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Ontario Geological Survey
Open File Report 6029

Mines and Wines: Industrial Minerals, Geology and Wineries of the Niagara Region – Field Trip Guidebook

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ONTARIO GEOLOGICAL SURVEY

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Mines and Wines: Industrial Minerals, Geology and Wineries of the Niagara Region – Field Trip Guidebook

by

K.G. Steele and S.J. Haynes

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INTRODUCTION

This field trip was given on September 14, 2000 for staff of the Resident Geologist Program of the Ministry of Northern Development and Mines. Both authors have given versions of this trip to other audiences over the past few years. This guide is presented so those visiting Niagara area wineries have an overview of the scenic and economic geology of the area, and a perspective on how geology is an important element of the wine industry.

FOCUS OF THE TRIP

Geologists and other professionals within the minerals industry may not automatically associate the area around western Lake Ontario to the west and south of Toronto, including the Niagara Peninsula, as a major mining camp. However, the area has major extraction operations for shale/brick, gypsum/wallboard and crushed stone aggregate. Mineral production for the area is estimated at $265M in 1999.

Likewise, those imbibing Niagara vintages may not realize the direct influence of geology on the location of wineries, types of grapes and quality of wines. The Niagara Peninsula is the dominant wine-producing region in Canada. In 1999, retail sales of Niagara wines were approximately $270M.

The mining and wine industries of the Niagara region have a common element – the local geology provides a bountiful harvest for each. The geological element is woven throughout the field trip. Some of southern Ontario's major industrial mineral operations will be visited, with discussion on the geological resource, mining techniques, products, and site rehabilitation. The scenic wonders of Niagara Falls and the Whirlpool expose spectacular geological sections. Winery visits provide the backdrop for an overview on the geological foundation for terroirs of the Niagara Peninsula.

This trip is based on data contained and cited by source in Haynes (2000) and Steele (2000).

LOCATION AND ROUTE

For most of the day, the field trip route will be near the Niagara Escarpment, a prominent cuesta landform that extends from central New York State in the east to Lake Huron in the west. In Ontario, the north-, then east-, facing cliff-face of this cuesta extends from Queenston, near Niagara Falls, for 725 kilometres to Tobermory on the Bruce Peninsula. The Escarpment has been produced by differential erosion of harder and softer Paleozoic sedimentary rocks over the past 250 million years.

The first stop of the field trip is southwest of Toronto, where Canada Brick's Burlington brick operation works in the shadow of the Escarpment, quarrying red Queenston shale. We shall then cross south over the Escarpment to Georgia Pacific's gypsum mine at Caledonia to visit their wallboard plant.

Lunching "en autobus" we shall travel northeast to the Niagara Escarpment at Vineland to view the crushed stone quarry operation of Walker Industries Holdings Ltd. From there, the route will be generally eastward along the Escarpment, visiting geologic/scenic viewpoints and wineries along the way, to arrive at the Niagara River Gorge. Here, we shall descend by elevator to a boardwalk along the banks of the thundering Niagara River Rapids (Great Gorge Adventure). The trip will finish at Niagara Falls.

OVERVIEW OF THE GEOLOGY OF SOUTHERN ONTARIO

Introduction

The bedrock of southern Ontario consists of Paleozoic sedimentary rocks that stretch for nearly 600 km in a broad zone from Kingston to lakes Huron and Erie. The zone is bounded to the north by Precambrian rocks of the Canadian Shield. The sedimentary succession includes Cambrian, Ordovician, Silurian and Devonian strata.

The sediments that make up southern Ontario's Paleozoic succession were deposited mainly in shallow marine environments, at a time when the area was inundated by a series of inland seas centred about the Allegheny (Appalachian) and Michigan basins (Figs. 1 and 2). The sedimentary sequence includes limestone, dolostone, shale and sandstone. The strata are essentially undeformed and nearly flat-lying with shallow regional southwesterly dips averaging 6 m/km. Units thicken to the southwest with the maximum thicknesses of Cambrian, Ordovician, Silurian and Devonian strata being 165, 920, 620 and 390 m respectively. The regional southwesterly dip, coupled with over 250 million years of erosion that has peneplaned the rocks, has resulted in successively younger rocks being exposed to the southwest. The eroded surface is effectively flat, except where interrupted by north- and east-facing escarpments, formed in resistant carbonate rocks underlain by recessive-weathering shale. The Niagara Escarpment (Fig. 1) forms a prominent feature across southern Ontario. The Escarpment, composed of Late Ordovician and Silurian strata, separates the Silurian and Devonian rocks to the west from the Cambrian and Ordovician rocks to the east (Fig. 2). Smaller escarpments, often partly buried beneath Quaternary sediments, occur both south/west and north/east of the Niagara Escarpment (e.g., the Onondaga Escarpment; Figure 3).

Tectonic Setting

The major structural elements, which affected Paleozoic deposition across southern Ontario, are the Allegheny (Appalachian) and Michigan basins, and the Findlay and Algonquin arches (Fig. 1).

The Allegheny Basin, is an elongate foreland sedimentary basin, which parallels the Appalachian Mountains, and is centered in the states of New York and Pennsylvania. The basin's marginal edge extends into Ontario along the Niagara Peninsula and beneath Lakes Erie and Ontario. As a result of intermittent orogenic activity along the eastern margin of the basin throughout the Paleozoic, the deposits within the basin are mostly clastic dominated.

The Algonquin Arch is a broad, northeast trending, basement ridge forming the spine of the southwestern Ontario peninsula. A continuation of this feature south into the United States is the Findlay Arch, and the depression separating the arches is called the Chatham Sag. Cambrian and Early Ordovician strata in southern Ontario are truncated against the flanks of the Algonquin Arch, whereas, Middle Ordovician strata onlap and overlap the arch, indicating it was a positive feature in Paleozoic time. Once buried, the arch remained a positive feature and exerted influence on the deposition of Silurian strata of the Niagara Escarpment and Devonian units of southwestern Ontario.

The Michigan Basin is a circular intracratonic sedimentary basin centered on the lower-peninsula of Michigan and extending east to the Algonquin Arch. The basin was formed by the regional subsidence of Precambrian basement rocks. Carbonate and evaporite deposition was dominant within the basin.

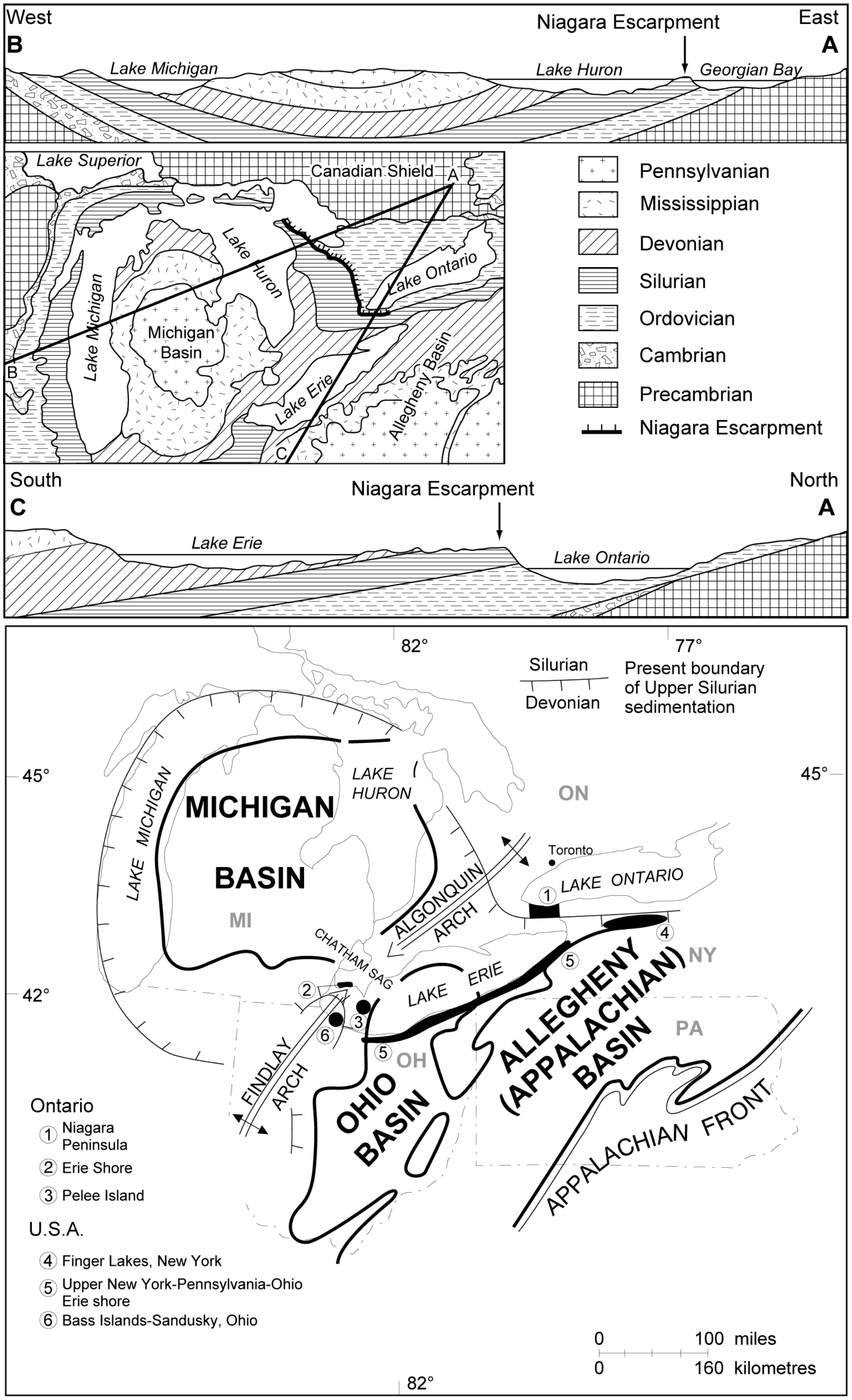

Figure 1 Geology of the Great Lakes (upper) and relation of the wine grape regions of Ontario,Upper New York state, Pennsylvania and Ohio to major structural elements of the Allegheny, Michigan and Ohio basins, during Silurian time (lower). Modified from Haynes (2000).

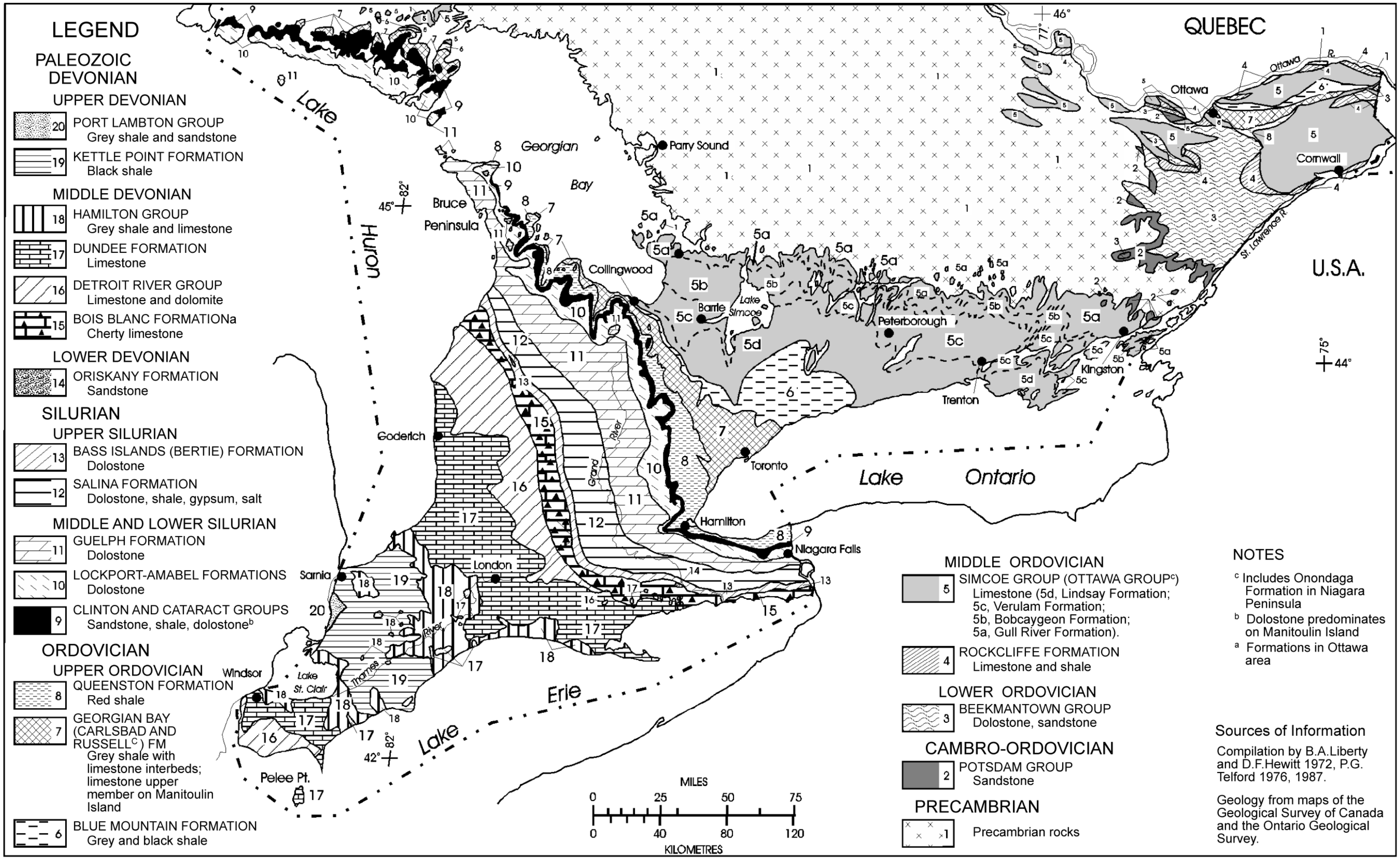

Figure 2 Bedrock geology of southern Ontario.

The Paleozoic sequence is complicated by facies changes, as strata of the Allegheny Basin interfinger with strata of the Michigan Basin in complex onlap-offlap patterns, over the Algonquin Arch.

In addition to the above major structural elements, clastic supply to the inland seas was important to the types and thickness of sediments deposited. Major clastic source areas were the Canadian Shield to the north and the highlands to the east, which were periodically uplifted, including the ancestral Taconic Highlands and the Appalachian Mountains.

Due to the regional dip of strata to the southwest, successively younger rocks are exposed from Kingston to Windsor (Fig. 2). In the following sections, the Paleozoic sequence is presented from oldest to youngest.

Cambrian Strata

The oldest Paleozoic strata in southern Ontario are Late Cambrian sandstone and dolostone. Except for small, isolated outcrops adjacent to Precambrian rock in the Kingston area, Cambrian rocks are known in subsurface onlapping the Algonquin Arch.

Ordovician Strata

Middle to Late Ordovician carbonates and shales underlie the area southwest from the Canadian Shield to the Niagara Escarpment. The Simcoe Group is a succession of bioclastic carbonates, carbonate mudstones, and shales of the Gull River, Bobcaygeon, Verulum and Lindsay formations. The strata represent a relatively continuous deposition on a generally deepening shelf.

Overlying Ordovician strata are characterized by orogen-derived clastic rocks deposited in marine and non-marine settings. The Blue Mountain Formation consists of grey, noncalcareous shale. The Georgian Bay Formation reflects a change to shaly and impure carbonates. The Queenston Formation is a thick sequence of red shale prominently exposed along the base of the Niagara Escarpment. It is a maroon, slightly calcareous to noncalcareous, shale with interbeds of grey-green shale. The formation ranges in thickness from 45 to 335 m.

Silurian Strata

Silurian sediments are exposed along the face of the Niagara Escarpment and in an outcrop belt extending up to 70 km southwest of the Escarpment. The regional distribution and stratigraphy of Silurian strata are different in areas influenced by the Allegheny Basin (Niagara Peninsula) and the Michigan Basin (Hamilton to Bruce Peninsula). The Cataract Group, at the base of the Silurian succession, consists of the Whirlpool, Manitoulin, Cabot Head and Grimsby formations. The Whirlpool is orthoquartzitic sandstone. The Cabot Head Formation, consists of shale with subordinate calcareous sandstone, limestone and dolostone interbeds. On the Niagara Peninsula, the maroon sandstones and shales of the Grimsby Formation comformably overlie the dark shales and buff sandstones and carbonates of the Power Glen Formation (the Allegheny Basin equivalent of the Cabot Head Formation of the Michigan Basin).

In the Niagara Peninsula, the Clinton Group consists of, in ascending order, the Thorold, Neahga, Reynales, Irondequoit, Rochester and Decew formations. Most of these units pinch out or are truncated by unconformities to the west and north. Clinton Group units are a succession of quartzose sandstones, shales, argillaceous dolostones, dolomitic limestones, limestones and siltstones. The Lockport Formation unconformably overlies the Clinton Group. The dolostone and dolomitic limestone rocks of the Lockport Formation form the brow and main cliffs of the Niagara Escarpment along the Niagara Peninsula. In southern Ontario, outside of the Niagara Peninsula and Lake Erie areas, carbonate deposition predominated during the time period of the Cataract and Clinton groups. North of Hamilton, the white weathering, thick-bedded dolostones of the Amabel Formation (approximately equivalent to the Lockport Formation of the Niagara Peninsula) form the main cliffs of the Niagara Escarpment.

Across southern Ontario, the Guelph Formation overlies the Lockport/Amabel Formation. The Guelph Formation consists of reef and interreef deposits, characterized by tan, sugary, fossiliferous dolostone. After a probable unconformity, evaporites (halite, gypsum, anhydrite), evaporitic carbonates and shales of the Salina Formation were deposited. Dolostones of the Bertie and Bass Islands formations are the youngest Silurian strata.

Devonian Strata

The Lower Devonian in southern Ontario was characterized by an extended period of erosion with a depositional interval of white silica sand of the Oriskany Formation. In Ontario, the Oriskany Formation is only preserved in outcrop near Cayuga, as most of this unit was eroded by subaerial processes later in the early Devonian. In most areas, the Middle Devonian Bois Blanc Formation is the oldest Devonian stratum. The Bois Blanc Formation is cherty limestone overlying a basal glauconitic sandstone in the Allegheny Basin but dolostone in the Michigan Basin. Overlying strata are the Onondaga Formation limestone in the Niagara Peninsula and the Detroit River Group elsewhere across southwestern Ontario. In ascending order, the Sylvania Formation sandstone, and Amherstburg and Lucas Formation limestone and dolostones are included in the Detroit River Group. The Dundee Formation, the subcrop strata for broad area between lakes Erie and Huron, is fossiliferous, micitric limestone.

The overlying Hamilton Group makes a sharp change from carbonate to clastic dominated strata. It consists of mudstones and shales with thin carbonate horizons. An unconformity separates the Hamilton Group from the overlying Kettle Point Formation. The Kettle Point Formation is a siliciclastic, organic-rich shale. The Port Lambton Group disconformably overlies it. This group of clastic rocks consists mainly of grey and black shales and sandstones. In southern Ontario, Port Lambton Group strata are restricted to the subsurface in an area south of Sarnia.

Geology of the Niagara Escarpment

The Niagara Escarpment is a prominent geological and physiographic (a cuesta landform) feature that extends in Ontario from Queenston west and then north to Tobermory. Although, as a geological feature the Niagara Escarpment is continuous, it is not always present as a prominent topographic feature due to its mantling or burial by later deposits of glacial drift. The Niagara Escarpment is present in many forms throughout its length, the most common of which are: rock scarp; mantled scarp; buried scarp; terraced scarp; multiple scarp; incised scarp; outlier; and stripped scarp. The Niagara Escarpment is an erosion escarpment, where hard and resistant dolostones of the Lockport or Amabel (north of Hamilton) formations dip gently to the southwest and are underlain by softer shales, sandstones and limestones of the Clinton and Cataract groups and by the soft shales of the Queenston and Georgian Bay formations.

The type section for the Niagara Escarpment is at Niagara Falls, where the escarpment is approximately 90 m high. Here, a caprock of resistant Lockport dolostone is underlain by nearly 60 m of shales, limestones and sandstones of the Clinton and Cataract groups, with the base of the Escarpment being in the upper 15 to 23 m of the Queenston shale. The maximum height of the escarpment is 270 m (south of Georgian Bay) where the escarpment extends as high stratigraphically as the lower part of the Guelph Formation dolostone, and as low stratigraphically as the base of the Georgian Bay Formation.

Quaternary Geology

All of southern Ontario has an extensive cover of Quaternary deposits. Drift cover can exceed 200 m, but is generally between 30 and 60 m. Major bedrock exposures occur only along and immediately west of the Niagara Escarpment, across the Bruce Peninsula and directly south of the Canadian Shield. Ontario has been subjected to several glacial episodes during the past two million years. The last period of ice advance was the Late Wisconsinan glaciation. Approximately 20,000 years ago, the ice margin began to melt back from its maximum position south of the Great Lakes in a series of retreats and successively-smaller advances until about 12,000 years ago, when ice finally retreated from southern Ontario.

In southern Ontario, numerous till sheets were deposited during the successive advances and retreats of the ice sheets. The textures of these till sheets reflect the bedrock and overburden types eroded immediately up-ice. The carbonate bedrock across much of southern Ontario resulted in broad areas of silt-rich till.

Ice flow was controlled by the broad topographic depressions of the Great Lake basins. Lobes of ice, extending beyond the main body of the ice sheet, developed in these basins and acted at times independently in response to local conditions. As the ice retreated, an ice lobe occupied the Lake Ontario basin and another lobe occupied the Lake Huron-Georgian Bay basin. A series of proglacial lakes formed and disappeared with fluctuations in the ice margin during deglaciation. The numerous abandoned shoreline features, which ring the Great Lakes basins, record the complex sequences of ancestral lake levels that occurred during deglaciation.

Considerable volumes of meltwater were generated by, and discharged from, the ice sheets. Large amounts of glacial debris were transported by meltwater and deposited as stratified sediments under the glacier in conduits and cavities, along the ice margin, and beyond the ice margin in rivers and lakes. Southern Ontario has large areas of glaciofluvial and glaciolacustrine gravel, sand, silt and clay.

THE INDUSTRIAL MINERALS INDUSTRY IN SOUTHERN ONTARIO

Economic Geology

A conservative estimate of mining and quarrying of minerals, for 1999, in Ontario south of the Canadian Shield is $1.5 billion of production, or approximately 30% of Ontario's total mineral production. The following minerals and rocks were extracted– salt (rock and brine), gypsum (wallboard), shale (brick), limestone (cement, lime, aggregate), dolostone (dolime, aggregate, building stone), sandstone (building stone), sand and gravel (aggregate). All of the province's salt, gypsum and cement production, almost all of the shale products and lime production, as well as a large percentage of its' sand and gravel, and stone production are from southern Ontario.

In southern Ontario, a total of 4 mines, 44 quarries and 3 brine well fields produce industrial minerals, non-aggregate stone and building stone (Fig. 3). In addition, approximately 60 crushed stone quarries and several hundred, sand and gravel pits extract aggregate material.

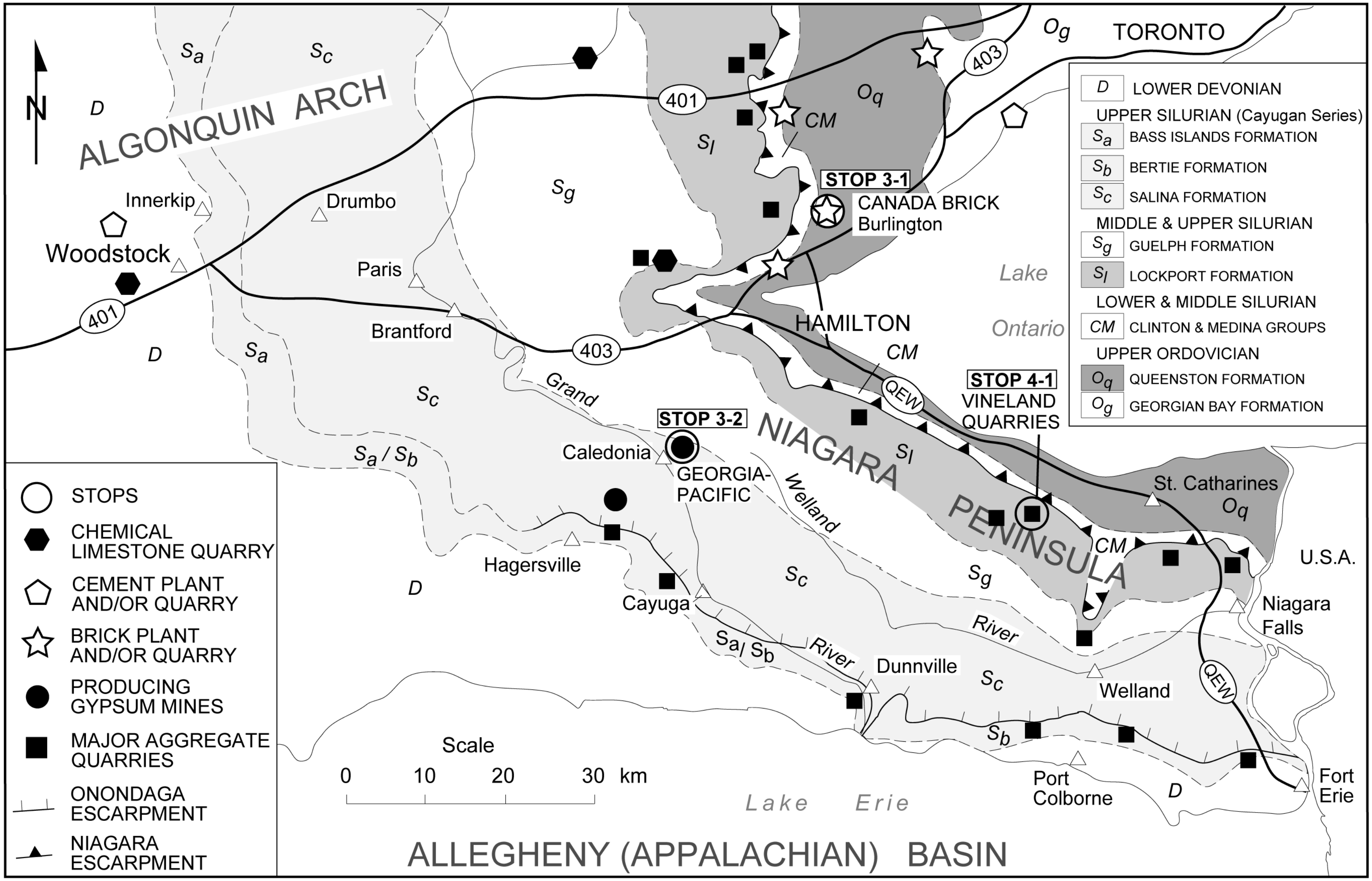

Figure 3 Geological map of the Niagara Peninsula with location of major Industrial Rock and Mineral mines and quarries.

The following table lists geological formations with current production or future production potential.

Commodity	Geological Formation
Aggregate	Gull River, Bobcaygeon, Verulum, Lindsay, Manitoulin, St. Edmund, Lockport, Amabel, Guelph, Bertie, Bois Blanc, Onondaga, Amherstburg, Lucas, Dundee
Cement	Verulum, Lindsay, Lucas, Amherstburg, Dundee
Brick	Georgian Bay, Queenston, Arkona
Dolostone/marble/building stone	Manitoulin, Amabel, Lockport, Guelph (Eramosa Member), Amherstburg
Gypsum	Salina
Lime	Lucas, Amherstburg, Lockport, Amabel
Dolime	Guelph
Silica	Sylvania
Salt	Salina
Sandstone/building stone	Whirlpool

Aggregate

Aggregate is a major mineral commodity produced in southern Ontario. In 1999, production in southern Ontario is estimated at $500 million. The buoyant economy of southern Ontario is producing strong demand for both crushed stone and sand and gravel aggregate products.

Crushed Stone

Strong demand resulted in approximately $240 million of production in 1999. Seven of the 20 largest quarries in Canada extract crushed stone for the southern Ontario market. Top quarries, are listed below.

Quarry Name & Operator	National Ranking	1999 Production	Geological Unit
Milton Quarry, Dufferin Aggregates	1	5.76 Mt	Amabel Fm.
Dundas Quarry, Lafarge Canada	5	3.5 Mt	Guelph Fm.
Acton Quarry, Blue Circle Aggregates	6	3.3 Mt	Amabel Fm.

The main rock formations quarried for crushed stone aggregate are Gull River, Bobcaygeon, Lockport, Amabel, Guelph, Bois Blanc, Dundee, and Lucas. The major crushed stone source areas are along the Niagara Escarpment, particularly in the Milton area; east of Lake Simcoe; and in the Port Colborne area. Major crushed stone quarries on the Niagara Peninsula are listed below. The Thorold Quarry was Canada's 18th largest last year with production nearing one million tonnes. All production from the Port Colborne Quarry is exported to the USA by Great Lakes shipping.

Quarry Name	Operator	Geological Unit
Thorold Quarry	Walker Brothers Quarries Ltd.	Lockport Formation
Queenston Quarry	Lafarge Canada	Lockport Formation
Vineland Quarries	Walker Industries Holdings Ltd.	Lockport Formation
Lincoln Quarry	Nelson Aggregate	Lockport Formation
Port Colborne Quarry	Port Colborne Quarries Ltd.	Bertie Formation
Ridgemont Quarry	Ridgemount Quarries Ltd.	Bertie Formation
Law Quarry	Hard Rock Paving	Bertie & Bois Blanc Formations

Sand & Gravel

Sand and gravel aggregate production in southern Ontario is estimated at $260 million for 1999. Nine of the 20 largest pits in Canada extract sand and gravel for the southern Ontario market. Top pits are listed below.

Plant Name & Operator	National Ranking	1998 Production	Geological Unit
Mosport Pit, TRT Aggregates	2	1.92 Mt	Oak Ridges Moraine
Aberfoyle Pit, Blue Circle	5	1.40 Mt	Puslinch outwash
Mosport Pit, Dufferin Aggregates	6	1.33 Mt	Oak Ridges Moraine
Stouffville Pit, Lafarge Canada	7	1.21 Mt	Oak Ridges Moraine
Caledon Pit, James Dick Construction	9	1.15 Mt	Caledon outwash

The major sand and gravel source areas include along the Oak Ridges Moraine northeast of Toronto, and within outwash deposits in Caledon and Puslinch townships and in the London, Cambridge and Brantford areas. The only pit on the Niagara Peninsula is the Fonthill Pit of Blue Circle Aggregates. The pit is situated on the Fonthill Kame, a major topographic feature 18 km west of Niagara Falls.

Cement

The cement industry uses limestone resources from south central and southwestern Ontario. In south central Ontario, Ordovician age limestone is extracted from quarries along the north shore of Lake Ontario. In southwest Ontario, cement quarries extract Devonian age limestone.

Five separate companies currently own and operate seven cement plants within southern Ontario. Production value in 1999 was $510 million. In 1998, total cement production in Ontario exceeded 8.2 million tonnes. The largest operation was Blue Circle Cement's Bowmanville Quarry and Plant with 2.6 Mt of cement produced. Ontario production is sold across Canada and the United States, however, the majority of production is for the southern Ontario and United States Great Lakes markets.

Shale/Brick

The brick products industry in Ontario currently extracts resource materials from the Queenston Formation shale. A significant amount of historical production came from Georgian Bay Formation shale. The Ordovician Queenston Formation occupies a narrow, wedge-shaped area located immediately east of the Niagara Escarpment and extends from Georgian Bay to the Toronto and Hamilton areas (Fig. 2). Much of the area underlain by the Queenston Formation is highly urbanized.

Currently, three companies extracted shale at six quarries in southern Ontario. The shale supplied five brick manufacturing operations. The brick industry had production valued at $129 million in 1999. More than 80 percent of these bricks were sold for residential construction, dominantly in southern Ontario. The remainder was used in architectural, industrial and institutional construction. Two large operators, Canada Brick and Brampton Brick, have both quarrying and manufacturing facilities. Century Brick Ltd. operates a small quarry near Georgetown and brick plant in Hamilton.

In 1999, Canada Brick quarried Queenston shale at their Streetsville, Milton, Burlington and Aldershot West quarries located between Toronto and Hamilton. Canada Brick currently operates three large brick plants; one beside their Streetsville Quarry and two adjacent to their Burlington Quarry. In response to continuing strong demand for brick in the southern Ontario market, the company is currently building a new 150 million brick unit per year plant at the Aldershot West Quarry. Production is scheduled for fall 2000. With this expansion, Canada Brick will have a production capacity of 480 million brick units per year from their Ontario plants. The company currently holds a 70% share of the Ontario and Quebec brick market.

Brampton Brick Ltd. currently trucks Queenston shale from their Cheltenham Quarry a distance of 10 km to their brick plant in northwest Brampton. In 1999, the Ontario housing boom prompted Brampton Brick to begin a $33 million plant expansion. When completed in 2000, production capacity will have increased from 120 to 200 million brick units per year.

Limestone and Dolostone Chemical, Metallurgical and Filler Products

The chemical, metallurgical and filler limestone and dolostone products industry in Ontario uses calcium-rich limestone and calcium/magnesium-rich dolostone, almost exclusively from resources found in southwest Ontario, as raw materials for manufacturing lime and associated products. The industry currently exploits or plans to develop limestone deposits within the Detroit River Group, Lucas and Amherstburg (Formosa Reef limestone) formations. High-purity dolostone deposits used by the industry occur within the Guelph and Amabel formations.

Six operations extract limestone or dolostone for use in the lime, chemical, metallurgical and filler products industries. The 1999 value of lime products from southern Ontario was $120 million. The quicklime, dolime, hydrate lime, pulverized limestone and other processed lime products are utilized for a wide range of metallurgical, industrial, environmental, chemical and construction applications.

Dimension/Building Stone

Some of the operators within the dimension, building and landscape stone industry in southern Ontario extract materials for interior and exterior home construction, but all supply stone for landscape and/or engineering purposes. The geological units currently being utilized by the industry in ascending stratigraphic order are Gull River Formation limestone, Whirlpool Formation sandstone, Amabel Formation dolostone, and Eramosa dolostone. These geological units meet the right combination of factors that makes them marketable, including suitable physical properties, good exposure and proximity to markets.

In 1999, approximately 25 quarries in the southern Ontario extracted material for dimension, building and landscape stone uses. The largest concentration of stone producers is in the Wiarton area where 12 operations extracted Eramosa Member dolostone during 1999. Most quarries are seasonal operations that operate continuously from April through December, during which time they employ a workforce of approximately 500 workers.

Gypsum

Gypsum is widespread in the Silurian Salina Formation in south central Ontario along the southeastern flank of the Algonquin Arch. Gypsum is known in the subsurface from Woodstock east to Niagara Falls and occurs in a number of thin, lenticular beds interbedded with dolomite and dolomitic shale.

Numerous small mines have been in production from the Salina Formation since as early as 1822. The early mines extracted gypsum from tunnels dug into the banks of the Grand River between Paris and Cayuga.

The Salina Formation is divided into eight units. Gypsum is mined currently in Ontario at two locations: from the B Unit at Caledonia by Georgia-Pacific Canada Inc.; and from the E Unit at Hagersville by CGC Inc. Both operations have on-site wallboard manufacturing facilities. Westroc Inc., operator of the Drumbo Mine from 1978 until its closure in 1995, continues to operate a wallboard facility in Mississauga; using flue gas desulphurization gypsum supplied by Ontario Hydro and other sources.

Total gypsum production in 1999 was 1 143 000 tonnes with a production value of $15 million.

Salt

Salt deposits in Ontario occur within the Silurian Salina Formation in the Sarnia-Goderich areas at the eastern margin of the Michigan Basin, as well as in the Windsor and Chatham areas within the Chatham Sag.

In 1999, three companies extracted salt in Ontario for a combined production value of $246 million. Sifto Canada Inc., located at Goderich, and The Canadian Salt Company Limited, located in south Windsor, operate both rock salt mines and brine well fields. General Chemical Canada Limited operates Ontario's largest brine well field, south of Windsor near Amherstburg.

Almost all production from the Goderich and Windsor rock salt mines goes to road de-icing. Other uses include water softening, feed salt and use in the chloralkali industry. The salt from the brine operations is used as raw materials for the chemical and food industries.

STOP 3-1 Canada Brick's Burlington Quarry and Brick Plant

At the Burlington site, Canada Brick operates a shale quarry and two adjacent brick manufacturing plants. Operations at the site started in 1959 as the former Diamond Clay Products Limited – Tansley Quarry and Brick Plant. In 1987, Canada Brick constructed a second brick plant. The original Burlington plant has a capacity of 75 million brick equivalents per year, and plant 2 produces 140 million bricks per year. Currently, 90% of production is used in new home construction, mostly in southern Ontario, and 10% is supplied for institutional, commercial and industrial structures.

Shale raw material is quarried on site and additional shale is trucked in from Canada Brick's nearby Milton and Aldershot Quarries. The two Burlington plants require 450,000 tonnes of shale annually.

At the Burlington Quarry, approximately 30 m of the Queenston Formation comprises a mixture of thin to very thinly bedded red and green shale. The green beds are more carbonate rich. Rounded gypsum nodules are occasionally embedded in the red shale layers. The composition of Queenston shale is 55-65% clay minerals (largely illite and chlorite), 10-35% carbonates (mostly calcite) and minor quartz (Guillet, 1967). Impurities include 0.1% fluorine (within the illite crystal structure) and gypsum. The gypsum can be neutralized by adding barium carbonate to stop surface scum on bricks. The firing colour of bricks is controlled by the shale's carbonate and iron contents. Buff colours result from high calcite contents (>25%), whereas reds result from high iron contents. The general composite chemistry of Queenston shale from the Burlington Quarry is 45% SiO_2, 11.9% Al_2O_3, 4.6% Fe_2O_3, 14.3% CaO, 2.6% MgO, and 3.0% K_2O. This shale fires to a natural buff/brown colour.

The quarry is immediately adjacent to Bronte Creek: an environmentally sensitive area of significance with a cold-water fishery. The creek is protected by erosion control and slope stability work. The annual quarry production is approximately 150,000 tonnes.

Queenston shale quickly softens through natural weathering, this improves plasticity and workability for the brick making process. Slope weathering has been the predominant practice for past 20 years. Bulldozers, to expose material for weathering, rip an excavation slope of about 4:1 or flatter. Excavation is done by bulldozer, pushing the softened and ripped surface layer to the toe of the slope for stockpiling and trucking.

At Burlington Plant 2, a scraper blade automatically pushes the dumped shale into the crusher at the rate of 250 tons per hour. The grinding process reduces the crushed shale to a consistency not unlike beach sand. Water is added to increase the moisture content to approximately 12%. Shale is blended with appropriate amounts of barium carbonate, to control soluble salts, or colouring pigments, such as limestone for buff colours or manganese dioxide for brown colours. The mix is then fed into a vacuum chamber, which extracts the air. The mixture is extruded into long columns, the length and height of the finished brick. The extruder produces 35,000 brick per hour. If desired, surface texturing and surface colouring with sand or slurries takes place immediately after the column leaves the extrusion machine. Residential bricks are surface coated products as the marketplace is more tolerant of variations in shale colour. In contrast, institutional, commercial and industrial bricks are uncoated or through the body colour.

The raw brick column is wire cut into individual bricks. The brick is loaded on computer controlled kiln cars. Each car holds over 5000 brick. The cars travel to the dryer, which uses recycled heat from the kilns. In the dryers, which are heated to approximately 260 degrees Celsius, the moisture content of the product is reduced from approximately 12% to less than 1% over a period of 20 hours. The brick cars continue into the natural gas fired tunnel kilns. Kiln temperature range from 200 degrees Celsius at entry to over 1040 degrees Celsius in the firing zone. The kilns are major gas consumers; gas costs are approximately 30% of overall production costs. The four kilns have a throughput time of 20 hours, with each kiln producing 100,000 brick per day. The cars deliver the finished bricks to the automated packaging area. At this stage, samples are taken for quality control and a visual inspection is made of the product for colour and quality.

STOP 3-2 Georgia-Pacific Canada Inc. Caledonia No.3 Mine and Wallboard Plant

Georgia Pacific operates an integrated mine, mill and wallboard plant complex at Caledonia, 20 km southwest of Hamilton. Georgia-Pacific bought the operations in 1996 from Domtar Construction Materials. Caledonia No. 3 Mine began full production in 1992. Mines No. 1 and No. 2, on adjacent sites, had been in continuous production since 1905.

Gypsum is extracted from the B Unit Evaporite of the Salina Formation. In the mine area this unit is 20 to 25 m below the ground surface, varies in thickness from 2.5 to 5 m, and is approximately 75% pure. A twin ramp system and a small shaft access the mine. Gypsum ore is extracted on conveyor system via the ramp. The company uses a continuous mining method, using two electric Paurat tunnelling machines. The machines are used to develop the mining panels in a chevron pattern off the main conveyor lines through the central part of the ore body.

In 1999, 418 000 tonnes of gypsum was mined from the Caledonia No. 3 Mine. The mine is in the midst of capital improvements comprised of the sinking of a new ventilation shaft and the purchase of a third continuous mining machine, both to be operational in 2000. The additional continuous miner will increase mining capacity to 450 000 tonnes per year.

The basic process of manufacturing gypsum wallboard involves combining two raw materials, gypsum rock and paper for use as wallboard facing and backing. Crushing and grinding reduces rock gypsum into a fine, chalk-like powder called land plaster. Heating the gypsum and removing the majority of the water produces calcined land plaster, called stucco. At the mixer, water and foam are added. The foam creates a slurry that will make the wallboard lighter in weight. The wallboard forming line starts by pouring the slurry onto a sheet of paper and covering it immediately with a top sheet. The slurry and paper sandwich then passes through a series of forming plates. The sandwich travels as one continuous board down a 200 m conveyor line. During this trip, the water and other ingredients added in the mixer rehydrate the stucco, causing it to harden. At the end of the line, knives cut the now hardened board into 8 or 9-foot lengths. The cut boards are then fed into the kiln in stacks. The kiln completes the drying process, leaving the gypsum board virtually moisture free. Stacks of finished board are bundled for transport to customers.

GEOLOGY AND PHYSIOGRAPHY OF THE NIAGARA PENINSULA

The relation of geology to physiography of the Niagara Peninsula is illustrated in Figures 4 (a composite cross section), 5 (physiography and climate zones) and 6 (plan of surface geology, general soil types, physiography and wine terroirs).

Throughout the Niagara Peninsula, the Niagara Escarpment forms a variety of landforms from the sheer cliffs about 90 m in height of the Niagara Gorge, to the broad till-covered terraces of the Vineland Double Bench (Fig. 6): both of which will be examined on the trip. These landforms were determined by the glaciogenic erosion of the Lower and Middle Silurian strata, which comprises, from top to bottom: the highly-resistant caprock of Lockport and Decew dolostones; the easily-eroded Rochester shale; the moderately-resistant package of Irondequoit dolostone, Reynales and Neagha limestones and shaly limestones, and Thorold and Grimsby sandstones; the easily-eroded Grimsby and Power Glen shales; the resistant Whirlpool sandstone (Fig. 4). The base of the Escarpment lies at the top of the highly-erosive Upper Ordovician Queenston shales (Figs. 4).

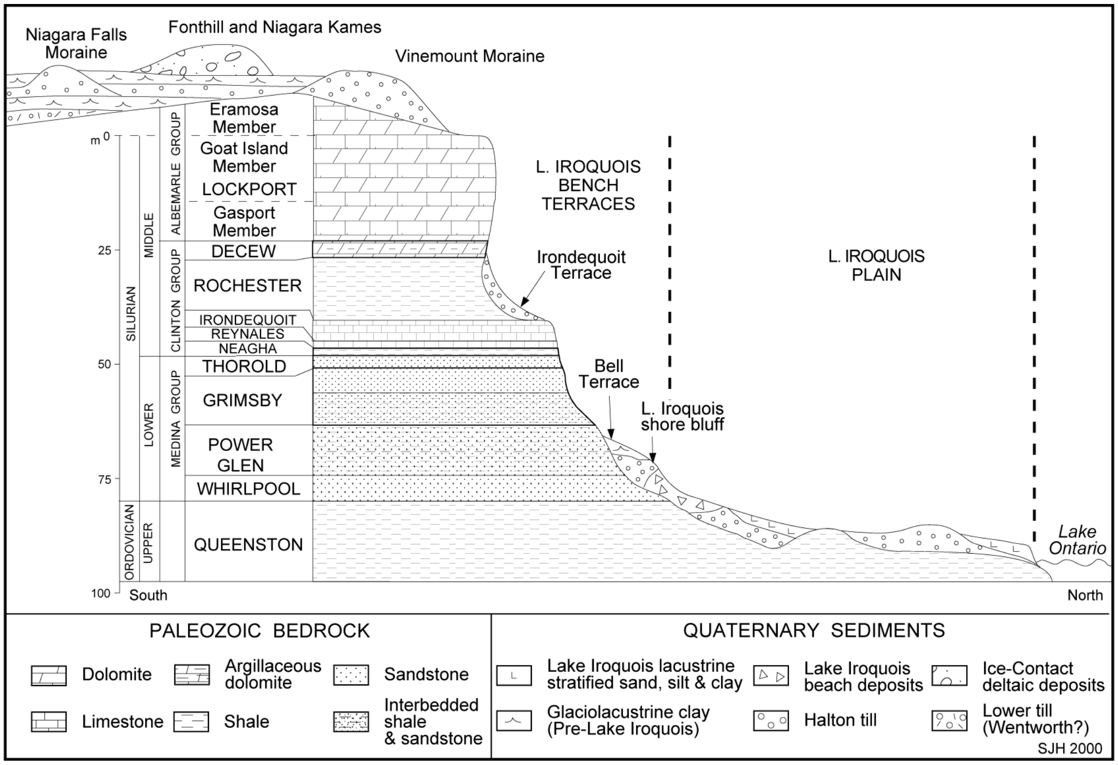

Figure 4 Composite north-south section of the geology and physiography across the Niagara Escarpment (modified from Haynes, 2000).

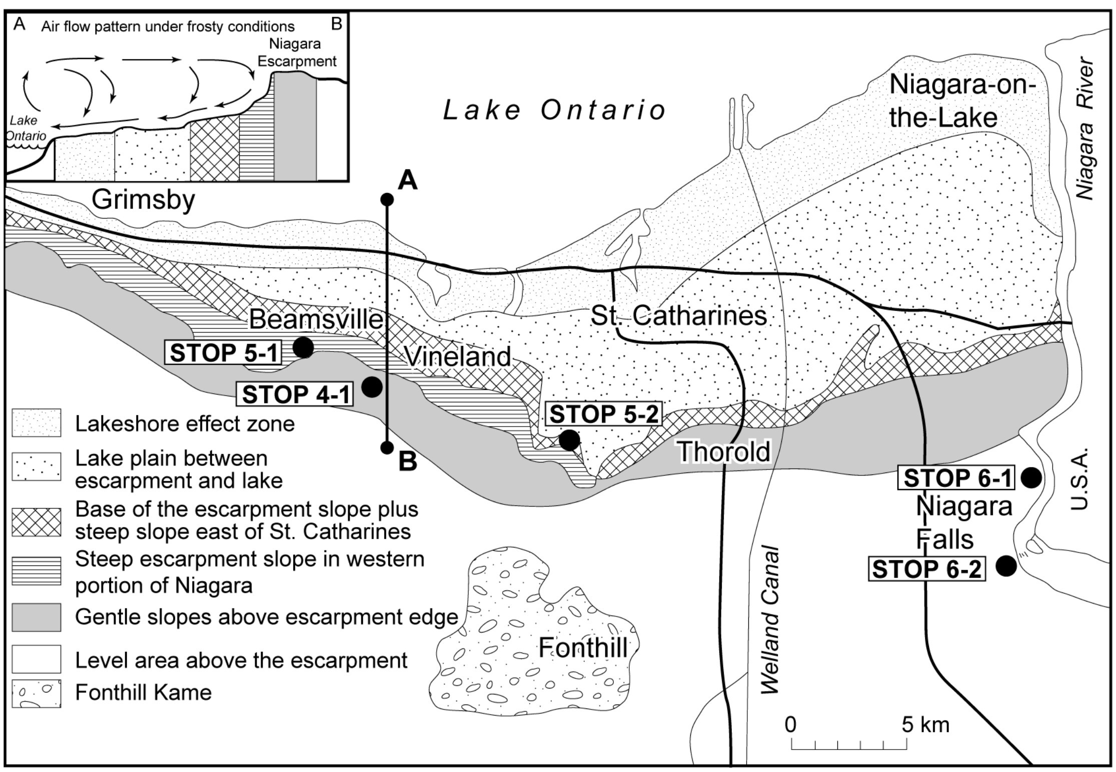

Figure 5 Grape climatic zones in Niagara. (Modified from Wiebe and Anderson, 1977).

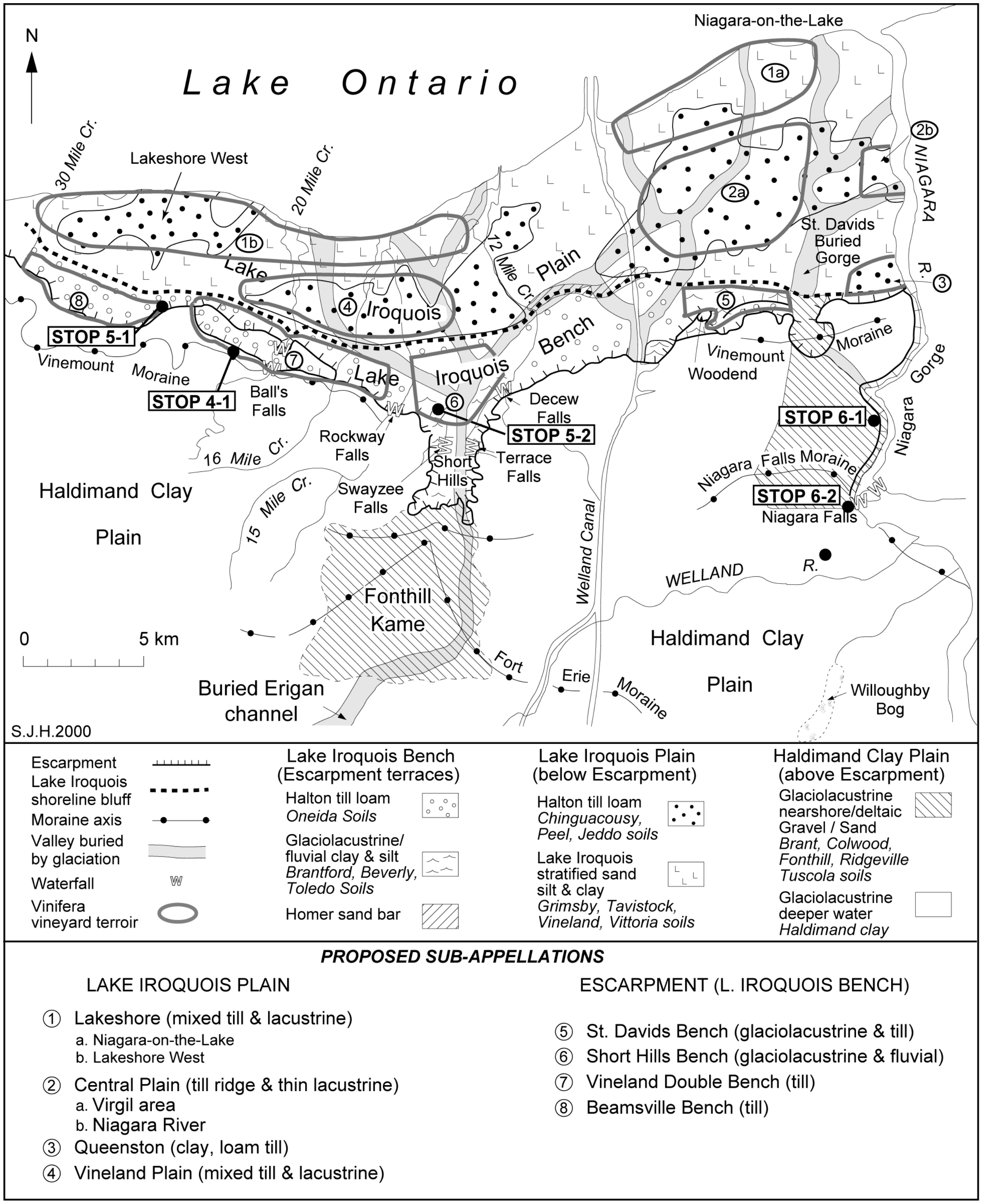

Figure 6 Relation of surface geology, generalized soil types and physiography to vinifera vineyard terroirs and proposed sub-appellations of the northern Niagara Peninsula (from Haynes 2000).

On the face of the Escarpment, two terraces (Bell and Irondequoit terraces, Fig. 4) are usually present (see: Haynes, 2000). At the base of the Niagara Escarpment, the Bell Terrace lies above a prominent north-facing bluff of gravels (Fig. 4) that can be traced around Lake Ontario, to Toronto. This bluff marks the shoreline of the Late Pleistocene - Early Holocene proglacial Lake Iroquois (the precursor to modern Lake Ontario) that formed about 12,000 years ago as the continental ice-sheet retreated north of Toronto. Although narrow in the east and west of the Niagara Peninsula, the Bell Terrace is often wide and reaches a maximum of about 3 km between the Welland Canal and 15-Mile Creek (Fig. 6). The glaciolacustrine deposits on the Bell Terrace and below it on the Iroquois Plain (Fig. 6) vary from massive clay to silt to sand, with sands more common nearer Lake Ontario.

The Irondequoit Terrace develops where the Rochester shale has been eroded southward above the scarp of resistant Irondequoit limestone (Fig. 4). Usually the Irondequoit Terrace is very narrow but west of 16-Mile Creek, the Escarpment is lower (about 62 m high) and this terrace is 1-2 km wide above a narrower Bell Terrace (Vineland Double Bench, Fig. 6). Here, vineyards are located on the terraces in picturesque settings reminiscent of those in northern Europe, and the major creeks (15-Mile, 16-Mile and 20-Mile Creeks, Fig. 6) cascade over a series of waterfalls that vary in height from a few metres to about 24 m. These waterfalls are due to differential erosion of the three thick packages of shale (Rochester; Grimsby - Power Glen; Queenston) that underlie the two resistant sequences of: dolostones (Lockport-Decew), and; carbonates (Irondequoit – Reynales) overlying sandstones (Thorold - Grimsby). The two terraces of the Vineland Double Bench have formed over: 1. an upper, thick, ledge of Irondequoit, and Reynales dolomitic and argillaceous limestones, and Thorold and Grimsby sandstones, and; 2. a lower, thin, ledge of Whirlpool sandstone that coincides, at the base of the Escarpment, with the top of the shorebluff of proglacial Lake Iroquois (Fig. 6). The width of each rock ledge is highly variable but the lower is usually wider, being up to 2 km wide in this part of the Niagara Peninsula. Further west, toward Beamsville, the Irondequoit Terrace recedes back to the Escarpment scarp, while the Bell Terrace widens about I.5 to 2 km to form the Beamsville Bench (Fig. 6). On both terraces, bedrock is overlain by a ramp of Halton till and other Quaternary glacigenic sediments (Fig. 6). Due to limited exposure, these sediments are poorly understood, and in fact may not even be Halton till but a deposit from an earlier glacial advance. Although the till may be subglacial sediments, possibly formed by debris flow as a wedge of dead ice below the Escarpment (which provided a ramp for the advancing ice sheet) melted out on ice retreat, it is likely that the two terraces formed by a combination of both ice carving by older glaciers and shore erosion by older lakes, prior to Lake Iroquois, of the Escarpment rock ledges.

The eastern end of the Vineland Double Bench is truncated by the Short Hills reentrant into the Escarpment (Fig. 5). This is a picturesque area, characterized by V-shaped valleys and round hills (short hills) formed during the post-glacial incision by 12 Mile Creek (and its tributaries) of glacigenic sediments deposited in the, now partly–buried, ancient Short Hills Gorge. The sides of this 3 km wide reentrant are cut by several water courses; the most significant being Beaverdams Creek, which has cut a gorge and waterfall (Decew Falls: the type location of the Decew Formation). At Power Glen (type section of the Power Glen Formation), where the Niagara Escarpment meets the Short Hills reentrant, 12-Mile Creek has deeply incised the Lake Iroquois beach sediments built across the northern exit of the Short Hills Gorge.

To the south, the Short Hills are terminated by the Fonthill Kame (Figs.5 and 6). This is an irregular square hill, which stands 67 m above the surrounding plain of Haldimand clay, characterised by a steep convex-upward northern slope (ice-contact side) and shallower concave-upward southern, eastern and western slopes. It is formed of stratified well-washed sands and gravels derived as the ice-contact delta to a melting glacial lobe that filled the long southward re-entrant of the Short Hills Gorge. It supplies all the sand and gravel used in the Niagara Peninsula.

On the brow of the Escarpment are located many historic building/crushed stone quarries. Today, only a few are still operating due to land-use restrictions on the Niagara Escarpment as a UN Biosphere Preserve. New quarries are located on or south of the Vineland Moraine: a water-lain till that sub-parallels the Escarpment throughout much of the Niagara Escarpment (Figs 4 and 6).

STOP 4-1 Walker Industries Holdings Ltd. Vineland Quarries & Crushed Stone

The quarry is situated near the brow of the Niagara Escarpment south of the village of Vineland. The Vineland Quarries property of over 300 ha encompasses three separate quarries. The original quarry, first opened in 1958, is mined out. The office, processing plant and stockpiles are located within this quarry. A major portion of the quarry has been rehabilitated. Vineland Quarries recently completed the planting of a 5 ha vineyard test plot with the assistance of the University of Guelph (see Appendix 1). Pending the outcome of this test, it is hoped future rehabilitation will include more lands for the production of high quality grapes. The company maintains an ongoing progressive rehabilitation program and has received numerous awards.

Current production is from the Clinton and south quarries. A tunnel under Cherry Avenue connects the Clinton Quarry to the west with the original quarry. A tunnel has been constructed from the original quarry beneath Fly Road to access the newly developed south quarry. Current yearly production is approximately 700,000 tonnes.

The Vineland Quarries expose 9 m of Middle Silurian rocks (OGS, 1989). The basal Rochester Formation consists 0.3 m of shaly dolostone, which is overlain by the Decew Formation, 1.2 m of a dark grey, fine crystalline, massive and irregularly bedded dolostone. The Lockport Formation exposure is 7.4 m, of grey to light buff, medium to coarse crystalline, fossiliferous dolostone of the Gasport Member and light brown, buff weathering, subcrystalline, massive dolostone of the Goat Island Member.

Material is trucked to central location for primary crushing and processing. Vineland Quarries has the capability to produce different grades of concrete, asphalt and crusher run stone, and variety of associated products. Products are sold to markets across the Niagara Peninsula.

GEOLOGICAL FOUNDATION FOR *TERROIRS* OF THE NIAGARA PENINSULA

Terroirs and *Appellations*: a Summary

In France, an *appellation* refers to an individual viticulture district of a wine region that displays characteristic meteorological (climatic), physiographic (landform), pedological (soil), geological (subsoil) and viticultural (grape-growing practice) features that constitute its *terroir*. However, that term is defined by a large number of factors decreed by the refined Appellation laws of 1935 and each new application is evaluated by a team of about six scholars, including two geologists, under the auspices of the INAO (*Institut National des Appellations d'Origine*), and; the legal control is implicit as the term is short for *Appellation d'Origine Contrôlée* (A.O.C.). Furthermore, an *appellation* can be subdivided into sub-*appellations*, and even further down to the specific vineyard, in terms of relative differences in its *terroir* (see: Haynes, 2000). Outside France, the term, “appellation”, is used in a loose sense as a geographic area of *vinifera* vineyards. In

Ontario, such geographic areas are termed officially, Designated Viticultural Areas (DVAs), and are allocated in Ontario and British Columbia by an independent alliance, the Vintners Quality Alliance (VQA), who determine the regulations governing the right of vintners to use a DVA on their labels. In Ontario, the largest DVA is Niagara Peninsula; the others are Lake Erie North Shore and Pelee Island (Fig. 1). VQA regulations governing the production and sale of wine have recently become separate Provincial laws in British Columbia and Ontario, but Federal legislation is needed for sale of Canadian wine in E.E.C. countries as there are four distinct Provincial wine regions that contain separate viticulture districts: Ontario, British Columbia (Okanagan and Similkameen Valleys, Fraser Valley, Vancouver Island), Quebec (Montérégie and Estrie), and Nova Scotia; the partridgeberry wines of Newfoundland may constitute the fifth region. Thus, it is important that the separate provincial professional geoscientist associations, as well as the provincial and federal, "mines ministries", be represented on the VQA to give geological substance to determination of Canadian *appellations* (DVAs) and sub-*appellations*.

The recognition of wine *terroirs* can be made at progressively smaller levels depending on the information available. The largest is the macro-level of a wine region which is the scale of the Niagara Peninsula Designated Viticultural Area (DVA). The next is the meso-level of a French *appellation* which would be the equivalent of the division of the Niagara Peninsula into, at least three longitudinal segments: 1. the Lake Iroquois Plain (between Lake Ontario and the base of the Niagara Escarpment), 2. the Niagara Escarpment (from the base of the Escarpment to the Vinemount Moraine), and 3. the Haldimand Clay Plain (south of the Vinemount Moraine); the roughly circular area of the Fonthill Kame constitutes a fourth *appellation.* Others may consider these as sub-*appellations* of a Niagara Peninsula *appellation*; there being no rules on size, nor on exact definitions. The next smaller is the mini-level of a sub-*appellation*, which have been defined by Haynes (2000) for the Lake Iroquois Plain and the Escarpment (Fig. 6). The absolute smallest level of a French *terroir* is the micro-level of a vineyard for a specific varietal wine: a *climat*. In all Canadian wine districts it will be many years of work before we can begin to determine specific *climats*.

Niagara Peninsula *Terroirs*

Wiebe and Anderson (1977) divided the Niagara Peninsula DVA into seven climate zones based on the different effect of air flow over the eastern Niagara Escarpment (narrow terraces) and western Escarpment (wide terraces), and an airborne thermal imagery study of infrared radiation along a north-south traverse of the northern Niagara Peninsula through Vineland (Fig. 5). Niagara's climate on and below the Niagara Escarpment is dominated by the moderating effect of its position between the large water masses of Lakes Erie and Ontario. In winter, this contributes to warmer than normal temperatures such that distance north of the Escarpment is the determining climate factor in vineyard site selection in terms of: the likelihood of hard frosts in April that cause severe bud damage. In the, "level area above the Escarpment", and including the Fonthill Kame (Fig. 5), the virtual absence of lake effects results in fewer frost-free days in spring and colder winter temperatures below -20^{o}C, that cause severe damage to the vines and restrict grape plantings to North American *labrusca* varieties, which are hardier than European *vinifera* varieties. The longest frost-free season, and therefore the least cold injury danger to vines is the zone of, "Steep escarpment slope in western portion of Niagara", due to the escarpment-effect winds (see cross-section, Fig. 5). Moderate cold injury danger is experienced in the, "Lakeshore effect" (which continues south along the Niagara River), and, "Base of the escarpment slope (in the west) plus steep slope east of St. Catharines", zones, and, at only slightly greater risk, the zone of, "Gentle slopes above escarpment edge". The flat, "Lake plain between escarpment and lake", zone is at greater frost risk than the other zones below the Escarpment because it is furthest from both the Escarpment and Lake Ontario.

In terms of physiography, drainage, bedrock, drift and soils, two distinctly different *vinifera terroirs* are present in the Niagara Peninsula (Fig 6): the Lake Iroquois Plain (the area between Lake Ontario and the base of the Niagara Escarpment), and; the Escarpment (the terraces of the Lake Iroquois Bench, and also locally slopes above the Niagara Escarpment, north of the Vinemount Moraine). Topographically, the plain has mainly gentle slopes, grading to both north and south, whereas the Escarpment terraces grade consistently north, often with moderate to steep slopes. Soils in the Niagara Peninsula are derived mainly by direct organic and weathering breakdown of the underlying Late Pleistocene-Holocene glacial, lacustrine, fluvial and alluvial sediments. From 1:20 000 scale mapping, Kingston and Presant (1989) demonstrated that the soils and their equivalent Pleistocene-Holocene subsoils exhibit a large number of types that exhibit rapid lateral changes. On the Lake Iroquois Bench: Oneida soils are above Halton clay till, and; Brantford, Beverley, Toledo (also, Cashel, Peel) soils are above glaciolacustrine silty clay, itself overlying Halton till. On the Lake Iroquois Plain: Chiguacousy, Peel and Jeddo soils overlie the ridges of Halton till clay, and; fertile Grimsby, Tavistock, Vineland and Vittoria soils overlie the stratified sands silts and clays of the Lake Iroquois lakebed.

By combining the differences in the climate zones, landform physiography, and the soil types the Lake Iroquois Plain can be subdivided into four (possibly six), and the Escarpment into four, separate *terroirs* or sub-*appellations* (Fig. 6). In general, these correspond with those recently proposed by winemaker J-L (Jean-Laurent) Groux, of Hillebrand Estate Winery, who has made an excellent study of the distinctive taste, bouquet, etc. of wines made by him in separate batches of wine under identical conditions (thus, removing the, "winemaker", factor) from different vineyard *terroirs* throughout Niagara. His database, which has been over 10 years in the making, has allowed him to distinguish nine different *vinifera terroirs* (sub-appellations). However, other sub-*appellation* terroirs are likely to emerge on further detailed study.

The characteristics of two different sub-*appellation terroirs* and their resultant wines will be examined at stops to two estate wineries.

STOP 5-1 Malivoire Wine Company

One of Niagara's newest estate wineries, Martin Malivoire and his associates have achieved a remarkable first by constructing their winery into the Lake Iroquois bluff such that grapes go in at the vineyard level at the top and emerge half-way down the slope as wine. According to winemaker Ann Sperling, this gravity-feed system creates less stress on the wine and makes a better product as the juice and wine do not require pumping as in a conventional winery.

The vineyards are located at the eastern end of the Beamsville Bench (Fig. 6) on prime-quality well-drained Halton till on the gently-sloping terrace between the top of the Lake Iroquois shorebluff and the steeply–sloping Escarpment. From here southwestward, the Escarpment is a prominent cliff past Cave Springs Conservation Area because the generally southwest-moving ice sheet gouged the Escarpment along a prominent SW-trending joint direction; with much of this eroded material being deposited as a till ramp at the western end of the Beamsville Bench. This cliff has enhanced the wind patterns off Lake Ontario, in combination with the prevailing southwesterlies, such that this is also a warm climate location and thus one of the best *terroirs* in the Niagara DVA..

STOP 5-2 Henry of Pelham Family Estate Winery

Run by the three Speck brothers and their late father since 1983 on the site of Henry Smith of Pelham's (their ancestor and Empire Loyalist) original land grant after his father's participation in the Revolutionary War of 1776. The vintage coaching inn (now the offices) has the original 1842 basement (now the tasting room) lined with red Grimsby sandstone from the outcrop 100 m to the south. Even though it is probably the only estate winery in North America to have its own graveyard, it is singularly unique in it coming complete with an uninterrupted line of Smiths and an interesting historical perspective on the use of local stone for grave markers. Together with winemaker Ron Giesbrecht, the Specks have made full use of their being the only Niagara estate winery on the Escarpment that is mostly on very thick monotonous glaciolacustrine clay, rather than glacial till. This, so they would argue, makes the grapes fight to achieve a better quality of juice for their international-award-winning wines.

They are the premier vineyard of the Short Hills Bench (Fig. 6), which in terms of soil (clay) and climate (mouth of the Short Hills re-entrant) are completely different from any other Escarpment or Lake Iroquois Plain *terroir.*

OVERVIEW OF THE GEOLOGY OF THE NIAGARA FALLS & GORGE

The most impressive view of the bedrock geology is the 50 or so metres exposed above the Niagara River at the Falls and Gorge. However, from soundings of the river it is known that the plunge pool of the Falls has excavated about a further 50 m below the surface of the river. In the eastern Niagara Peninsula, the highest vertical exposure is where the Niagara River exits the Niagara Gorge at Queenston Heights (Figs. 4 and 6). Here the Escarpment forms an abrupt steeply-sloping feature, about 76 m (250 ft) in height, of south-dipping Lower and Middle Silurian strata comprising, from top to bottom: the massive, cliff-forming, Lockport and Decew dolostones; Rochester shale; Irondequoit dolostone; Reynales and Neagha limestones and shaly limestones; Thorold and Grimsby sandstones; Grimsby and Power Glen shales; the Whirlpool sandstone, and; the top of the Upper Ordovician Queenston Shale, which extends along the Lower Niagara River to Niagara - on - the - Lake. The Silurian sequences were laid down over a time period of 20-25 million years, commencing 438 million years ago. At the base of the Escarpment, a terrace of gravels (Bell Terrace) forms a prominent north-facing bluff (see, cross-section, Fig. 4).

STOP 6-1 Great Gorge Adventure

The view from the Niagara Parkway looking into the Niagara Gorge encompasses the Silurian sequence from the Lockport dolostone caprock to the Gorge down to the Whirlpool sandstone (Fig. 4). We shall descend by elevator to a boardwalk along the Whirlpool Rapids which boast some of the world's largest standing waves, as well as the location of Ms Lane's rescue in the movie, "Superman". From here the geology can be viewed from the Lower Silurian units upward. On the opposite side of the river, a huge rockfall has covered the tracks of the late19th century electric tramway that followed the Gorge.

Downriver the Niagara River takes a 90^{o} turn to the northeast at the Whirlpool. Originally, the Niagara River flowed through the buried St. David's Gorge (Fig. 6) but during Late Wisconsinan glaciation it was filled with glacial sediment. At the close of glaciation, the river cut back from the Escarpment along its present path to reach the old gorge about 5000 - 6000 BC (Tinkler et al., 1994); about the same time as the earliest records of grape cultivation for wine in the Middle East; where in the ancient Persian empire, it was official government policy that "government ministers used to take important decisions when drunk, in the belief that the divine influence of wine would guide them", although, "such decisions were also reviewed by the ministers when sober the following day!" (Buckley, 1994). The Whirlpool usually rotates anticlockwise, but in times of low water volume (much of the water is taken by hydro-electric stations on both Canadian and U.S.A. sides of the gorge) it flows clockwise.

STOP 6-2 Niagara Falls

There two main falls at Niagara Falls: the linear American Falls (wholly within the U.S.A.), which tumbles over the side of the Niagara Gorge, and the Canadian Falls (or Horseshoe Falls), which forms the head of the Niagara Gorge (Fig. 6). The falls have carved away much of the 90 m (310 feet) vertical height between the Upper Lockport Formation and the Queenston shale (Fig. 4). However, the lower half of this height is filled with the water of the plunge pool of the lower Niagara River, below the falls: the falls themselves being about 45 - 51 m (~150 feet) high. The only rocks normally exposed in the walls of the falls are the Lockport, Decew, Rochester and Irondequoit formations.

Although the hydro-electric stations on the American side of the Upper Gorge were destroyed by major rockfalls, the one on the Canadian side is still working and can be seen from the Table Rock viewpoint. A closer viewpoint is accessed from the base of the Scenic Tunnels Tour elevator.

Above the Falls, the Upper Niagara River takes an abrupt turn to the southeast. Examination of Figure 3 indicates that the river preferentially followed the southwest and southeast joint sets in the bedrock as it carved its way down and back from the edge of the Escarpment.

ACKNOWLEDGEMENTS

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In Vino Veritas

APPENDIX 1

Vineland Quarries Rehabilitation Project

September 12/13, 2000

C. Clark, B. Cornelius, Vineland Quarries
K.H. Fisher, University of Guelph

The trial was initiated to establish that perennial crops, such as grapevines, could be grown on rehabilitated quarry land if the appropriate measures were taken to ensure good soil structure. Financial partners included Vineland Quarries and the Industrial Research Assistance Programme of the National Research Council. Subcontractors and consultants for the project were Vineland Quarries, Vailmont Vineyards, Kasper Land Drainage, Braemar Acres, K.L. Bellamy Associates, Niagara College, the University of Guelph and the former Quno/Donohue now Abitibi Consolidated Mills. The project started in May 1 1999 and was completed July 31 2000.

This location had not been systematically rebuilt and after initial grading in the early 1980's, was seeded and used for pasture. The land was rolling at the north part of the parcel and then steeply sloping toward the quarry floor. The initial work was to re-grade the slope to reasonable aspect to capitalize on the south face and allow for safe working conditions for conventional farm equipment working parallel to the slope.

The slope was graded to 12% and then ripped at 1.4 m centres to a depth of 0.8-1 m, both parallel and perpendicular to the slope. Because of the degree of soil movement required to regrade the slope, the new face was covered with about 0.5 m of topsoil from an undisturbed section of the quarry. The whole field was then tiled parallel to the slope at 3.75 m. Three separate headers were cut perpendicular to the slope and emptied into separate catch basins at the bottom of the field so that soil water could be monitored if necessary.

The field was then divided into 27 plots for three treatments with paper mill biosolids for the rehabilitation of the soil structure. This material is basically cellulose with some ink residues and is the product from one paper mill which produces only newsprint. The product is very consistent and is monitored very closely. Two rates and check plots with no biosolids are randomized throughout the field. This material was applied and then worked in and a cover crop of rye and radish sown. This spring, the cover crop was worked under and grapes planted. Eight varieties of wine grapes have been planted here, all red varieties and differing in their winter hardiness.

The soil quality has been monitored since the beginning of the trial and the cover crop has been analysed in November 1999 and June 2000. Vine growth, mineral nutrition and winter hardiness will be monitored and further trials regarding the appropriate cover crops and fertilization programmes are planned. Weather stations have also been installed to track the temperature differential on the slope and throughout the quarry.

Contact:
K.H. Fisher
University of Guelph, Ontario Agricultural College, Department of Plant Agriculture
4890 Victoria Ave. North, P.O. Box 7000, Vineland Station, ON, L0R 2E0

Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			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

	Multiplied by	
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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