deposits	24
Modern Alluvium	24
Organic Deposits	24
Modern Shore Deposits	24
Talus Deposits	26
Historical Geology	27
Economic Geology	29
Natural Granular Aggregates	29
Agricultural Soils	29
Water Supply	30
Engineering Geology	30
Acknowledgements	31
References	31
Metric Conversion Table	34

FIGURES

1. Location of map area.....	1
2. Digital elevation model of Bruce Peninsula showing northeast-trending fabric due to glacial erosion and erosion by subglacial outburst floods	3
3. Generalized Paleozoic geology of the Bruce Peninsula.....	5
4. Generalized isobases for Main Lake Algonquin in Bruce Peninsula area.....	21
5. Illustration showing water plane at 240 m asl, approximate Main Algonquin level.....	22
6. Illustration showing water plane at 195 m asl, approximate Nipissing Great Lakes level.....	23

PHOTOS

1. View of Niagara Escarpment from Barrows Bay.....	4
2. Airphoto showing northwesterly biohermal reef trend	8
3. View of typical biohermal dolostone outcrops.....	8
4. Karstic-solution-widened joints with intervening blocks.....	9
5. Example of sculpted furrows in carbonate rocks	11
6. Airphoto of Hay Bay area showing sculpted bedforms trending southwesterly on offshore rock platform.....	11
7. Gravel pit with subaqueous outwash fan materials	14
8. Proximal facies outwash from which beach gravels were derived.....	15
9. Laminated lacustrine silts in Nipissing Phase sediments	16
10. Abandoned shore bluff features near Hope Bay	19
11. Shingle beach development with rip-up clasts from Manitoulin Formation being tumbled into shingle gravel.....	25
12. Storm bars in shingle gravel.....	25
13. Boulder lag resting on rock, modern shoreline	26

TABLES

1. Paleozoic formations of the map area	6
2. Quaternary deposits and events.....	13
3. Summary of reported elevations of abandoned shorelines on Bruce Peninsula.....	18

MAP

Map 2679 Surficial Geology, Bruce Peninsula, Southern Ontario	back pocket
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Abstract

This report describes the surficial geology of the Bruce Peninsula north of Wiarton in Grey and Bruce counties, southern Ontario. The area is underlain by Paleozoic rocks ranging from Upper Ordovician to Upper Silurian in age, and features the updip scarp of the northeastern rim of the Michigan Basin known as the Niagara Escarpment. The escarpment is present on the east side of the peninsula where relief is up to 60 m or more. From the escarpment the rock surface slopes gently westward, and on the west side of the peninsula the surface is nearly flat, dipping beneath the waters of Lake Huron at a low angle. Bedrock is exposed over much of the peninsula as most glacial sediment was stripped off by late glacial catastrophic outburst floods produced by the release of stored subglacial meltwaters. This erosion is well marked by sculpted bedforms on the rock surface, which indicate a southwesterly flow of these meltwaters, a direction parallel to other glacial indicators in the area such as glacial striations. Karst features are present throughout the area, having a major impact on surface water and groundwater hydrology.

Glacial sediment remaining consists of: the Bruce till, a silt to sandy silt till, which occurs as ground moraine and in streamlined drumlinoid forms; ice-contact stratified drift occurring as subaqueous outwash fans at Tobermory and Lion's Head; minor outwash deposits; and glaciolacustrine sediments occurring at depth beneath the Eastnor silt plain and in small patches on higher ground. Late glacial and postglacial Great Lakes shoreline features are relatively sparse in the area due to the general shortage of glacial drift for eroding into bluffs or for reworking into beach deposits. Strong glacial Lake Algonquin features occur in a few locales at about 240 to 244 m asl, as do strong Nipissing Great Lakes features at about 190 to 195 m asl. Post-Algonquin shoreline features are sporadic and, for the most part, represent the short-lived lower Algonquin features. Post-Nipissing features are dominated by Lake Algoma shingle gravel bars. Nearshore sands and related sand dunes occur on the west side of the peninsula, primarily south of Pike Bay. Nipissing age silts form the uppermost unit of the widespread silt plain in the Lion's Head–Ferndale–Edenhurst area.

Natural granular aggregates are sparse in the area, requiring good resource planning and management. Bedrock aggregate and building stone quarries are common in the south part of the area; rocks in the north part of the area are either not highly suitable for aggregates or they are protected by various planning instruments.

Surficial Geology of the Bruce Peninsula, Southern Ontario

W.R. Cowan¹ and D.R. Sharpe²
Ontario Geological Survey
Open File Report 6211
2007

¹Cowan Minerals Ltd., Sudbury, Ontario

²Geological Survey of Canada, Ottawa, Ontario

Introduction

This report considers the surficial geology of the Bruce Peninsula north of latitude 44° 45' N in southern Ontario (Figure 1), an area of about 1200 km² of which about 9% is lakes and water. The area includes the mainland parts of the following NTS map sheets: 41 A/14 Cape Croker; 41 A/15 North Keppel; 41 H/3 Dyer Bay; 41 H/4 Dorcas Bay; and 41 H/5 Flower Pot Island. The objective of this report and accompanying map (Map 2679, back pocket) is to provide information on the distribution, properties and history of surficial geologic materials in the map area for use in planning, engineering, hydrologic, pedologic, geologic and environmental studies. Field work for most of the area was completed by D.R. Sharpe and G.R. Jamieson in 1977 (Sharpe 1977); however, maps for this work were never compiled. W.R. Cowan completed further field work in 2006 to augment the work of Sharpe and Jamieson, and completed airphoto interpretation and mapping of the area utilizing ground control as described above. In addition, detailed work by P.S.G. Kor for several nature reserves on the Bruce Peninsula was utilized to enhance the information base in those areas. The bedrock outcrop mapping of D.K. Armstrong (Armstrong and Dubord 1992; Armstrong 1993a, 1993b) was invaluable in providing ground control for photo interpretation and mapping. Field work consisted of rock outcrop plotting; test augering of soil materials; and the examination of road cuts, stream banks or test pits in overburden materials. Water well records were used extensively, as were the previous works of other researchers. Mapping was compiled at a scale of 1:50 000 from airphotos. In general, only materials 1 m or more in thickness are displayed on the maps; similarly, small areas of materials are not shown at the current scale.

Access to the area is via Highway 6, which traverses the peninsula from south to north. When coming from the north, one must take a ferry from South Baymouth on Manitoulin Island to Tobermory on the northern end of the peninsula.

The Cape Croker Indian Reserve 27 was not mapped during this program.

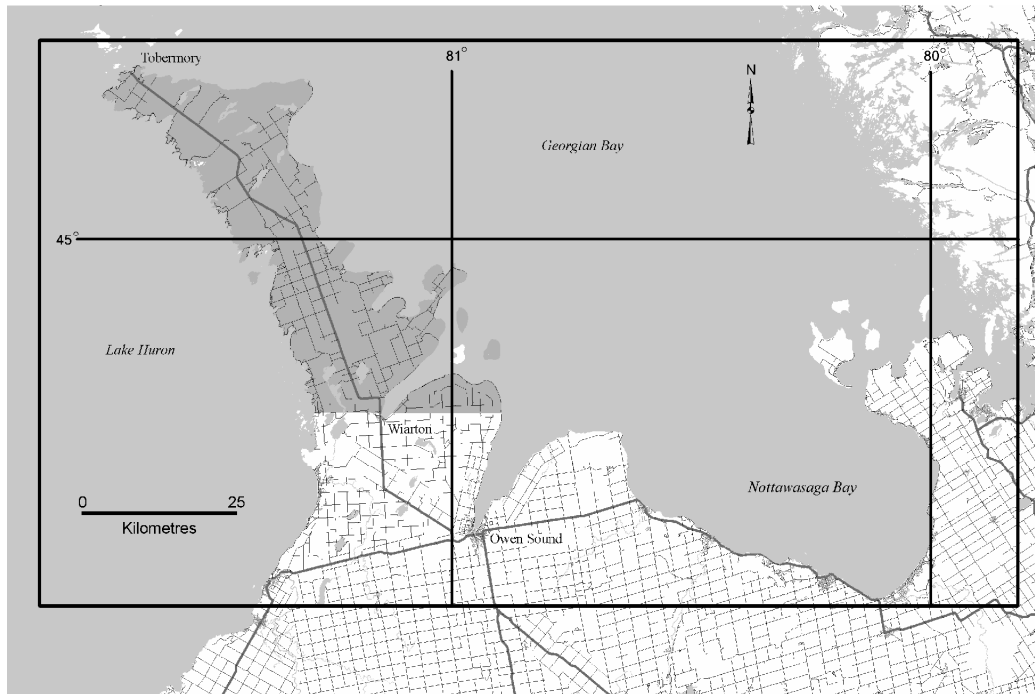


Figure 1. Location of map area.

PREVIOUS WORK

Work on the distribution and history of the surficial materials on the Bruce Peninsula has proceeded slowly over many years. Some of the more germane literature is noted below. One of the earliest studies reported was by Goldthwait (1910) who recorded raised shorelines in the Dyer's Bay, Lion's Head and Hope Bay areas. Goldthwait's projected isobase for Lake Algonquin in central Bruce Peninsula was 807 feet asl (246 m); for the Nipissing Great Lakes* he portrayed an isobase at 630 feet asl (192 m) trending through the south-central part of this map area. He also opined that the Lake Algonquin shoreline should occur at about 820 feet asl (250 m) in the Dyer's Bay and Lion's Head area.

Chapman and Putnam (1951, 1966 and 1984) mapped the physiographic features on the Bruce Peninsula and commented on the shorelines of the glacial and postglacial Great Lakes. They noted probable Lower Algonquin features on Cape Croker; a Lower Algonquin beach at Lion's Head; probable Nipissing Phase beach features at 640 feet asl (195 m) near Pike Bay; and a large marly silt plain in Eastnor Township, which they related to the Nipissing Phase. They also noted beach features at Hope Bay, Dyer's Bay and Dunks Bay, which they related to the Nipissing Phase.

Soil surveys by Hoffman and Richards (1954) and Gillespie and Richards (1954) portray the distribution of soil types and their interpretation of parent materials. Their maps well demonstrate the predominance of surface and near-surface bedrock on the Bruce Peninsula north of Wiarton.

Nichols (1972) surveyed several suites of raised shoreline features within the current project area and related these to the overall Great Lakes history in the Georgian Bay area. Specifically, for the current project area, she surveyed several profiles in the Cape Croker, Sydney Bay, Hope Bay and Lion's Head areas. In her detailed interpretation, the Main Algonquin lake level is not represented in this area.

Sly and Lewis (1972) reported on various features on the Bruce Peninsula. In their guidebook they speculated on where the levels of glacial and postglacial Great Lakes should occur at Gillies Lake near Cabot Head, and they described a sequence of shorelines near Gillies Lake.

Stadelman (1973) completed a study of deglaciation and postglacial history of the Bruce Peninsula and interpreted glaciofluvial deposits at Tobermory and Lion's Head as evidence of a late glacial standstill or readvance, and suggested that evidence for Early Lake Algonquin is present. He discovered 2 organic sites; radiocarbon dates for these were interpreted as relating to Nipissing Phase events. The first of these was a charcoal sample from a soil layer at the base of a sand dune near Spry Lake. This has been dated at 5109 ± 131 years BP (BGS-79). A second site, located at Dyer's Bay, consisted of a charcoal layer embedded in a cobble beach and has been dated at 5452 ± 63 years BP (BGS -78). These dates were reported by Terasmae, Karrow and Dreimanis (1972).

Sharpe (1977) reported on his field work in the area. He noted that the general direction of glaciation was toward 220° ; that the area was probably continuously ice covered from the time of the Nissouri Stadial (Nissouri Phase) until post-Port Huron Stadial (Port Huron Phase) time; that the general lack of glaciofluvial sediment indicates rapid deglaciation without stagnation; that the Lake Algonquin shoreline is at about 244 m asl (800 feet); and that the Lake Nipissing water level is represented by features near Pike Bay at 198 m asl (650 feet) and up to 206 m asl (675 feet) at Dyer's Bay. Sharpe also noted that a prominent beach ridge along Georgian Bay 15 to 20 m above lake level is probably related to Lake Algoma.

* Nipissing Great Lakes or Nipissing Phase is used herein to describe a high-level phase of the Great Lakes about 5000 years BP.

P.S.G. Kor completed numerous studies in the Bruce Peninsula during the 1990s, some components of which are incorporated into this project. As a result of this work, and that of D.R. Sharpe and others, a model for catastrophic subglacial meltwater sheetflood events has been proposed for the peninsula to explain the overall lack of glacial sediment, the presence of numerous sculpted bedrock forms, the origin of the Mar drumlin field and some characteristics of the Niagara Escarpment morphology (Kor and Cowell 1998). Specifically, Kor and Cowell propose that the Niagara Escarpment in this area has been “significantly backwasted and sculpted through erosion by subglacial outburst floods.”

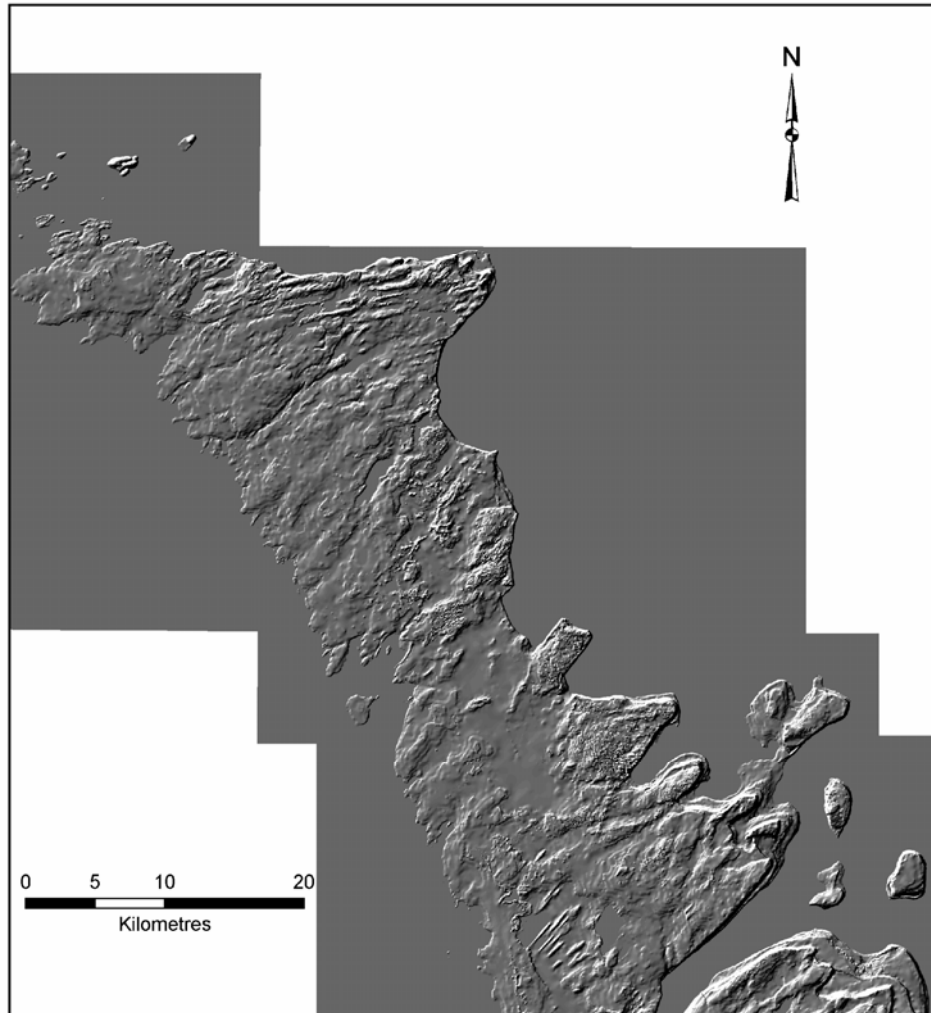


Figure 2. Digital elevation model (DEM) of the Bruce Peninsula showing northeast-trending fabric due to glacial erosion and erosion by subglacial outburst floods.

Aggregate resources in the northern part of the area have been assessed by the Ontario Geological Survey (1995). While potential bedrock aggregate supplies are substantial, it was noted that “the possible resources of available sand and gravel are likely to be insufficient for local needs in the future, and will require supplementation from other sources. Care should be taken to ensure the proper utilization of the remaining resources.” A similar statement was made regarding granular aggregates in Keppel Township (Ontario Geological Survey 1985).

Finally, earth scientists who have carried out work on the peninsula have been struck by the degree to which the bedrock surface has been subject to dissolution and the widespread development of karst features. This development has a major effect on surface water runoff as much of the surface drainage is internal and in many instances small streams disappear into karst openings. Clint and gryke systems are well developed over much of the Amabel and Guelph formations terrain. Much knowledge on this topic has been contributed by D.W. Cowell (Cowell 1974, 1976; Cowell and Ford 1983).

PHYSIOGRAPHY AND DRAINAGE

The Bruce Peninsula trends northwesterly from Wiarton in the south to Tobermory in the north, a distance of about 75 km. It is located on the northeastern rim of the Michigan Basin with rock units dipping southwesterly in an estimated range of about 4.8 to 7.6 m/km. On the updip eastern side (Georgian Bay side) of the peninsula is the Niagara Escarpment, with spectacular cliffs that stand as much as 100 m above Georgian Bay (Photo 1). Here, northerly winds cause wave erosion of the rocks, which are cast up on shore as shingle gravel forming storm bars up to several metres above lake level. In contrast, the westerly shore of the peninsula (Lake Huron side) is on the downdip side with low, nearly flat, rock surfaces extending out into the lake. Here the shoreline consists primarily of gently dipping flat rock surfaces with gravel or boulder lags resting directly on the rock. In some areas sandy zones exist where postglacial deposits of sand were laid down and subsequently reworked by wind and shoreline processes. The interior of the peninsula is flat to low rolling dolostone plain with local topography frequently reflecting the biohermal surfaces of the Amabel and Guelph formations. Quaternary features of physiographic note include: a few drumlins of the Mar drumlin field near Sky Lake; some spectacular raised shoreline features related to late-glacial and postglacial levels of the Great Lakes; and two features cored with ice-contact stratified drift, which have been considerably reworked by the above-noted high-level Great Lakes. In the central part of the peninsula, surrounding Edenhurst, there is a large flat area underlain by lacustrine silt, sand and minor clay deposited in the postglacial Nipissing Great Lakes and predecessor glacial lakes. Overall, the Bruce Peninsula is notable for the general absence of glacial sediment.



Photo 1. View of Niagara Escarpment from Barrows Bay.

Drainage is heavily controlled by the southwesterly dipping bedrock surface. This gradient is augmented by differential glacio-isostatic rebound toward the north-northeast. This causes the eastern side of the peninsula to be uplifted at a slightly greater rate than the western side, in a direction approximately perpendicular to the strike of the peninsula itself. Thus, most surface drainage is in a southwesterly direction toward Lake Huron.

In addition to the surface drainage, karst development in the Silurian carbonate rock units allows for a considerable amount of internal drainage directly into the subsurface. Cowell and Ford (1983) portrayed a system wherein waters on the east side of the peninsula drain almost entirely internally and exit as springs along the escarpment. West of this zone, waters drain both internally and along stream courses. Toward the west side of the peninsula high water tables result in less internal drainage and more surface drainage. This is particularly important where there is no forest cover. There is also a considerable amount of soil loss into the karstic openings.

Bedrock Geology

PALEOZOIC GEOLOGY

The Paleozoic geology of the Bruce Peninsula has been studied and mapped several times over the last century, the most comprehensive being the work of Liberty and Bolton (1971). More recently, Armstrong (1993a, 1993b) and Armstrong and Dubord (1992) have mapped and described the existing rock units and expanded upon the somewhat controversial lithostratigraphy of the Amabel and Guelph formations. The Bruce Peninsula is underlain by up to 500 m of Paleozoic strata of which less than 170 m of the uppermost strata are exposed. The following notes on the Paleozoic geology (Figure 3, Table 1) are summarized from Armstrong's work (Armstrong 1993a, 1993b; Armstrong and Dubord 1992).

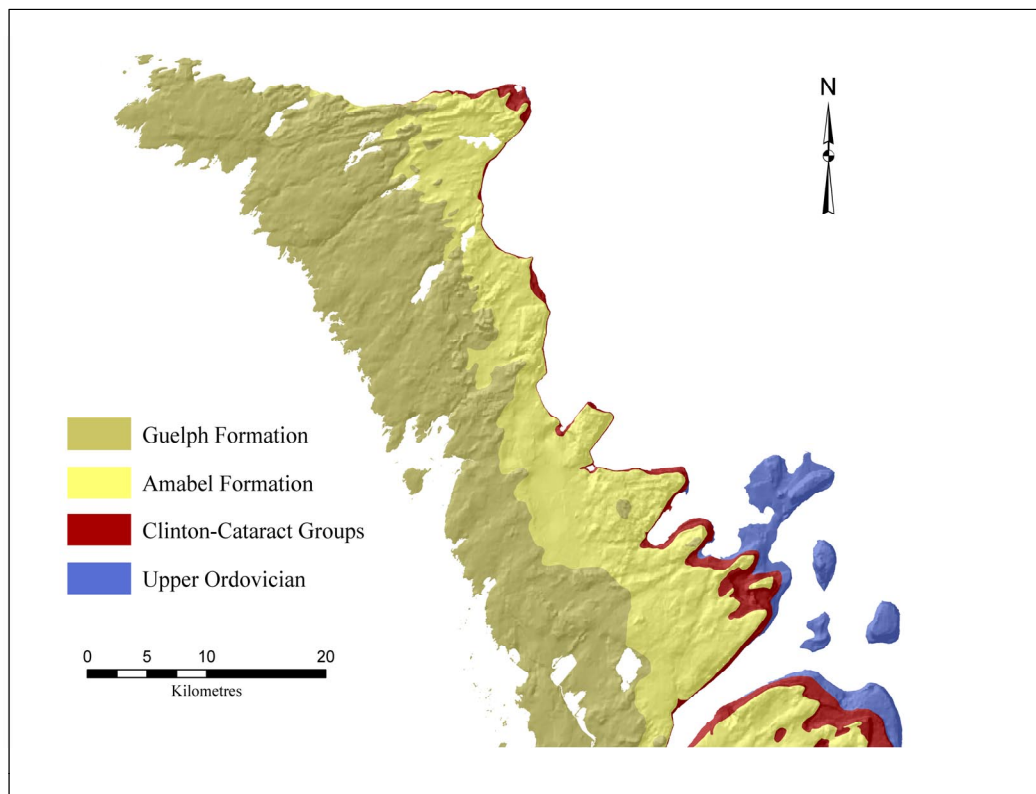


Figure 3. Generalized Paleozoic geology of the Bruce Peninsula (*adapted from* Armstrong 1993a, 1993b; Armstrong and Dubord 1992).

The oldest rocks outcropping in the area are the Upper Ordovician Georgian Bay and Queenston formations. The former only crop out in the Cape Commodore and Cape Croker areas, generally at or near lake level. The Georgian Bay Formation consists of grey to green shale with siltstone and limestone interbeds. The Queenston Formation consists of red to grey shales with interbeds of siltstone and limestone. It occurs extensively on the lower slopes in the Big Bay and Cape Croker areas and at or near water level in the Hope Bay and Cabot Head areas. In the Big Bay area the Queenston Formation forms an extensive eroded red shale slope between the secondary scarp formed by the Manitoulin Formation and Georgian Bay. This unit is up to 60 m thick in the subsurface in the Bruce Peninsula area.

Table 1. Paleozoic formations of the map area (*from* Armstrong and Dubord 1992). (See text for explanation of abbreviations for members in Guelph and Amabel formations.)

AGE	GROUP	FORMATION	MEMBER	LITHOLOGY	
Upper Silurian	Albemarle	Guelph	lithofacies Gd	biohermal dolostone	
			lithofacies Gc	dolostone	
			Eramosa Mbr.		
			lithofacies Gb	dolostone	
				lithofacies Ga	bituminous dolostone
		Albemarle	Amabel	Wiarion/Colpoy Bay Mbr.	
				lithofacies Ac	biohermal dolostone
				lithofacies Ab	dolostone
	Lions Head Mbr.				
			lithofacies Aa	dolostone	
Middle Silurian	Clinton	Fossil Hill		dolostone, chert	
	Clinton	St. Edmund		dolostone	
	Clinton	Wingfield		dolostone, shale	
	Clinton	Dyer Bay		dolostone	
Lower Silurian	Cataract	Cabot Head		red shale	
	Cataract	Manitoulin		dolostone	
Upper Ordovician		Queenston		red/green shale	
		Georgian Bay		shale, limestone	

The oldest Silurian rocks overlying the Queenston shale are of Lower Silurian age and comprise the Cataract Group, which includes the Manitoulin Formation and the Cabot Head Formation, in ascending order. The Manitoulin Formation is exposed from Cabot Head eastward, commonly forming a small escarpment on top of the recessive Queenston shale, which it disconformably overlies. Examples of this escarpment are evident at Cabot Head and south of Big Bay. Similarly, it is also overlain by recessive shales of the Cabot Head Formation, which has allowed wave-cut platforms to be constructed on the Manitoulin Formation. The Manitoulin Formation consists of thin- to thick-bedded dolostones and calcareous dolostones. Thickness of this unit ranges from about 5 to 8 m.

The second unit of the Cataract Group, the Cabot Head Formation, is a recessive-weathering red shale with thicknesses from 15 to 35 m, though not all of this unit is exposed at surface. It takes its name from Cabot Head, as its type section is located in a cliff at Rocky Bay, along Cabot Head. Outcrops occur near the base of the Niagara Escarpment from the Cabot Head area south. The Cabot Head shale serves as an aquitard for downward percolating groundwaters in the Amabel and Guelph formations; along the Niagara Escarpment area and elsewhere this results in the creation of springs.

The Lower Silurian Cataract Group is overlain by Middle Silurian rocks of the Clinton Group, which consists of 4 formations: Dyer Bay; Wingfield; St. Edmund; and Fossil Hill, in ascending order. The Dyer Bay Formation rocks consist of thin- to medium-bedded dolostone that is moderately to highly fossiliferous. It is generally up to 5 m in thickness and may form low scarps along the east shore of the peninsula near Dyer's Bay, Cape Chin, Lion's Head and elsewhere.

The Wingfield Formation consists of interbedded dolostones and shale and is up to 10 m in thickness. Because of the shale content it is prone to recessive weathering and is best observed at its type section in the cliffs at Rocky Bay.

The St. Edmund Formation is a thin-bedded dolostone locally capped by a thin zone of green-grey shale interbeds. It is best exposed at its type section at Rocky Bay where it is about 4 m in thickness; elsewhere thicknesses may range from 0 to 8 m.

The uppermost unit of the Clinton Group is the Fossil Hill Formation, which consists primarily of thin- to medium-bedded fossiliferous dolostone; fossils are abundant and commonly silicified. This unit commonly forms a subordinate escarpment below the main Niagara Escarpment. Thickness is from 2 to 7 m in the study area.

Upper Silurian rocks in the area include the Amabel and Guelph formations, in ascending order, the Amabel Formation being the primary cap rock and scarp-forming unit of the Niagara Escarpment in this area. On the Bruce Peninsula the Amabel Formation is variously subdivided into 2 or 3 members, the lower being the Lions Head Member, which is overlain by the Wiarton/Colpoy Bay Member. Armstrong and Dubord (1992) subdivided the latter into non-biohermal and biohermal lithofacies (lithofacies Ab and Ac, respectively; *see* Table 1). The Lions Head Member outcrops in the Niagara Escarpment area between Halfway Rock Point and Wiarton and consists of light grey to tan-coloured, thin- to thick-bedded dolostone.

The Wiarton/Colpoy Bay Member has a lower non-biohermal facies, which consists of light grey to tan-coloured, thick-bedded to massive dolostone. The overlying biohermal facies consists of tan to light grey biohermal dolostone with undulatory to lensoidal bedding. The biohermal facies form north-northwest-trending reefal ridges, which are readily evident in road cuts and impart a very distinctive pattern to airphoto imagery in the area (e.g., Photo 2). The full thickness of the Amabel Formation may be as much as 25 m.

The uppermost Paleozoic rock unit in the area is the Guelph Formation, which directly underlies most of the western and northern parts of the peninsula. Armstrong and Dubord (1992) have subdivided the Guelph Formation into 4 lithofacies units in this area (*see* Table 1). Lithofacies Ga and Gb correspond to the Eramosa Member of older nomenclature; this unit was formerly assigned to the upper part of the Amabel Formation. Lithofacies Gc and Gd represent non-biohermal and biohermal facies, respectively.

The Eramosa Member generally consists of thin-bedded, bituminous dolostone. Lithofacies Ga consists of tan-grey to black, thin- to medium-bedded, moderately to very bituminous, laminated dolostone with numerous interbeds of facies Gb. Lithofacies Gb is light tan to grey-tan, thin- to thick-bedded, slightly to moderately bituminous dolostone. It is commonly interbedded with lithofacies Ga and is transitional in character between lithofacies Ga and lithofacies Gc.

Lithofacies Gc comprises the bulk of the Guelph Formation on the Bruce Peninsula. It consists of light grey-tan or brown, thin- to thick-bedded dolostone that is typically tabular bedded and horizontally oriented, except where the beds are draped over bioherms of lithofacies Gd (e.g., Photo 3). Lithofacies Gd is generally a light grey-tan to tan, thin- to thick-bedded, fossiliferous dolostone that is generally

considered to be biohermal in origin. This facies is very similar to Amabel Formation biohermal lithofacies, which it may directly overlie. As with the Amabel Formation, the Guelph Formation biohermal lithofacies may form northwest-trending ridges. Total thickness of Guelph Formation in the area may exceed 80 m.



Photo 2. Airphoto showing north-northwest-trending biohermal reef trend in Warton/Colpoy Bay member.



Photo 3. View of typical biohermal dolostone outcrops of the Guelph Formation, Highway 6.

ECONOMIC GEOLOGY

Quarry operations have existed in the southern part of the Bruce Peninsula for over a century, with building stone from the Amabel and Guelph formations being the primary product. Several quarries in the area were described by Derry Michener Booth and Wahl and Ontario Geological Survey (1989). All operating quarries are located in Amabel and Albemarle townships, as suitable materials are not available in Lindsay or St. Edmunds townships, though in past times a quarry operated in the Guelph Formation just north of Cape Chin. Armstrong and Dubord (1992) suggest that potential exists for developing building stone quarries in the Eramosa Member in the Marley and George lakes area. Development of the Amabel Formation for aggregates is restricted by planning limitations related to the Niagara Escarpment.

Sphalerite (zinc sulphide) occurrences within the peninsula have sparked interest by base metal explorationists over the years. Older exploration shafts exist on the peninsula. At the time of writing no significant occurrences have been found that would cause modern advanced exploration projects to commence.

KARST DEVELOPMENT

The development of karst features through dissolution of carbonate rocks is pervasive throughout the project area. Though the most common feature is clint and gryke development (Photo 4), large conduits have developed in some areas that completely capture surface runoff. In addition, there are numerous caves in the escarpment area. Comprehensive studies of these processes and features are required to understand and protect the groundwater supply in the area.



Photo 4. Karstic-solution-widened joints (grykes) with intervening blocks (clints), Ira Lake Road.

Surficial Geology

BEDROCK TOPOGRAPHY AND DRIFT THICKNESS

No bedrock topography maps have been constructed for the area. However, review of the present surficial materials map (Map 2679, back pocket), the soil survey map (Hoffman and Richards 1954) and the aggregate resources maps (Ontario Geological Survey 1995) makes it apparent that such a map is redundant as bedrock is at or near the surface almost everywhere. The general absence of drift has been related to erosion by catastrophic sheet floods, as described in a previous section. This greatly contrasts with most areas of carbonate terrain in southern Ontario where drift thickness is usually considerable, i.e., several metres to several tens of metres. Thus the overall picture on the Bruce Peninsula is one of cuestas and escarpments on the updip eastern side of the peninsula, with a gently dipping flat to low rolling surface to the Lake Huron shore on the west side of the peninsula. Maximum rock elevations for the map area reach 300 m asl in North Keppel Township while, in general, surface of the rock on the west side is at lake level or about 177 m asl, resulting in about 130 m of total surface relief. On the east side of the peninsula, the bedrock topography is characterized by re-entrants into the escarpment and/or salients jutting out into Georgian Bay, giving rugged topography with local bedrock relief up to 80 or 100 m or more on the surface. In addition, the re-entrants extend well below water level due to fluvial, glacial and subglacial sheetflood erosion, giving the bedrock topography much more relief than is apparent. The re-entrants were initially created through backwasting of the Niagara Escarpment enhanced by preglacial fluvial erosion; this was further accentuated by several episodes of glacial erosion and finally by the aforementioned extreme erosion by subglacial sheetfloods (Kor and Cowell 1998).

Within the biohermal rock areas local relief can be up to 15 m on the biohermal ridges, which results in the topographic maps and airphotos having a very distinctive appearance. Elsewhere in the central and west side of the peninsula local relief on the rock surface is up to 15 m or more.

Drift thickness over much of the area mapped as rock dominated is usually less than 1 m. However, in the more rolling and biohermal terrains the drift may be several metres thick in small pockets or over small areas. In these areas drift may appear to be more prevalent than it actually is to the casual viewer. Close inspection will inevitably find more outcrop than is immediately evident, especially where the rock surface is quite flat. Elsewhere drift thickness is usually less than 15 m in thickness but in a few locales it may exceed 30 m.

DIRECTIONAL INDICATORS IN GLACIATED TERRAIN

The direction of the last glaciation in the area is well portrayed by 3 types of indicators. Firstly, glacial striations for the area have a mean direction of about 220°. Secondly, sculpted bedrock forms found throughout the area have an average trend of 237° (Kor and Cowell 1998). The latter forms (s-forms) are sculpted and streamlined features attributed to turbulent sheetflood events beneath glacial ice; they have been shown to parallel other glacial directional features such as glacial striations (Photos 5 and 6). Finally, the drumlins in the Mar-Sky Lake area indicate glacial flow toward the southwest (220 to 235°).



Photo 5. Example of sculpted furrows in carbonate rocks, Dorcas Bay (courtesy P. Kor, Ontario Parks).

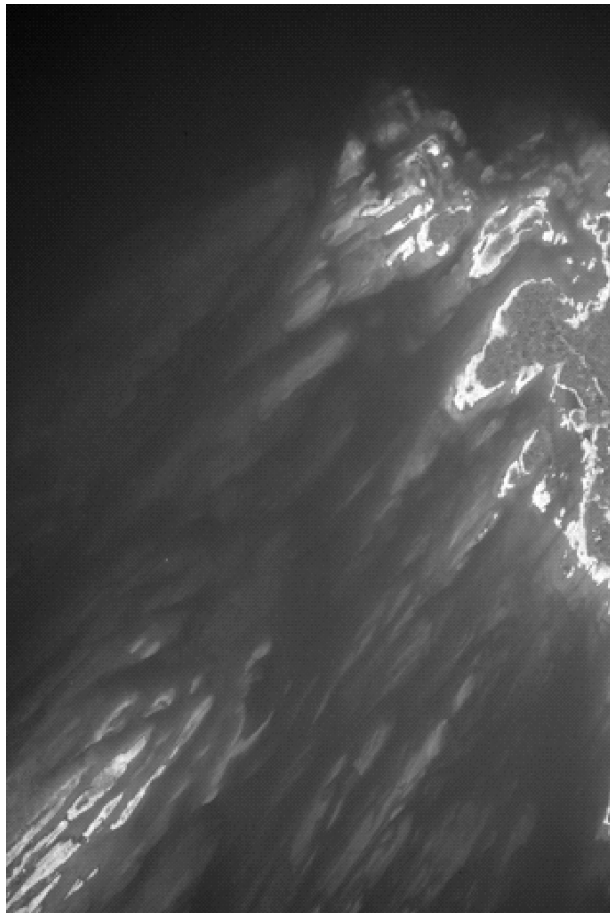


Photo 6. Airphoto of Hay Bay area showing sculpted bedforms trending southwesterly on offshore rock platform (courtesy P. Kor, Ontario Parks).

SURFICIAL MATERIALS AND FEATURES

Till Deposits

While carbonate terrains usually generate considerable drift during glacial events, the Bruce Peninsula has only a sparse drift cover and till is not a major component of the landscape. Till occurs in the terrain mapped as “rock dominated” in thin, discontinuous patches or in small, thicker deposits adjacent to rock knobs. A few areas considered to be ground moraine occur in the Adamsville–Purple Valley area and elsewhere. Till can occur in the re-entrant valleys of the escarpment, where it seemingly is plastered on to the valley walls.

The till mapped in the Bruce Peninsula (Table 2) has been informally named the “Bruce till” by Sharpe and Jamieson (1982) who have mapped it southward to where it forms a continuum with till believed to represent the Nissouri Stadial (Nissouri Phase) of Late Wisconsinan age (Michigan Subepisode); this interpretation, with which we concur, is consistent with earlier interpretations of northerly exposures of the Elma Till (Cowan et al. 1978) and implies that the area was ice covered continuously through Late Wisconsinan time (Michigan Subepisode) until the end of the Port Huron Stadial (Port Huron Phase). Five samples of till collected in 2006 indicate that the most common till facies found in the area is a sandy silt to silt till containing 10 to 36% sand; 58 to 78% silt; and 5 to 13% clay. Stone content varies from 5 to 15% and the till is yellowish brown in colour when oxidized. Carbonate content in the fine fraction of the till ranges from 33 to 42% (average 38.6%) and the ratio of calcite to dolomite ranges from 0.78 to 1.20 (average 0.95). Locally, the till may contain greater amounts of silt and clay where it is derived from adjacent outcrops of shale such as that from the Queenston or Cabot Head formations. No till sequences representing more than one glacial event were observed during the present survey.

The drumlin field in the Mar–Sky Lake area is composed predominantly of till, though exposures of stratified drift indicate that some of the drumlins may be partially cored with stratified materials. The drumlins are up to two or more kilometres in length and up to 15 or 20 m in height. Orientation of the drumlins is between 220 and 235°, which is consistent with measured glacial striae, indicating a general southwesterly ice flow during glaciation. The orientation of the Mar sediment drumlins is also similar to the orientation of rock drumlins and s-forms identified across the study area. These observations may imply that both the rock and sediment drumlins on the Bruce Peninsula are erosional in origin. Their directional correspondence with sculpted erosional forms suggests that meltwater erosion may have been involved in drumlin formation (Shaw and Sharpe 1987). Kor and Cowell (1998) postulate that the drumlins were formed by erosion of a pre-existing till by a subglacial outburst flood (*see also* Shaw and Sharpe 1987). The drumlins in this area may be considered to be an extension of the Arran drumlin field to the south; that drumlin field has also been interpreted as having been formed all or in part through the action of subglacial meltwater (Harry and Trenhaile 1987).

The drumlins formed islands in the Great Lakes during lower post-Algonquin lake levels and Nipissing Great Lakes; as a result they have been somewhat modified by shoreline processes in many places with patchy beach gravels, wave-cut notches and a general smoothing of the topography as evidence.

Water well data suggests that the till may be up to 15 m in thickness but is generally much less than this, more frequently in the 2 to 6 m range. Well records also indicate that the till may overlies proglacial fine to coarse sediments, which could have been deposited either in front of the advancing Late Wisconsinan (Michigan Subepisode) glacier or a retreating older glacier.

Table 2. Quaternary deposits and events, Bruce Peninsula.

<u>EPOCH</u>	<u>STAGE</u>	<u>AGE X 1000</u>	<u>DEPOSIT/EVENT</u>	<u>MATERIALS</u>	<u>LANDFORMS</u>
RECENT		2.5	modern lakeshores	gravel, sand, boulders	bars, flats, storm ridges
		3.0	Lake Algoma	shingle gravel, sand	beach ridges, bars
		5.0+	stream alluvium	sand, silt, gravel	flood plains
		5.0+	bogs, swamps	muck, peat, marl	filled depressions
		5.0	eolian	fine sand	dunes
		8.5 - 3.5	Nipissing Great Lakes	sand, gravel	sand flats, shore features, bluffs
				silt, clay	lacustrine plains
		10.5 - 8.5	low level Lake Hough, Georgian Bay	weathering, erosion	Bruce Peninsula expanded
		10.4 - 10.0	Post-Algonquin Great Lakes	sand, gravel, cobbles	raised shoreline bars, bluffs
	PLEISTOCENE	LATE WISCONSINAN	11.5 - 10.4	Main Lake Algonquin	sand, gravel, cobbles
				silt, clay	lacustrine plains
12.5 - 12.0			Early Lake Algonquin	silt, clay	lacustrine plains
12.5 - 0.0			talus development	blocks, rock rubble	talus slopes on scarps
12.5 - 0.0			karst development	dissolution features	grykes, caves, etc.
13.0 - 12.5			glaciofluvial deposits	sand, gravel	subaqueous fans, outwash
14.0 - 13.0			sheetflood erosion	massive sediment removal	sculpted forms
25.0 - 12.5			Bruce till	sandy silt-silt till	ground moraine, drumlins

Glaciofluvial Ice-Contact Deposits

Deposits of glaciofluvial origin are rare in the map area. In previous work, two areas have been interpreted as being of glaciofluvial ice-contact origin. In both instances these have been subsequently reworked into beach deposits at the surface. The first of these is the aggregate extraction area in the vicinity of the Tobermory airport, elevation 213 m asl. Stadelman (1973) considered this deposit to be cored by glaciofluvial materials from which the beach deposits were reworked. Ontario Geological Survey (1995) indicated that the gravels and sands are up to 6 m in thickness but that groundwater may have imposed a limit on the depth of aggregate excavation. They considered the beach features to be mainly related to the Nipissing Great Lakes. A water well record from near the airport records the following information: 0 to 5.4 m – coarse gravel; 5.4 to 9.1 m – sand; 9.1 to 11.6 m – clay; 11.6 to 48.2 m – stones. Elsewhere, rock is much closer to the surface. The present writers have not observed sufficient internal structures in the pits at this aggregate extraction area to make interpretations on the origin of the original feature. The depression in the central part of the feature may have been the result of stranded ice melting out. Based upon its location, isolation and reported properties, it would not be unreasonable to assign the original feature to a stagnant ice deposit such as a kame; however, we believe that it may be a subaqueous outwash fan.

The second feature usually described as being of ice-contact origin is located immediately south of Lion's Head. The feature is locally known as Astrop's Hill. Stadelman (1973) considered this feature to be a kame moraine cored with ice-contact stratified drift, which has been totally modified in the upper few metres by wave action of various high-level postglacial Great Lake phases. The sediments contain features such as faulting and very varied sediment shifts over short distances, which suggest an ice-contact chaotic depositional environment (Photo 7). The feature overlies a deep trough extending into Georgian Bay. Stadelman considered that the feature was constructed when the ice stood in Lake Algonquin at this location. Kor (1992a) suggested that this deposit more likely originated as a subaqueous outwash fan deposited whilst the ice was grounded on local uplands with the terminus of the glacier lying to the south in glacial Lake Algonquin. Paleoflow direction for crossbeds in these sediments is southerly, which is consistent with the subaquatic fan interpretation.



Photo 7. Gravel pit with subaqueous outwash fan materials, Astrop's Hill near Lion's Head.

This feature has been extensively extracted for granular aggregates and what remains is protected as an Area of Scientific and Natural Interest (ANSI). The elevation of the feature, as well as work summarized by Kor (1992a), indicates that the modification of this deposit was accomplished during lower Algonquin lake phases (Cedar Point and Payette) as well as the Nipissing Phase. A water well through this deposit reported the following information: 0 to 5.5 m – previously dug (most probably gravel); 5.5 to 7.6 m – gravel; 7.6 to 23.8 m – quicksand; 23.8 to 24.9 m – hardpan; 24.9 to 32.3 m – rock. Typically the hardpan descriptor used by drillers refers to a very compact till.

Stadelman (1973) also suggested that a possible glaciofluvial deposit exists south of Adamsville. Review of this deposit suggests that the feature is cored with material described as clay with gravel and stones (till) in the water well records. Old pit data from the beaches developed on the flanks of this feature suggest beach gravel in association with either immature beach gravels or outwash.

Geomatics International Inc. (1994) mapped small end moraine segments near Cabot Head and suggested that these may represent a minor readvance during deglaciation. The feature is shown by a moraine symbol on the accompanying map (Map 2679, back pocket) but as it is considered to be modified by Main Algonquin and younger waters, it is difficult to interpret.

Small deposits of glaciofluvial ice-contact materials may exist in various additional locales to those shown on the map (Map 2679). However, because so much of the area was modified by late glacial and postglacial Great Lakes events, most of these have been reworked and would appear, during mapping at the current scale, to be shoreline deposits.

Glaciofluvial Outwash

Sediments that could be described as glaciofluvial outwash are rare within the map area. The coarse gravels believed to represent the Main Algonquin level at the head of Sydney Bay (Photo 8) may well have originated as proximal facies outwash while ice stood in the bay abutting the escarpment, as there is a meltwater channel trending southerly from this location. Small deposits of sand and gravel have been mapped as outwash elsewhere.



Photo 8. Proximal facies outwash from which beach gravels were derived, Sydney Bay. Beach gravels have been removed from the upper part of this exposure.

The general lack of these deposits or normally related landforms (e.g., tabular gravel bodies) further reflects the work the subglacial meltwater sheetflood events may have accomplished in stripping the peninsula of glacial drift.

Glaciolacustrine and Postglacial Lacustrine Deposits

DEEP-WATER DEPOSITS

The principal deep-water glaciolacustrine deposits, consisting of laminated to varved silts and clays, are largely buried on the Bruce Peninsula. In addition, they occur as thin patches of sediment in rock-dominated terrain. Where they exist, they may relate to the Main Algonquin lake level as it lasted a considerable amount of time. Alternatively, the lower sediments in the Eastnor Plain area could be Early Algonquin, as the ice margin may have been well removed from this area during Main Algonquin. For the most part these sediments lay beneath the postglacial silts described below.

Deep-water sediments related to the postglacial Nipissing Great Lakes are widespread, forming a considerable component of the drift cover on the Bruce Peninsula. Of particular note is the large flat area in the Lion's Head–Ferndale–Edenhurst area, which is dominated by silt but also consists of laminated silt, fine-grained sand and clays. Observed thickness of these deposits is up to 2.5 m, but up to 25 m or more in thickness may be interpreted from water well records; thicker sections would include both glaciolacustrine and postglacial lacustrine sediments. These Nipissing Phase sediments are shell bearing (P.F. Karrow, University of Waterloo, personal communication, 2006). The provenance of the upper silt is somewhat problematic as there was no related glacial sedimentation and till deposits for reworking are not extensive. Perhaps much of the Nipissing Phase silt is reworked from underlying Lake Algonquin or Early Algonquin sediment.



Photo 9. Laminated lacustrine silts in Nipissing Phase sediments, Little Pike Bay Road.

SHALLOW-WATER DEPOSITS

Shallow-water and/or nearshore glacial and postglacial lacustrine deposits occur in small deposits over the area but do not cover extensive areas in many places, perhaps the most significant being in an area south and west of Sky Lake. Here sands and pebbly sands of the postglacial Nipissing Great Lakes and subsequent falling water levels have left a significant area of sand complete with residual suites of offshore sand bars. These appear on airphotos as a series of curved lines, commonly with swampy areas between the bars. In the Red Bay area these sands may be up to 10 m in thickness. The retreating lake waters of the day left these sand flats open to the prevailing westerly winds, which reworked the finer-textured portions of the sands into sand dunes on the downwind side of the sand flats. These eolian sands are described in a later section of this report.

The large silt plain described in the preceding section usually has a veneer of shallow-water sand. As well, the shore areas of this plain often have some associated sands.

Shallow-water sands are mapped in patches throughout much of the area where they form remnants of small pondings or nearshore processes.

ABANDONED SHORELINE FEATURES AND DEPOSITS

Fragments of raised, abandoned shoreline features representing former levels of the Great Lakes are common in the area but they are usually only well developed over very short distances due to the nature of the terrain. These features result from the effects of glacio-isostatic rebound during and following deglaciation and the opening and closing of various outlets related to either the presence or absence of ice and/or isostatic effects on those outlets while the Great Lakes evolved from being covered by glaciers to their present state. Within the Huron and Georgian Bay basins, late glacial and postglacial shorelines are measured against two prominent shorelines known as the Main Algonquin and the Nipissing Great Lakes shorelines. Main Algonquin had an elevation of 184 m asl (605 feet) at Port Huron, as did the postglacial Nipissing Great Lakes (herein referred to as the Nipissing Phase). However, due to the age difference between these two lake phases and the changes in rates of isostatic rebound over time, the difference in elevation in the Bruce Peninsula is about 50 m. In some areas in the Huron Basin an Early Algonquin feature is also recognized. Sandwiched between the Main Algonquin and Nipissing Phase shorelines in the Georgian Bay area are three strandlines known as the “upper group” and four or more strandlines known as the “lower group.” The former were named by Deane (1950) and comprise the Ardtrea, Upper Orillia and Lower Orillia, in descending order. Deane stated that these are well defined in only a few localities. The lower group shorelines were named by Stanley (1936, 1937) and comprise the Wyebridge, Penetang, Cedar Point and Payette, in descending order. These post-Algonquin levels existed for a very short time and, as a consequence, are only well developed in optimal locations over short distances. Table 3 summarizes reported elevations of shorelines by various workers on the Bruce Peninsula; no shoreline survey work was completed during the present study.

One of the earliest studies on Bruce Peninsula shorelines was by Goldthwait (1910) who recorded raised shorelines in the Dyer’s Bay, Lion’s Head and Hope Bay areas. At Dyer’s Bay he reported benches at 593 feet (181 m), 609 feet (186 m), 610 feet (186 m), 618 feet (188 m) and 623 feet asl (190 m), and beaches at 634 feet (193 m), 684 feet (208 m) and 686 feet asl (209 m); here he placed the Nipissing shoreline at 641 feet asl (195 m). At Lion’s Head he placed the Nipissing shoreline at 636 to 642 feet asl (194 to 196 m), and measured gravel ridges at 665 feet (203 m), 673 feet (205 m), 692 feet (211 m), 697 feet (212 m) and 723 feet asl (220 m). He noted up to 20 shingle beach ridges between the Nipissing level and modern shoreline. At Hope Bay he placed the Nipissing shoreline at 636 feet asl (194 m) and

measured a strong beach at 621 feet asl (189 m), a beach crest at 629 feet asl (192 m) and a distinct beach at 664 feet asl (202 m). Goldthwait's projected isobase for Lake Algonquin in central Bruce Peninsula was 807 feet asl (246 m); for the Nipissing shoreline he portrayed an isobase at 630 feet asl (192 m) trending through the south-central part of the current map area. He also opined that the Lake Algonquin shoreline should occur at about 820 feet asl (250 m) in the Dyer's Bay and Lion's Head area.

Table 3. Summary of reported elevations of abandoned shorelines on Bruce Peninsula: **EA** = Early Algonquin; **MA** = Main Algonquin; **LA** = Lower Algonquin; **WY** = Wyebidge; **PT** = Penetang; **PY** = Payette; **CP** = Cedar Point; **NP** = Nipissing; **AG** = Algoma.

Location	Goldthwait 1910	Nichols 1972	Stadelman 1973	Kor 1992 a, b and c, 1994	Karrow 2006, pers. comm.	Sly and Lewis 1972
Slough of Despond				240 m, MA	241 m, MA	
Cooks Dr.-Purple Valley Rd.			845 ft (258m), EA 805 ft (245m), MA		241 m, MA	
Gravelly Bay					245 m, MA	
Sydney Bay		240-244 m, WY? 207.6 m, CP 197-200 m 191-194 m, NP 187-189 m, AG			243 m, MA	
Hope Bay	664 ft (202 m) 636 ft (194 m), NP 629 ft (192 m) 621 ft (189 m)	212.5 m, PT 192.6 m, NP 190.8 m 189.0 m		246 m, MA		
Lion's Head	723 ft (220 m) 697 ft (212 m) 692 ft (211 m) 673 ft (205 m) 665 ft (203 m) 642 ft (196 m), NP 636 ft (194 m)	212.5 m 209.7 m, CP 203.6 m, PY 198.7 m 194.5 m, NP	682 ft (208 m), LA 650 ft (198 m), LA 632 ft (193 m), NP 618 ft (188 m), AG	247 m, MA 212 m, CP 210 m, CP 203-205 m, PY 202 m, PY 200 m, PY 197 m, PY 192.5 m, NP		
Dyer's Bay	686 ft (209 m) 684 ft (208 m) 641 ft (195 m), NP 634 ft (193 m) 623 ft (190 m) 618 ft (188 m) 610 ft (186 m) 609 ft (186 m) 593 ft (181 m)					
Cabot Head			857 ft (261 m) MA Projected	250 m, MA		269 m?, MA 228 m, PT 223 m, CP 194 m, NP 186 m, AG
Tobermory			685 ft (209 m), LA 638 ft (194 m), NP			



Photo 10. Abandoned shore-bluff features near Hope Bay.

Chapman and Putnam (1951 et seq.) stated that beaches in the area north of Wiarton were fragmentary and noted Lower Algonquin beaches on Cape Croker; a Lower Algonquin beach at Lion's Head; and probable Nipissing Phase beach features at 640 feet asl (195 m) near Pike Bay on the west side of the peninsula. They also noted that "the most important effect of Lake Nipissing (Nipissing Phase) on the Bruce Peninsula was to leave the marly silt in the flat plain of Eastnor Township."

Nichols (1972) carried out a study on the shorelines of southern Georgian Bay. Within the present project area she surveyed several profiles of raised shorelines in the Cape Croker, Sydney Bay, Hope Bay and Lion's Head areas. Her statistical analysis and interpretations led her to conclude that the highest shoreline features within the present project area were not strong enough to be related to Main Lake Algonquin. She suggested that the Wyebridge, Penetang, Cedar Point and Payette levels are present at one or more locations. Specifically, she suggested that the Wybridge level is present at Sydney Bay; the Penetang level at Hope Bay (212.5 m asl); the Cedar Point level at Lion's Head (209.7 and 212.5 m asl) and possibly Sydney Bay (207.6 m asl); the Payette is possibly at levels of 203.0 m and/or 198.7 m asl at Lion's Head; and Nipissing as the lowest strandline at Lion's Head and perhaps Hope Bay (192.6 m asl) and Sydney Bay (193.6 and 191.4 m asl).

Stadelman (1973) mapped Main Lake Algonquin and Nipissing Phase shorelines utilizing recognizable shoreline features and isobase data provided by Goldthwait (1910) and Nichols (1972). He also identified features near Adamsville that he related to Early Lake Algonquin; these reportedly occur at about 845 feet asl (257 m). He noted a strong beach at 805 feet asl (245 m) in the same vicinity, which he asserted was Main Algonquin. Stadelman interpreted the upper beaches at Astrop's Hill (685 and 650 feet asl (209 and 198 m)) near Lion's Head and the Tobermory area (685 feet asl (209 m)) as being Lower Algonquin. Isobases portrayed by Stadelman suggest that the Nipissing level ranges from 625 feet asl (190 m) in the southwest part of the area to about 640 feet asl (195 m) in the northwest. He obtained two

radiocarbon dates for the area related to the Nipissing Phase; these were in the range of middle Nipissing Phase of 5000 to 5500 years BP.

Sharpe, during his field work on this project, placed the Lake Algonquin shoreline at about 244 m asl (800 feet) and the Nipissing Phase shoreline at 198 m asl (650 feet) near Pike Bay and 206 m asl (675 feet) near Dyer's Bay.

Kor (1992a, 1992b, 1992c, 1994 and Varga et. al 1992) placed the Main Algonquin shoreline at about 240 m asl (787 feet) at the Slough of Despond; 246 m asl (807 feet) at Hope Bay; 247 m asl (810 feet) at Lion's Head; and 250 m asl (820 feet) at Cabot Head. Kor's elevations were interpolated from isobase data compiled by Goldthwait (1910) and Nichols (1972).

P.F. Karrow (University of Waterloo, personal communication, 2006) has surveyed Main Lake Algonquin features in recent years as follows: Slough of Despond - 241 m asl (790 feet); Gravelly Bay - 245 m asl (803 feet); Cooks Drive - 241 m asl (790 feet); and Sydney Bay - 243 m asl (797 feet). He also notes that the Nipissing Phase shoreline is at 191 m asl (626 feet) and that it is very consistent over short distances.

Sly and Lewis (1972) described a section at Gillies Lake near Cabot Head and suggested that the Algoma beach occurs at approximately 186 m asl; the Nipissing at 194 m asl; and high-level beaches at 223 m asl (Cedar Point water plane?) and perhaps 228 m asl (Penetang water plane?). The upper two proposed water planes were postulated on the Main Algonquin having an estimated elevation of 269 m asl at this location, based on extrapolation from isobases.

The Main Algonquin shoreline can only be found on the east side of the Bruce Peninsula where islands occurred within the lake. From data presented above, these islands would have occurred at present elevations above 239 m asl (785 feet) and ranging up to 250 m asl (820 feet), depending on location. As stated by Goldthwait (1910) the isobases for the glacial and postglacial Great Lakes trend more or less parallel to the Bruce Peninsula. Post-Algonquin and Nipissing shorelines occur below this level, with Nipissing shorelines ranging from 190 m (623 feet) to 206 m asl (675 feet) from west to east.

Based on the above discussion and field observations by the writer(s) the following interpretation of shorelines is suggested for the project area. Strong Main Algonquin shoreline features are considered to exist at Sydney Bay, Cooks Drive and Slough of Despond, the latter comprising a spectacular barrier bar complex that is without doubt Main Algonquin. These are described by different observers as being at elevations of 240 to 243 m asl (787 to 797 feet) at Slough of Despond. Northward, Main Algonquin elevations rise to more than 250 m asl (820 feet) at Cabot Head (Kor 1994) where its presence is speculative; extrapolation from isobases by Stadelman (1973) places the hypothetical shoreline at 261 m asl at Cabot Head, while Sly and Lewis (1972) place it at 269 m asl at Cabot Head. Similarly, generalized isobases constructed for this study (Figure 4) indicate that the Main Algonquin water plane occurs at a hypothetical elevation of about 270 m asl at Cabot Head, which is above current shoreline features of significance.

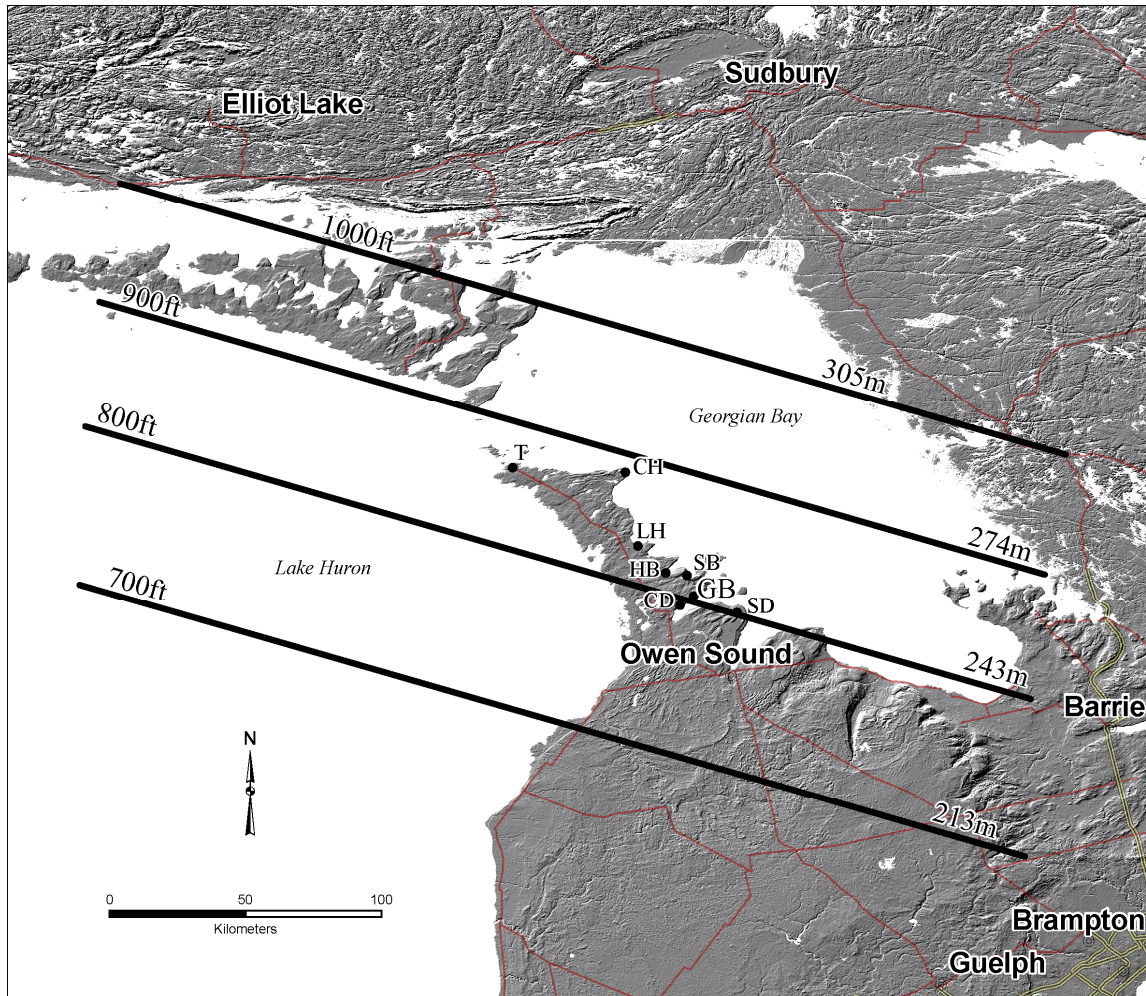


Figure 4. Generalized isobases for Main Lake Algonquin in the Bruce Peninsula area. T = Tobermory; CH = Cabot Head; LH = Lion's Head; HB = Hope Bay; SB = Sydney Bay; GB = Gravelly Bay; CD = Cooks Drive; SD = Slough of Despond.

Shoreline development is generally neither strong nor continuous due to the nature of the topography and the availability of substrates for reworking. Main Algonquin deposits consist of shingle gravel, open-work gravel and sandy gravels, depending on location and available substrate. At Niagara Escarpment locations such as Cabot Head, any shore features developed by Main Algonquin may be primarily sea stacks and shore caves created by wave action on suitable rock faces (P.S.G. Kor, Ontario Parks, personal communication, 2006).

Post-Algonquin levels occur below 238 m asl (780 feet). These are generally not well developed due to the short time available between Main Algonquin time and the lowering of the Great Lakes to well below present-day levels, about 10 000 years BP. Indeed, Nichols (1972) suggested that the several post-Algonquin levels must have formed over several hundred years between 10 400 and 9700 years BP, a very short time. Others have suggested that the post-Algonquin levels were constructed in a still shorter time-frame, between about 10 500 and 10 200 years BP (e.g., Lewis and Anderson 1985).

Figure 5 outlines the approximate land area that would have been exposed during Main Algonquin. It is not corrected for the isostatic differential between south and north, so the land area portrayed is slightly greater than the real situation at the time.

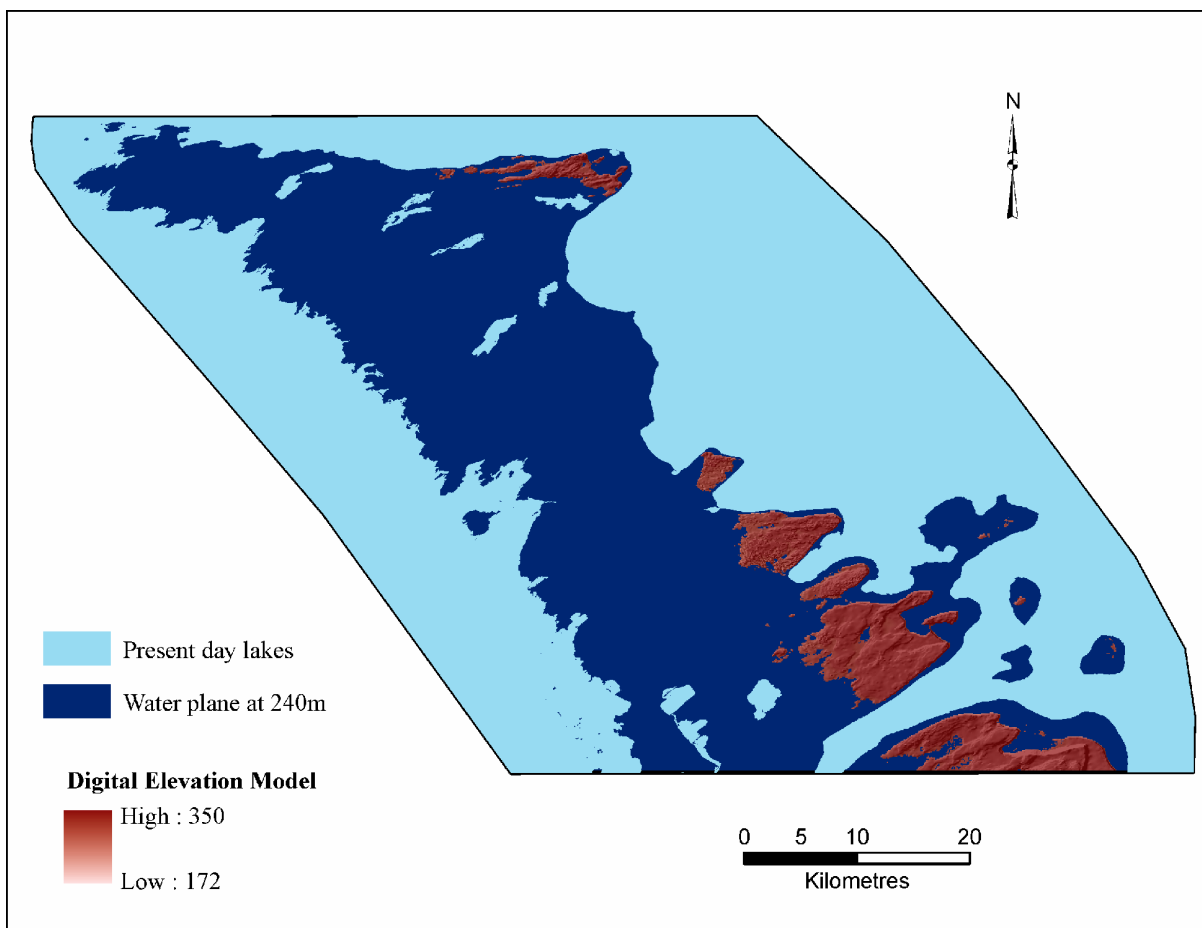


Figure 5. Illustration showing water plane at 240 m asl, approximate Main Algonquin level.

Most post-Algonquin shorelines recorded in the project area appear to fall within the elevations of the Lower Algonquin group; e.g., Tobermory airport area, Lion’s Head glaciofluvial feature and others. This is readily explainable by the reality that time frames were very short and the amount of available land area with workable substrates was minimal until the water plane fell below about 220 m asl. Upper group shoreline features undoubtedly exist as short fragments and would probably occur above 229 m asl where present. Similarly, Lower Algonquin shoreline features would most likely occur between 197 and 229 m asl.

Shoreline features for the Nipissing Great Lakes occur on both the east and west sides of the Bruce Peninsula. On the west side, features consist of sandy beach deposits, small pockets of gravel from reworking older sediments and short segments of shore bluffs. Because of the nature of the shore area in general, the opportunity to develop significant features over any distance is limited. Here, Nipissing features occur in the 190 to 195 m asl range.

On the east shore of the Bruce Peninsula, Nipissing Phase depositional shore features are composed dominantly of flaggy shingle gravel of fairly coarse size, though sand segments are present. As well, numerous erosional bedrock platforms, sea stacks and shore caves are credited to the Nipissing Phase. Reported elevations range from 189 to 200 m asl, though many observations fall in the vicinity of 195 m asl.

Figure 6 outlines the approximate land area that would have been inundated during the Nipissing Great Lakes. It is not corrected for the isostatic differential between south and north, so the land area portrayed somewhat exceeds the real situation at the time.

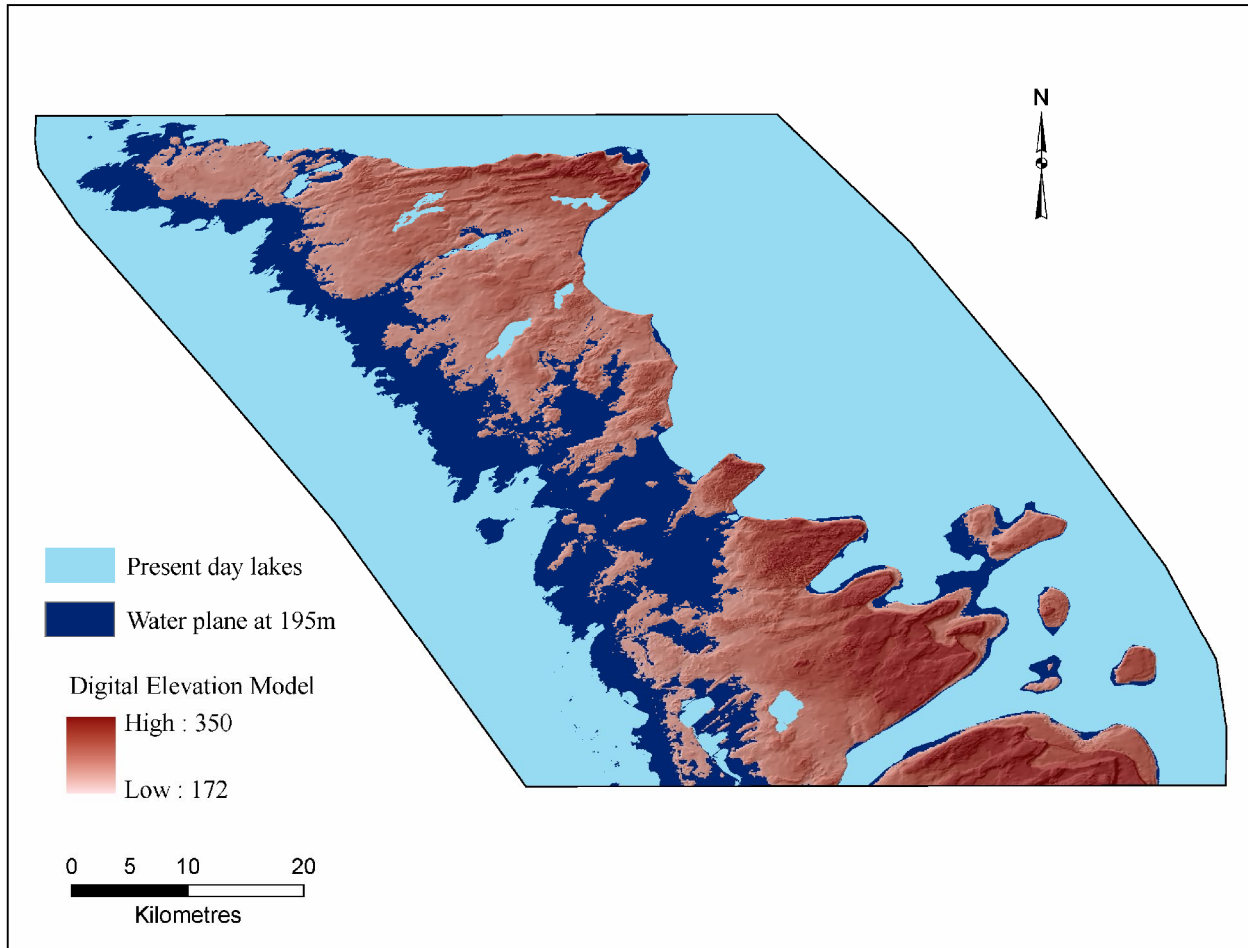


Figure 6. Illustration showing water plane at 195 m asl, approximate Nipissing Great Lakes level.

Stadelman (1973) discovered 2 organic sites interpreted as relating to Nipissing Phase events. The first of these was a charcoal sample from a paleosol under a sand dune near Spry Lake. This has been dated at 5109 ± 131 years BP. A second site, located at Dyer's Bay, consisted of a charcoal layer embedded in a cobble beach and has been dated at 5452 ± 63 years BP. These dates were reported by Terasmae, Karrow and Dreimanis (1972). They are both within reported ranges for the age of the Nipissing Great Lakes.

The Nipissing Phase had a profound impact on the peninsula, with large areas of lacustrine silts being deposited in the silt plain between Edenhurst and Ferndale; these overlay varved clays perhaps related to Early Lake Algonquin and younger phases. Most of these sediments lay within a 195 m asl contoured water plane, excluding elevation differential due to isostatic uplift. In addition, much of the area below about 200 m asl has a thin gravel to cobble lag deposit wherever the substrate would provide the necessary materials. The silt plain is broken by rock outcroppings and pockets of till or other older sediments.

Eolian Deposits

Eolian deposits consist of windblown sands that occur primarily as sand dunes on the western side of the Bruce Peninsula. These dunes were created as the Nipissing Great Lakes waters receded from the area leaving a broad flat of nearshore and shoreline sands available for wind erosion and redeposition. The dunes are up to 18 m in height and consist of fine- to very fine-textured sand. A radiocarbon date was obtained by Stadelman (1973) from the base of a sand dune near the southwesternmost corner of the project area. The date was obtained from charcoal in a paleosol located at the base of the dune and about 6 m below its crest at an elevation of about 199 m asl (655 feet), or just above the Nipissing level. The dune sand overlies the Nipissing bluff (P.F. Karrow, University of Waterloo, personal communication, 2006). This has been dated at 5109±131 years BP. D.P. Schwert (North Dakota State University, personal communication) examined this site in 1975 and found numerous terrestrial mollusks. His collection included: 1 *Retinella indentata*; 18 *Zonitoides arboreus*; 1 *Mesodon cf. thyroides*; 1 *Anguispira alternata*; and 11 *Discus cronkhitei*.

Eolian sands occur elsewhere in the area but they are of minor extent and generally too small in area or too thin to map at the present scale. The Ontario Geological Survey (1995) mapped a few eolian sand areas as potential granular aggregate sources.

Modern Alluvium

Alluvial sediments deposited by modern streams are generally sparse within the map area. There are several reasons for this. Firstly, the bedrock surface is generally near ground level and slopes gently toward the Lake Huron shore; streams are frequently floored by rock and there is little or no downcutting. Secondly, glacial and postglacial sediments are limited so that there is little erosion and redeposition. Finally, much of the area drains internally into solution openings (grykes) in the carbonate rocks, thus reducing the amount of surface run-off and related fluvial erosion and deposition. Mapped alluvium consists of sand, gravel, silt and some organic deposits, and is generally 1 to 2 m in thickness.

Organic Deposits

Organic deposits occur in low-lying, poorly drained areas. These deposits consist primarily of muck with some peat and marl. Thickness ranges from 1 to 1.5 m. Many of the bogs directly overlie rock; others commonly overlie silty or sandy lacustrine deposits. Kettle holes are very rare and during the present survey no sites with thick organic materials were identified.

Modern Shore Deposits

As noted elsewhere in this report, the east and west shorelines of the Bruce Peninsula are vastly different in character due to the configuration of the bedrock, which is updip on the east side and downdip on the west side. On the updip east side of the peninsula, the rock is subject to continuous erosion by strong northerly winds, which rip up slabs of carbonate rock and gradually reduces these slabs to coarse pebble and cobble gravel, forming continuous cobble beaches in many areas. Storm waves create gravel or cobble bars up to 4 m above current lake levels. Thus, in areas where a series of older shorelines are continuous with the current shoreline, a suite of coarse cobble bars may span many metres of elevation. Longshore currents or enhanced wave action in embayments has created some spectacular cobble beaches, notably the recurved spits at Cabot Head and Cape Dundas. Due to the lack of suitable substrate

on the east side of the peninsula, sand beaches are uncommon, the sand beach at Dunks Bay being an exception. Photos 11 and 12 portray some examples of the above-described processes.



Photo 11. Shingle beach development with rip-up clasts from Manitoulin Formation outcrop being tumbled into shingle gravel, Cabot Head area.



Photo 12. Storm bars in shingle gravel, Cabot Head.

On the west side of the peninsula the rocks gently dip into the lake, leaving a generally flat surface for Lake Huron wave processes to work on. The result in many places is a shoreline with bare, nearly flat-lying rock with a discontinuous lag deposit of cobbles and boulders (Photo 13). South of Pike Bay there are sandy shorelines derived from Nipissing and post-Nipissing shallow-water sands. In several places flights of offshore sandbars are present just above the present shoreline, representing previous higher water levels.



Photo 13. Boulder lag resting on rock, modern shoreline, Little Pike Bay area.

Talus Deposits

Along the face of the Niagara Escarpment, and other subordinate escarpments such as those of the Manitoulin Formation, flaggy to blocky materials, freed up by karstic and other weathering processes, have fallen from the scarp faces and brows to form a layer of chaotic debris lying directly on rock or older Quaternary sediments. In places, individual chunks of this material can be many cubic metres in volume. In general, the size of material found in the talus debris is much greater beneath those scarps formed from massive units of the Amabel or Guelph formations than from formations that form secondary scarps, such as the thinner bedded Manitoulin Formation. This falling debris can be hazardous to residences built along the lower edge of the escarpment. Due to the relatively small area occupied by these materials, they were not mapped as a separate unit. It can be assumed that they exist in varying quantities continuously along the face/base of rock escarpments present in the area.

Historical Geology

The Bruce Peninsula has very limited glacial sediment due to the massive late glacial erosion that is related to proposed catastrophic subglacial meltwater sheetflood events during late glacial times (Kor and Cowell 1998). Thus, little or no stratigraphic evidence of glacial or interglacial events that predate the Late Wisconsinan glaciation (Michigan Subepisode) has been found. Kor (1994) has reported older glacial striations trending at 111° on the east shore of Gillies Lake. Though he postulated that these may represent an older glaciation, the evidence is too sparse to say much about this possibility. All glacial sediments discussed within this report are related to the most recent glaciation, the Late Wisconsinan glaciation (Michigan Subepisode).

It is believed that the Bruce Peninsula was continuously ice covered during the Nissouri through Port Huron Stadials (Phases), about 25 000 to 12 500 years BP, and perhaps even longer. During this glacial episode the Laurentide Ice crossed the peninsula in a southwesterly direction as recorded by glacial striations (220 to 235°), drumlins in the Mar drumlin field (general orientation 235°) and sculpted bedrock forms created by subglacial meltwater (general flow direction 237° (Kor and Cowell 1998)). Till deposits, consisting primarily of locally derived carbonate debris, were laid down during this period. At some point during this glacial event massive sheetfloods of released subglacial meltwaters, which had accumulated beneath the ice upglacier, stripped most of the glacial drift from the peninsula, eroded great quantities of dolostone from the escarpment brow, and created a widespread suite of streamlined sculpted rock features (s-forms) and the sediment-cored drumlin field southeast of Mar, a truly catastrophic event. The timing of the subglacial meltwater sheetfloods is unknown but it is suggested that this may have occurred sometime between 14 000 and 13 000 years BP. It has been demonstrated that a massive pulse of glacial meltwater into the Atlantic Ocean occurred about 14 200 years BP (an event known as mwp-1a). It has also been suggested that a component of this meltwater may have come from the Laurentide ice sheet (Peltier 2005); if so, the age of the sheetfloods may be in the 14 000 years BP range. As well, though the location of the ice front at the time of these events is unclear, the timing proposed above suggests that the Huron Basin would have been ice covered, with outflows several kilometres inland into both Ontario and Michigan.

Glacier retreat across the peninsula towards the northeast was accompanied by the deposition of subaqueous outwash fans near Tobermory and Lion's Head and by the outwash sediments located at Sydney Bay. The former two deposits were considered to be kame moraines by Stadelman (1973) but Kor (1994) has interpreted these as subglacial outwash fans, which is in keeping with other evidence of subglacial meltwater events.

Retreat was also accompanied by a proglacial lake, perhaps Early Lake Algonquin, into which the above features may have been deposited as well as much of the deeper clays in the Eastnor silt plain. Stadelman (1973) has suggested that there may be shoreline features representing Early Algonquin near Adamsville.

The Huron and Georgian Bay basins were glacio-isostatically depressed at this time through loading by glacier ice, so that waters occupying these basins are recorded by raised shoreline features and sediments in the lowlands of the present landscape. During the time frame 12 500 to 12 000 years BP the retreating ice front was located in Georgian Bay and the waters drained easterly through the Trent River system to Lake Ontario (Kirkfield or Fenelon Falls outlet) about 12 000 years BP. Subsequent blockage of this eastern outlet by either readvancing ice or through uplift of the outlet created a rising water level draining through the St. Clair River, which gave rise to Main Lake Algonquin, which existed approximately 11 500 to 10 400 years BP. The highest principal shoreline in the study area is the Main Algonquin shoreline, which occurs at or slightly below 243 m asl (800 feet) through much of the area.

During this time only a few islands existed on the east side of the Bruce Peninsula as we know it today, and some residual shoreline features existed on the higher locations. As the ice further retreated northeastward, glacio-isostatic rebound occurred on an axis of about 21° east of north so that the shoreline features are tilted in that direction (*see* Figure 4). For instance, the Main Lake Algonquin shoreline near Wiarton is in the range of 243 m asl (800 feet), whereas it occurs at about 184 m asl (605 feet) near Sarnia. The uplift curves vary from linear to curvilinear depending on the length of a segment and the time frame during which it existed; i.e., uplift was most rapid immediately following deglaciation and continues even today at a very reduced pace.

Northward retreat of the ice allowed additional easterly outlets to be opened further to the north, while at the same time the land continued to rebound. This gave rise to a series of shorelines referred to as post-Algonquin in the Georgian Bay and Lake Simcoe areas between about 10 400 and 10 000 years ago. In general, the shorelines representing these water levels are not well developed on the Bruce Peninsula due to the short time of their existence, uplifting land and the lack of suitable materials to rework. However, some post-Algonquin shorelines are recorded at Tobermory and Lion's Head on reworked gravel deposits, and elsewhere along the escarpment. These have been suggested as representing the lower post-Algonquin levels of Stanley (1936, 1937).

Further ice retreat to the north allowed the opening of an easterly outlet through the French River–Mattawa system to the Ottawa River via the North Bay outlet. This glacio-isostatically depressed outlet was much lower than the present level of Lake Huron, which allowed a rapid lowering of the post-Algonquin waters to well below the current lake level, as witnessed by forest growth in certain areas beneath the waters of present day Georgian Bay (i.e., many submerged stumps have been found). This occurred about 10 000 years BP. This low water level is known as Lake Stanley in the Huron Basin and Lake Hough in Georgian Bay, which, at the time, was only a shadow of present-day Georgian Bay.

Subsequent uplift of the North Bay outlet caused a gradual increase in water level in the Great Lakes, which is recorded by radiocarbon dates on organic materials from raised alluvial terraces in rivers graded to rising water levels in the Great Lakes. These radiocarbon dates span a time frame from 9000 to 3500 years BP. At about 5000 years BP, a stabilized water level was achieved and drainage of Lake Huron was ultimately via the St. Clair River at Port Huron, though for a period of time there was drainage via North Bay, Port Huron and Chicago. This stabilized water body is variously known as the Nipissing Great Lakes or Nipissing Phase, and it created strong shorelines throughout much of the Great Lakes. On the Bruce Peninsula, shoreline features exist between the elevations of 190 to 200 m asl, depending on location. During the Nipissing Phase a broad area along the west side of the peninsula was inundated, as was a narrow belt on the east side. Of note is the large, flat area of silty lacustrine sediments occupying a large area west of Lion's Head; in this area the waters of Georgian Bay and Lake Huron were confluent, forming a large depositional area known as the Eastnor silt or clay plain. The lower part of the Nipissing Phase silts are fossiliferous, whereas underlying clays related to one or more Algonquin phases are not (P.F. Karrow, University of Waterloo, personal communication, 2007).

Continued uplift of the North Bay outlet and the Georgian Bay area in general, combined with the downcutting of the Port Huron outlet, resulted in the lowering of the Nipissing Great Lakes to modern day levels. On western Bruce Peninsula these lowering waters created suites of small offshore bars in locations where sand was present.

A transitory shoreline feature occurring 15 to 20 m above present-day Lake Huron is believed to represent a later phase between the Nipissing level and present-day Lake Huron—the Lake Algoma phase circa 3000 years BP. This is variously related to downcutting of the Port Huron outlet or climatic fluctuations during the lowering of the Nipissing Great Lakes (Larsen 1985). Lake Huron is believed to have attained its present-day level around 2500 years BP.

Overviews describing the evolution of the Great Lakes and the Quaternary geology of Ontario in a much broader context include papers by Barnett (1992), Karrow (1989), Eschman and Karrow (1985) and Lewis, Blasco and Gareau (2005).

Since deglaciation, the development of karst features in the carbonate rock has perhaps been the most dominant geological process. This has considerable impact on the drainage patterns of the peninsula with large areas being drained internally, especially on the east side. This karst development also allows for a considerable loss of soil to the karst openings and provides direct entry of contaminants into the groundwater system. Karst development along the Niagara Escarpment is also credited with enhancing backwasting of the escarpment through freeing up blocks of rock to be subjected to gravitational processes and the creation of talus deposits.

Economic Geology

NATURAL GRANULAR AGGREGATES

Sand and gravel deposits suitable for commercial extraction are of limited extent within the project area. Numerous small deposits are depleted and the major deposits located at Tobermory and west of Lion's Head are much reduced and, in the case of the Lion's Head feature, subject to protection or used for other purposes. The Ontario Geological Survey (1995, p.xi) stated that for the northern part of the peninsula "the possible resources of available sand and gravel are likely to be insufficient for local needs in the future, and will require supplementation from other sources. Care should be taken to ensure the proper utilization of the remaining resources."

For that part of the area laying within Keppel Township the same statement holds true (Ontario Geological Survey 1985). The most significant granular aggregate deposit (i.e., the Main Algonquin barrier bar complex near Slough of Despond) is nearly depleted and is currently protected as an Area of Natural and Scientific Interest.

Natural granular aggregates in the area, especially those located near the escarpment or downflow of the large re-entrant valleys, may be impacted by deleterious shale and siltstone, primarily derived from the Cabot Head Formation.

With time, the use of crushed dolostone and rock dust will become more important as replacements for natural granular aggregates.

AGRICULTURAL SOILS

The surface of the Bruce Peninsula is notable for the absence of significant glacial sediment over perhaps 60% or more of its area, and for the strong development of internal drainage through well-developed karst features. This results in several impacts on cleared lands. Firstly, internal drainage does not allow for moisture storage within the thin soils; and secondly, the vertical openings in the rock surface allow the existing precious soil materials to work their way underground, further depleting the sediment available for agriculture. Thus, good agricultural soils are at a premium. Most of the crop-based agriculture exists on the silt plain in the Ferndale–Edenhurst area and on the tills located mainly in the southern half of the peninsula. The rock-dominated area is most suitable for pasture and forestry.

WATER SUPPLY

Review of water well records for the Bruce Peninsula indicates that most wells are drilled into rock, as might be expected from earlier discussion in this report. Many of these wells encounter rock within 0 to 2 m of the surface. The generally thin sediment cover, in conjunction with the strong internal drainage due to karstic features, implies that great effort is needed to protect the groundwater supply from infiltration of surface contaminants, notably cattle manure, household sewage, agricultural fertilizers and pesticides, road salt and many other potential contaminants. Recommendation 2 of the Grey and Bruce groundwater study (Waterloo Hydrogeologic Inc. 2003) states that an investigation of karst along the Niagara Escarpment should be completed to better understand the importance of karst features to groundwater recharge and groundwater vulnerability. Work for the present project identified karst areas throughout the study area, so the scope of any future such karst investigation project should include most of the peninsula.

In addition to water wells, many coastal residences and seasonal cottages obtain domestic water supplies directly from Lake Huron and Georgian Bay.

Engineering Geology

Though construction works requiring detailed engineering are not numerous in the project area, some general comments may be made. Any construction work on the peninsula must take into account the surface or near-surface rock conditions and the probability for karst features to be present. These can create excavation and drainage problems, as well as a potential that significant voids may be present in the subsurface. In some locales, springs or high groundwater pressures may be the result of high groundwater flows through karstic-conductive systems.

Construction around the escarpment areas needs to consider the potential for release of large blocks from the upper margins of the escarpments and, conversely, works in the lower slopes of the escarpments need to consider the potential for rock fall damage to structures. Risk assessments for projects in the escarpment area should be completed prior to construction.

Quicksand is mentioned in numerous water well records for the area. Thus, high groundwater levels and flowing sand may be expected in areas mapped as sand, especially where swamps and bogs indicate near-surface water tables in the area. In these areas, excavations may require support during construction.

Near-surface silts and clays, particularly those in the Eastnor silt plain, may be expected to consolidate and settle under loading. Geotechnical testing should be completed prior to constructing significant buildings to determine whether pre-loading may be effective.

Similarly, organic materials in bogs and swamps may require pre-loading, complete excavation of the organic materials, or the use of stabilizing systems (e.g., geo-grids) to assure adequate foundations for certain types of projects.

Excavation in glacial sediments of any type always carries the potential to encounter oversized boulders.

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Metric Conversion Table

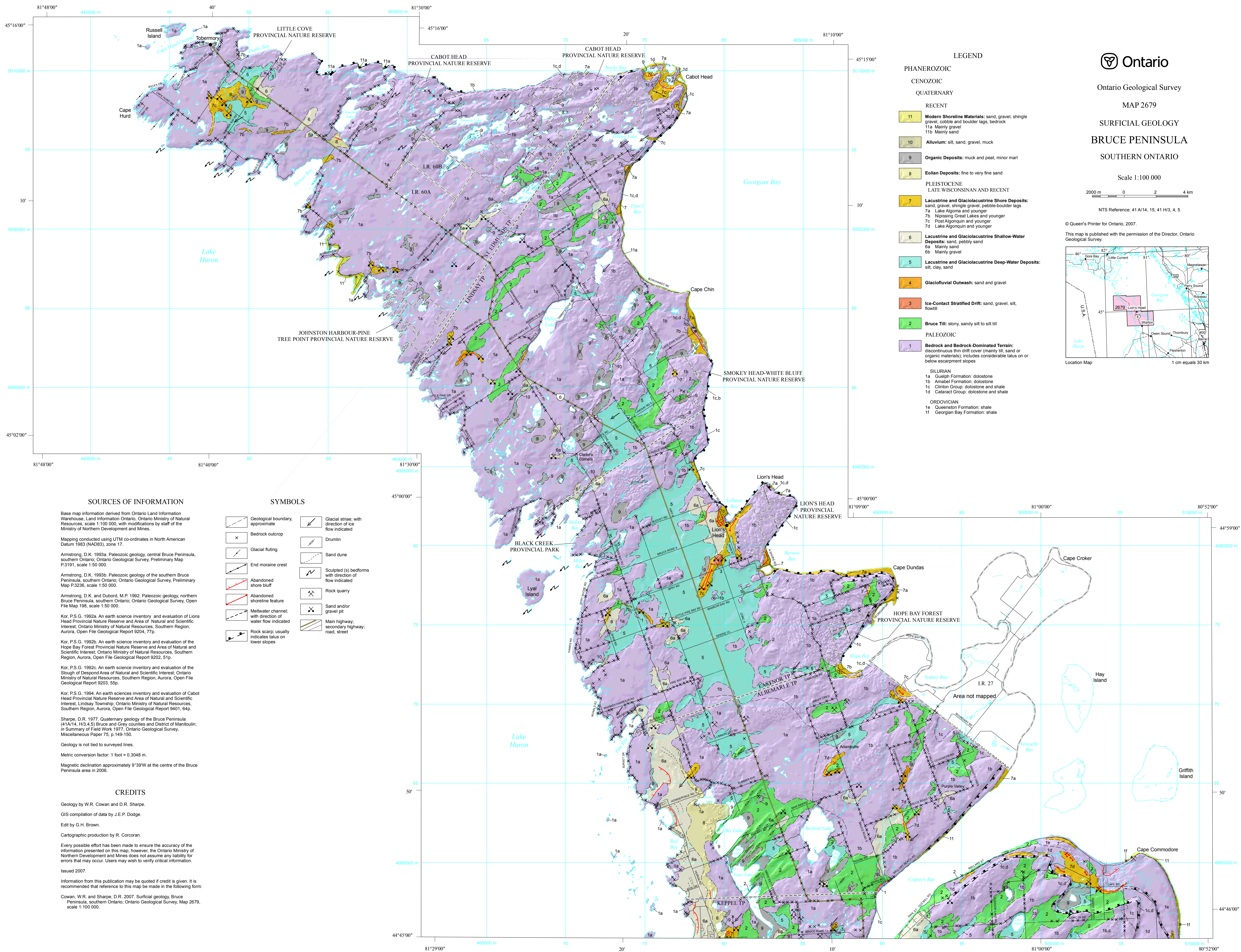
Conversion from SI to Imperial			Conversion from Imperial to SI		
<i>SI Unit</i>	<i>Multiplied by</i>	<i>Gives</i>	<i>Imperial Unit</i>	<i>Multiplied by</i>	<i>Gives</i>
LENGTH					
1 mm	0.039 37	inches	1 inch	25.4	mm
1 cm	0.393 70	inches	1 inch	2.54	cm
1 m	3.280 84	feet	1 foot	0.304 8	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	1.609 344	km
AREA					
1 cm ²	0.155 0	square inches	1 square inch	6.451 6	cm ²
1 m ²	10.763 9	square feet	1 square foot	0.092 903 04	m ²
1 km ²	0.386 10	square miles	1 square mile	2.589 988	km ²
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
VOLUME					
1 cm ³	0.061 023	cubic inches	1 cubic inch	16.387 064	cm ³
1 m ³	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m ³
1 m ³	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m ³
CAPACITY					
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	4.546 090	L
MASS					
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	31.103 476 8	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	0.453 592 37	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	907.184 74	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	0.907 184 74	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	1016.046 908 8	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	1.016 046 90	t
CONCENTRATION					
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	<i>Multiplied by</i>	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

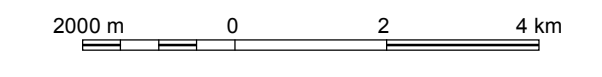
Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

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 MAP 2679
 SURFICIAL GEOLOGY
 BRUCE PENINSULA
 SOUTHERN ONTARIO

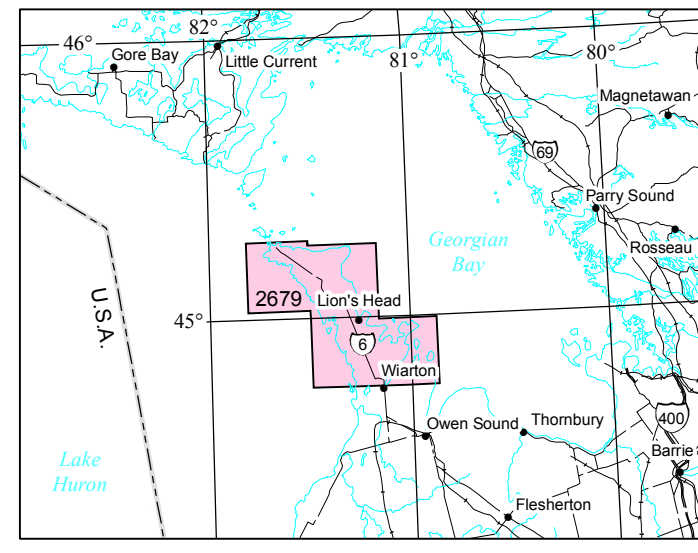
Scale 1:100 000



NTS Reference: 41 A/14, 15, 41 H/3, 4, 5

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- LEGEND**
- PHANEROZOIC**
- CENOZOIC**
- QUATERNARY**
- RECENT**
- 11 Modern Shoreline Materials: sand, gravel, shingle gravel, cobble and boulder lags, bedrock
 - 11a Mainly gravel
 - 11b Mainly sand
 - 10 Alluvium: silt, sand, gravel, muck
 - 9 Organic Deposits: muck and peat, minor marl
 - 8 Eolian Deposits: fine to very fine sand
- PLEISTOCENE LATE WISCONSINAN AND RECENT**
- 7 Lacustrine and Glaciolacustrine Shore Deposits: sand, gravel, shingle gravel, pebble-boulder lags
 - 7a Lake Algoma and younger
 - 7b Nipissing Great Lakes and younger
 - 7c Post Algonquin and younger
 - 7d Lake Algonquin and younger
 - 6 Lacustrine and Glaciolacustrine Shallow-Water Deposits: sand, pebbly sand
 - 6a Mainly sand
 - 6b Mainly gravel
 - 5 Lacustrine and Glaciolacustrine Deep-Water Deposits: silt, clay, sand
 - 4 Glaciofluvial Outwash: sand and gravel
 - 3 Ice-Contact Stratified Drift: sand, gravel, silt, flowfill
 - 2 Bruce Till: stony, sandy silt to silt till
- PALEOZOIC**
- 1 Bedrock and Bedrock-Dominated Terrain: discontinuous thin drift cover (mainly till, sand or organic materials); includes considerable talus on or below escarpment slopes
- SILURIAN**
- 1a Guelph Formation: dolostone
 - 1b Amabel Formation: dolostone
 - 1c Clinton Group: dolostone and shale
 - 1d Cataract Group: dolostone and shale
- ORDOVICIAN**
- 1e Queenston Formation: shale
 - 1f Georgian Bay Formation: shale

SOURCES OF INFORMATION

Base map information derived from Ontario Land Information Warehouse, Land Information Ontario, Ontario Ministry of Natural Resources, scale 1:100 000, with modifications by staff of the Ministry of Northern Development and Mines.

Mapping conducted using UTM co-ordinates in North American Datum 1983 (NAD83), zone 17.

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Geology is not tied to surveyed lines.

Metric conversion factor: 1 foot = 0.3048 m.

Magnetic declination approximately 9°39'W at the centre of the Bruce Peninsula area in 2006.

CREDITS

Geology by W.R. Cowan and D.R. Sharpe.

GIS compilation of data by J.E.P. Dodge.

Edit by G.H. Brown.

Cartographic production by R. Corcoran.

Every possible effort has been made to ensure the accuracy of the information presented on this map; however, the Ontario Ministry of Northern Development and Mines does not assume any liability for errors that may occur. Users may wish to verify critical information.

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Information from this publication may be quoted if credit is given. It is recommended that reference to this map be made in the following form:

Cowan, W.R. and Sharpe, D.R. 2007. Surficial geology, Bruce Peninsula, southern Ontario; Ontario Geological Survey, Map 2679, scale 1:100 000.

SYMBOLS

- Geological boundary, approximate
- Bedrock outcrop
- Glacial fluting
- End moraine crest
- Abandoned shore bluff
- Abandoned shoreline feature
- Meltwater channel; with direction of water flow indicated
- Rock scarp; usually indicates talus on lower slopes
- Glacial striae, with direction of ice flow indicated
- Drumlin
- Sand dune
- Sculpted (s) bedforms with direction of flow indicated
- Rock quarry
- Sand and/or gravel pit
- Main highway; secondary highway; road, street