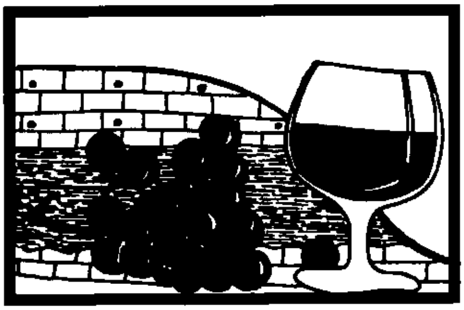
SERIES



Geology and Wine 2. A geological foundation for *terroirs* and potential sub-*appellations* of Niagara Peninsula wines, Ontario, Canada

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> No verse can give pleasure for long, nor last, that is written by drinkers of water.
>
> *Horace*

SUMMARY

All of the vineyards in Niagara are planted on soils derived from a variety of Late Pleistocene to Early Holocene, subglacial and proglacial sediments. These were deposited during a series of Late Wisconsinan continental ice advances and retreats, on a landscape that had been carved into the Paleozoic bedrock by this and earlier Quaternary glaciations to form the several landforms that exist above, on, and below the cuesta of the Niagara Escarpment. This paper proposes that the existing delineation of grape viticultural areas, by climate zone, be considerably modified by the recognition that it is the significant differences in the geology that control distinction of *terroirs* and sub-*appellations* based on variation of landform physiography, soil types, and groundwater flow conditions. From considerations of these geological and climatic differences, in combination with wine profiles distinguished by J-L. Groux, winemaker at Hillebrand Estates, the Niagara Peninsula Designated Viticultural Area can be divided into at least eight sub-*appellations*.

RÉSUMÉ

Tous les vignobles de la région du Niagara croissent dans des sols issus d'une variété de sédiments sous-glaciaux et pro-glaciaux de la fin du Pléistocène et du début de l'Holocène. Ces sédiments ont été déposés lors d'avancées et de retraits glaciaires wisconsiniens sur un substratum de couches ordoviciennes sculptées par l'action de glaciations qui ont précédées et qui ont laisser les nombreuses formes de relief que l'on peut voir sur et de part et d'autre de la cuesta de l'escarpement du Niagara. Dans le présent article, nous proposons que la délimitation actuelle des diverses zones viticoles par zone climatique soit révisée en profondeur afin de tenir compte de variations significatives de nature géologique et qui déterminent les différents terroirs et sous-appellations en fonction de la physiographie du paysage, des types de sol et des paramètres de l'écoulement hydrique. En combinant de telles considérations géologiques et climatiques aux différents profils viticoles établis par J.-L. Groulx, viticulteur au domaine Hillebrand, la région viticole du Niagara pourrait être subdivisée en huit sous-divisions au moins.

INTRODUCTION

Best known internationally for the magnificent panorama of Niagara Falls, the Niagara region of Ontario is also Canada's principal producer of *Vitus vinifera* (wine grapes of European origin) and French hybrid (crosses between *Vitus vinifera* and North American species) wine grapes. Although several of the wineries are winning international medals, particularly for icewines but also for white and red table wines, it is often not appreciated that the latitude (43°N) of Niagara is the same as the famous red wine regions of Provence in France, Chianti in Italy, and Rioja in Spain. At this latitude, near the midpoint between 30° and 50°, the hours of daylight and high summer temperatures are perfectly suited to the growing of grapes (Stevenson, 1997). But because the best areas for viticulture lie between the 10°C and 20°C annual isotherms (de Blij, 1983; Unwin, 1991), the marked depression of the 10°C annual isotherm in North America (Fig. 1) creates a shorter growing season and winter severity in the Niagara Peninsula that makes the climate marginal, even as a cool-climate viticultural region. Most *Vitus vinifera* cannot endure sustained temperatures below about -20°C, whereas North American varieties such as the Concord (a *Vitus labrusca* cross) are hardy to -29°C (Smart, 1999). However, it is this same winter severity that makes Niagaran wineries the world's leading producer of icewine (see, WINES, below).

When I arrived at Brock University in September 1974, Don Ziraldo and Karl Kaiser were getting ready to pick their first vintage and open Inniskillin Wines. In what was then the Department of Geological Sciences, the late Peter Peach had started a soil mineralogy project on samples collected by the late Jaan Terasmae along a north-south transect across the northern Niagara Peninsula in order to relate glacial and post-glacial deposits to vineyard and orchard development. This led to Brock's first (and probably Canada's?) wine-related geological thesis (Gombos, 1977), 20 years before Brock opened its Cool Climate Oenology and Viticulture Institute. Unfortunately these early geological efforts were not continued and, because Niagaran viticulturists have been fully occupied in determining which grape varieties are best suited to both the growing conditions and market taste, little attention has been paid, until recently, to the effect of different geological *terroirs* in the Niagara Peninsula on the nose, palate and quality of different wine varietals. In contrast, local differences between adjacent vineyards in France, including geology, can result in one designated a *Grand Cru* and the other a simple *Vin de Pays* (Pomerol, 1989; Wilson, 1998). However, as Tim Unwin, the editor of Journal of Wine Research states in his book, *Wine and the Vine* (Unwin, 1991):

> This diversity is not only the outcome of differences in geology and climate, but it is also the result of the labour of countless generations of vine growers and wine makers, each set in their own distinctive human context. (p. 1)

Not denying the quintessential value of the viticulturists and the winemakers, there is a lack of balance in arguments that disregard vineyard geology on the grounds that: 1) the vineyard soils of Niagara have been modified by installation of sub-drains, and 2) the wine quality and flavour profile is due entirely to climate, viticultural practices (planting density, trellising techniques, canopy management, type of clone, type of rootstock, *etc.*) and the skill of the winemaker. Fortunately, I have long been encouraged in my quest to geologically define the Niagara Peninsula *terroirs*: first by David Parker, Brock geology graduate and cellarmaster at Cave Spring Cellars; next by Matthew and Paul Speck, co-owners of Henry of Pelham; and then by Paul Bosc, the Algerian-born, French-trained winemaker and owner of Château des Charmes. The results of this encouragement are five *Geology and Wine* field trip guides (Haynes, 1992a, 1994a,b, 1999a; Haynes *et al.*, 1998) and two "popular press" publications (Haynes, 1995c, 1998). However, 29 September 1999 saw both Paul-André Bosc (son of Paul Bosc) of Château des Charmes, and Jean-Laurent (J-L.) Groux, the French-born and -trained winemaker at Hillebrand Estates, release wine data in support of Niagara Peninsula *terroirs* at the 1999 Niagara Grape and Wine Festival seminar on "*Terroir,*" at Brock University. Although these data are unpublished, both individuals have kindly permitted me to use their information, which has assisted considerably in the intent of this paper to quantify, in terms of geological *terroirs*, the recent statement by Tony Aspler (editor of *Winetidings* magazine) in his book, *Vintage Canada* (Aspler, 1999):

> Eventually, the geographic designations of the Niagara Peninsula and Lake Erie North Shore will be fragmented into smaller sub-zones, just as Bordeaux is broken down into communes such as St. Emillon, Pauillac, Graves, *etc.* There is a case for wines grown on the bench of the Niagara Escarpment to be differentiated from those grown on the Lakeshore plain since their taste profiles are perceptibly different. (p. 25)

It must be emphasized that this paper is concerned with the variation of wine taste/flavour profiles in relation to differences in vineyard *terroirs* and is not an assessment of different wineries. For a variety of reasons, many wineries combine grape juice from a variety of vineyards (and different growers) and many wineries blend wines prior to bottling. Thus, only those estate wineries that were known to the author to produce separate wines from specific vineyard soils are considered.

WINES OF THE NIAGARA PENINSULA

Early Developments

Historically, the first Niagaran wines are believed to have been offerings of fermented wild grape juice by aboriginal tribes to the gods, who lived at the foot of Niagara Falls, in a ceremony known as the "Wischgimi" (Aspler, 1999). Commercial wine production in Ontario until the late 1960s was based predominantly on grapes derived by American horticulturists from cross-pollination of European (*Vitus vinifera*) cuttings with native American grape varieties (mainly *Vitus labrusca*). The first crosses were the accidental results of unsuccessful attempts to grow *vinifera* cuttings in Virginia by Lord Delaware in 1619, and in Philadelphia by John Alexander (Governor John Penn's gardener) in the 1770s. Alexander's discovery resulted in the first commercial development of a North American grape hybrid (the Cape), around 1800, but this was soon eclipsed by newer American hybrids: the Isabella in 1816, and Catawba in 1823 (Aspler, 1999). Although the Catawba is still in use in Ohio today for wine (Borrello, 1995), the most successful commercial developments of *V. labrusca* crosses were the blue-skinned Concord in 1843 in Concord, Massachusetts (Schreiner, 1985) and the white Niagara in 1868 in Lockport, New York State (Aspler, 1999); both these varieties as well as several other *V. labrusca* crosses are still used in wineries around the Great Lakes in New York, Pennsylvania and Ohio and are the main source for grape juice and jam in Ontario.

20th Century Developments

Early in the 20th century, New York State's Geneva horticultural experimental station began planting hybrid vines developed by the pioneer French breeder Albert Siebel and, later, his fellow hybridizers François Baco, Eugene Kuhlmann, J-L. Vidal, and Bertille Seyve-Villard (whose names are honoured by the grape varieties Baco Noir, Vidal and Seyval Blanc). These hybrids were developed in France to overcome problems with weather and the *phylloxera* louse (a root-feeding aphid), which (together with powdery and downy mildew and other fungal diseases) had been the main reason for the failure of *Vitus vinifera* grapes in North America and which, when introduced to France on experimental North American native grape stock, had decimated the French vineyards in the latter half of the 19th century. Although tens of thousands of these "French hybrid" grape varieties were developed, most of them produced poor wines, so that by the 1950s the French began to limit their plantings, as they were concerned that they would displace traditional *V. vinifera* varieties to the detriment of their wines (Schreiner, 1985).

Beginning in about 1880, an alternative to using hybridization (cross-pollination) in order to resist infestation was the grafting of European *Vitus vinifera* cuttings onto a variety of North American native *Vitus* species rootstocks: the most effective species were *Vitus berlandieri*, *Vitus rupestris* and *Vitus riparia* against the *phylloxera* louse, and *Vitus aestivalis* against mildew. Today, most of the world's wine is produced from *V. vinifera* grafted onto a wide range of rootstocks that are custom selected for shallow- to deep-rooting soil conditions.

In 1946, Adhemar de Chaunac, the French-born winemaker at Bright's Wines (now part of Vincor), and J.R. van Haarlem, the grape specialist at Ontario's Vineland Horticultural Research Institute, began importing cuttings of both French hybrids and *Vitus vinifera*. This led in 1951 to the first successful commercial planting of *V. vinifera* (Chardonnay) east of the Mississippi in North America, and in 1956 the first *V. vinifera* table wines marketed by a Canadian winery (Schreiner, 1985).

Although wineries in Ontario and New York prospered with French hybrids from 1956 to the 1980s, it was the pioneering work of the Ukrainian-born Dr. Konstantin Frank, who in 1962 introduced wines from *Vitus vinifera* grapes grown at his winery in New York's Finger Lakes area (Borrello, 1995), that confounded the official skepticism of the viticulturists at both Ontario's Vineland and New York's Geneva research stations that *V. vinifera* grapes could not flourish. Frank convinced Paul Bosc, then the winemaker at Chateau-Gai, to plant *V. vinifera* red varieties such as Pinot Noir, Cabernet, Merlot and Gamay Beaujolais. Wines produced from these varieties in 1972 were impressing wine writers (Schreiner, 1985). However, it was the emergence of estate wineries, beginning with Don Ziraldo (the viticulturist) and Karl Kaiser (the winemaker) establishing Inniskillin Wines in 1975, and Paul Bosc's own winery, Château des Charmes in 1977, that set Niagara and the rest of Ontario on the track of quality table wines produced primarily from a wide range of both white and red *V. vinifera* grapes. An important aspect of progress was the work of Dr. John Paroschy on identification of winter-injury resistant *V. vinifera* clones or mutations.

French hybrids are still grown, but only the white Vidal, which is the mainstay for icewine (see below), has significant plantings, although the red Baco Noir and Maréchal Foch, and the white Seyval Blanc and Vidal (particularly as a "late-harvest" wine) have achieved some success as table wines. Today, in Niagara, the common *Vitus vinifera* grapes are: the white Chardonnay, Riesling, Gewurztraminer, Pinot Gris, and some Aligoté, Auxerrois, Muscat, Pinot Blanc, Sauvignon Blanc, Viognier; and the red Cabernet Franc, Cabernet Sauvignon, Gamay Noir, Merlot and Pinot Noir, and some Petite Syrah, Syrah and Zweigelt.

Interestingly, the Niagara wineries have become the world's largest producer of icewine. Although icewine originated in Germany, production there is sporadic because, unlike the Niagara Peninsula, consistent freezing conditions in early winter cannot be relied upon. Icewine is produced by leaving grapes to overripen on the vine until they freeze in early winter. The frozen grapes are hand-picked and pressed in the cold so that water is removed as ice crystals. The resulting "freeze-dried" liquor, which is enriched in natural sugars, is fermented slowly to produce an aromatic sweet wine of high alcohol content (10-13%) and high acidity (ideally). However, production costs are very expensive and young icewines retail at about $50 a half bottle, and older vintages may fetch double this amount. Icewines are made mainly from Vidal grapes and to a lesser extent Riesling, but also Gewurztraminer and Seyval Blanc grapes.

Canadian Wine Classification

In Canada, there are four distinct provincial wine regions that contain separate viticulture districts (Fig. 1). In descending order of size, these are Ontario (Niagara Peninsula, Lake Erie shore, Pelee Island), British Columbia (Okanagan and Similkameen valleys, Fraser Valley, Vancouver Island), Quebec (Montérégie and Estrie), and Nova Scotia. In France, the individual viticulture districts of a wine region display characteristic climatic, geologic and physiographic features and are termed an *appellation*. 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*). The legal control is implicit, as the term *appellation* is short for *Appellation d'Origine Contrôlée* (AOC or AC). Furthermore, in France, an *appellation* can be subdivided into sub-*appellations* (communal *appellations*), and even further down to the specific vineyard (a *climat*), in terms of relative differences in its *terroir*. Outside France, the term "appellation" is used in a loose sense as a relatively large geographic area of *Vitus vinifera* vineyards that often corresponds in France to the zonal *appellations* of the separate category of French wine classification of *vin de pays*, which are areas outside the AOCs that have less strict regulations (Stevenson, 1997). In Canada, such geographic areas are officially termed Designated Viticultural Areas (DVAs) and are allocated in Ontario and British Columbia by independent alliances, the Vintners Quality Alliances (VQA), who determine the regulations governing the right of vintners to use a DVA on their labels (*e.g.*, Ziraldo, 1995). In Ontario, the largest DVA is Niagara Peninsula; the others are Lake Erie north shore and Pelee Island (Figs. 1, 2). 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 the European Economic Community. It is hoped that the separate provincial professional geoscientist associations will be pushing for representation on the VQA to give geological substance to determination of *appellations* (DVAs) and sub-*appellations*.

NIAGARA REGIONAL GEOLOGIC SETTING

The cuesta landform of the Niagara Escarpment (Fig. 2) was carved by the Quaternary glaciations (Fig. 3), and the present river valleys and waterfalls by Holocene erosion into Paleozoic bedrock. Much of the region's glaciogenic sediment was derived originally by erosion of this Paleozoic bedrock.

Paleozoic History

The Niagara Region is located on the western margin of the Appalachian Basin on the east flank of the Algonquin Arch, a prominent feature that, today forms the topographic spine of southwestern Ontario between lakes Ontario-Erie and Lake Huron, but which developed as the border between the Appalachian and Michigan basins during the Silurian and Devonian (Fig. 2). In the Ordovician (Johnson *et al.,* 1992), this area was a shallow subtropical sea that changed during the Late Ordovician–Early Silurian Taconic Orogeny to foreland deltaic, and locally to shallow marine and non-marine epicontinental environments of the Upper Ordovician red shales of the Queenston Formation (Fig. 4). During the Silurian, a shallow epeiric sea developed across the Algonquin Arch, which itself was subject to episodic uplift and subsidence. This resulted in the Early Silurian accumulation of shales and sandstones of the Medina Group, then shales and dolostones of the Clinton Group, followed later in the Middle Silurian by dolomitic reefal and algal carbonates of the Lockport, Eramosa and Guelph formations (Figs. 2, 4). This culminated in the Upper Silurian with subtidal to supratidal evaporites of the thick Salina Formation (Haynes, 1999c) and algal subtidal to intertidal dolostones of the Bertie and Bass islands formations (Haynes, 1992b). As a consequence of continental plate tectonic movements in the Michigan and Appalachian basins and base-level fluctuations, the Silurian sequences tend to thin, or pinch out, toward the Algonquin Arch, and display a number of interfingering relationships that have caused controversy in stratigraphic nomenclature and correlation (Brett *et al.,* 1994).

The Early Devonian is marked by extensive subaerial erosion that was followed by sandy and dolomitic carbonates, and then, in the Middle Devonian, with shallow tropical marine reefal carbonates and calcareous shales that intertongued with nonmarine silty and sandy clastics derived from orogenic uplift of the adjacent Appalachians by the Acadian Orogeny. The Upper Devonian saw most of eastern North America covered by the Chattanooga Sea, a broad, shallow, inland seaway, west of the Acadian Orogen, that deposited a thick accumulation of black, organic-rich shales (Johnson *et al.,* 1992).

Following filling of the Michigan and Appalachian basins with Mississippian and Pennsylvanian sediments, Permian compression in the closing stages of the collision of North America with Africa (to form Pangaea), created the thrust sheets of the Appalachian Front (Fig. 2) during the Alleghanian (Appalachian) Orogeny, and uplifted much of the Great Lakes area. This was followed by erosion and deposition of nonmarine craton-derived clastic sediments, with local marine incursions related to breakup of Pangaea and formation of the Atlantic Ocean, from the Late Triassic to the mid-Cretaceous. Following deposition of the Mesozoic, all the bedrock in Ontario appears to have undergone a period of erosion that continues to the present, but was particularly severe during the Quaternary glaciations (Johnson *et al.,* 1992).

The vineyards of the Niagara DVA are located in the northern Niagara Peninsula, where they are underlain by Upper Ordovician and Middle Silurian bedrock on, and north of, the Niagara Escarpment (Figs. 2, 4). Of the other wine regions in the Great Lakes region (Fig. 2), only the Finger Lakes is of comparable size in terms of production of *Vitus vinifera* grapes to the Niagara district. This, and most of the other Great Lakes wine regions, are located on Devonian bedrock: except the Bass Islands-Sandusky district of Ohio which is on Upper Silurian bedrock (Haynes, 1994c). Interestingly, that part of New

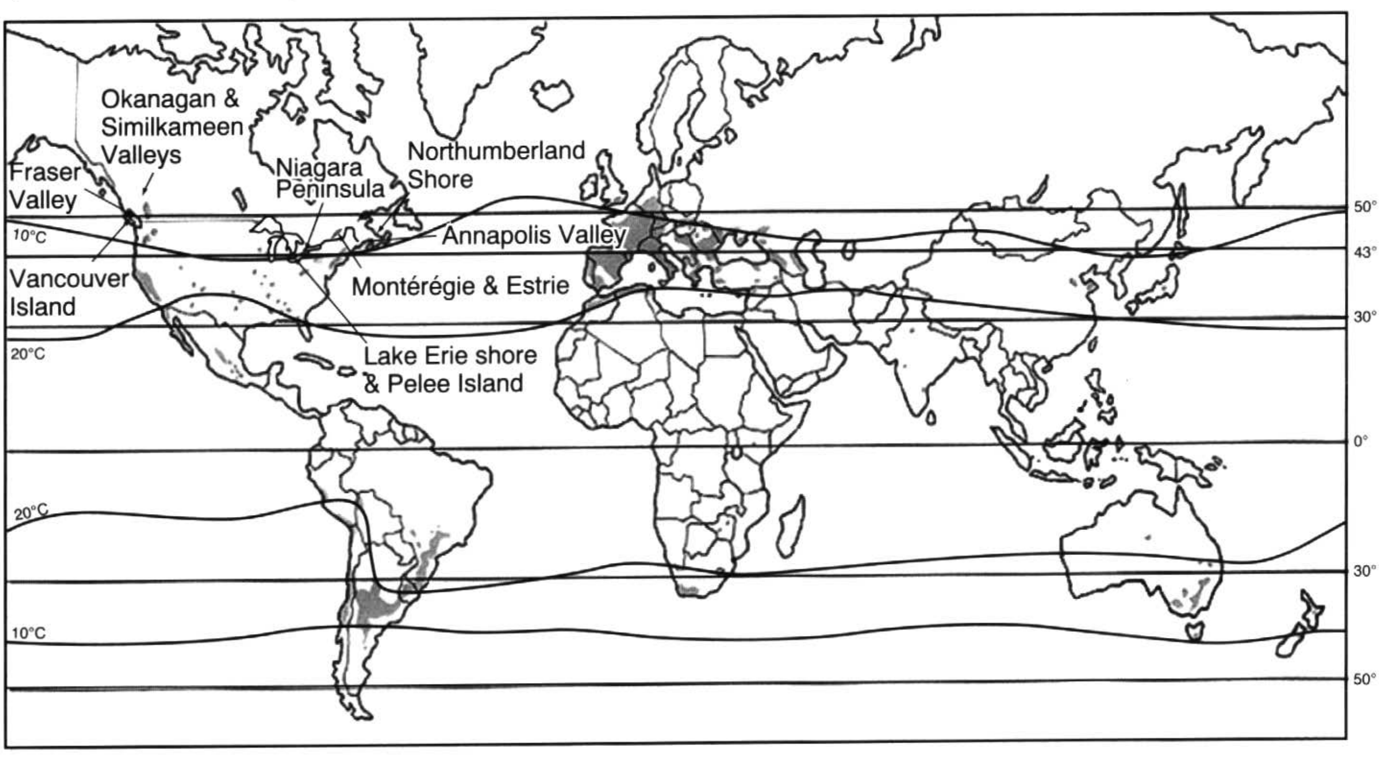

Figure 1 Location of Canadian viticulture districts in relation to the world's major areas of grape cultivation (shaded) between latitudes 30°-50°N and S (Stevenson, 1997) and the 10°C and 20°C annual isotherms (de Blij, 1983; Unwin, 1991).

York State contiguous to the Niagara DVA, north and along the Niagara Escarpment, has the same geology but has yet to be developed for vineyards.

Quaternary History

All of the vineyards in Niagara are planted on soils derived from Late Pleistocene to Early Holocene sediments. As well, the development of the present landforms of and around the vineyards, including the variable physiography of the Niagara Escarpment (a cuesta), resulted mainly from a series of Quaternary continental glaciations that carved the bedrock and laid down glacial sediment (till), consisting of rock fragments in clay or sandy silt, both during advance of the ice sheet and retreat of the ice front (Fig. 3). Quaternary deposits in southern Ontario (Barnett, 1992; Karrow, 1989) appear to represent only the last 190,000 years but include the Illinoian Glacial Stage (*circa* 135,000-190,000 years BP), the Sangamonian Interglacial Stage (*circa* 115,000-135,000 years BP), the Wisconsinan Glacial Stage (*circa* 10,000-115,000 years BP, when Ontario was covered by the Laurentide Ice Sheet), and the Holocene (*circa* 10,000 years BP to the present).

During interglacial periods between glaciations, large lakes (glaciolacustrine) and rivers (glaciofluvial) formed in front of the northward retreating ice sheets (Fig. 3). Because of the erosive power of each of these continental glaciers, usually only the results of the last glaciation (the Late Wisconsinan) are visible in most areas. Notable exceptions include: the Short Hills valley (Fig. 5), which was formed as a pre-Late Wisconsinan river gorge complete with a buried waterfall similar to the present Niagara Falls, and the wide upper terrace on the Escarpment in the Vineland area (Fig. 5) that resulted probably from a combination of ice carving by older glaciers and shore erosion by earlier lakes. As the ice front finally retreated north from the Escarpment, a series of lakes formed between the ice and the Escarpment, with deposition of glaciolacustrine clays and silt over the till on the terraces. Several smaller, local lakes were formed in the intervening period: for Niagara, Lake Warren (first-formed around 12,800 years BP) is the most important, as the large ice-marginal fan-delta at Fonthill (Fonthill Kame, Fig. 5) was constructed in a small re-entrant in the glacier margin during the early formation of Lake Warren. Late stages of Lake Warren are indicated by deposition of near-shore sediments and evidence of wave-cut platforms and shore bluffs near the crest of Fonthill (Feenstra, 1981). However, the steep northern slope of the Fonthill Kame indicates an ice-contact feature Feenstra (1981). As the ice front retreated north of Toronto, a large lake (Lake Iroquois) formed in front of it about

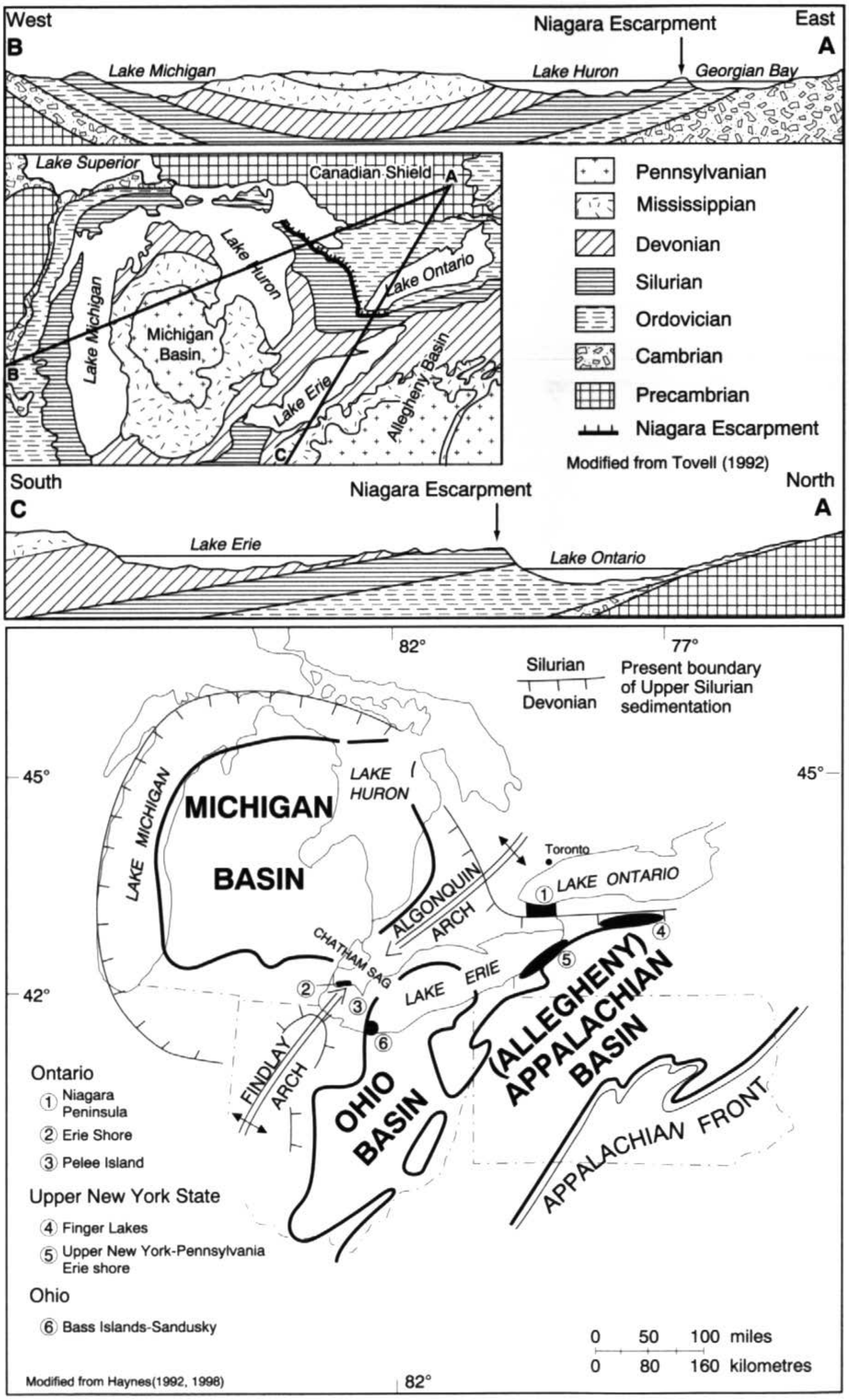

Figure 2 Geology of the Great Lakes (**top**) and relation of the wine grape regions of Ontario, Upper New York state, Pennsylvania and Ohio to major structural elements of the Appalachian, Michigan and Ohio basins, during Silurian time (**bottom**).

12,000 years ago and eroded the earlier glacigenic sediments, forming a shore bluff as a prominent ridge of beach deposits, and, below the shore bluff, lake deposits of stratified sand, silt and clay.

Glacial Lake Iroquois reached its maximum extent about 11,800 years BP; but as the ice retreated north of Brockville, Early Lake Ontario formed when water was able to drain out of Lake Iroquois to the Champlain Sea, which had also formed as melting of the ice sheet allowed the Atlantic Ocean to transgress up the valleys of the St. Lawrence and Ottawa rivers. The Champlain

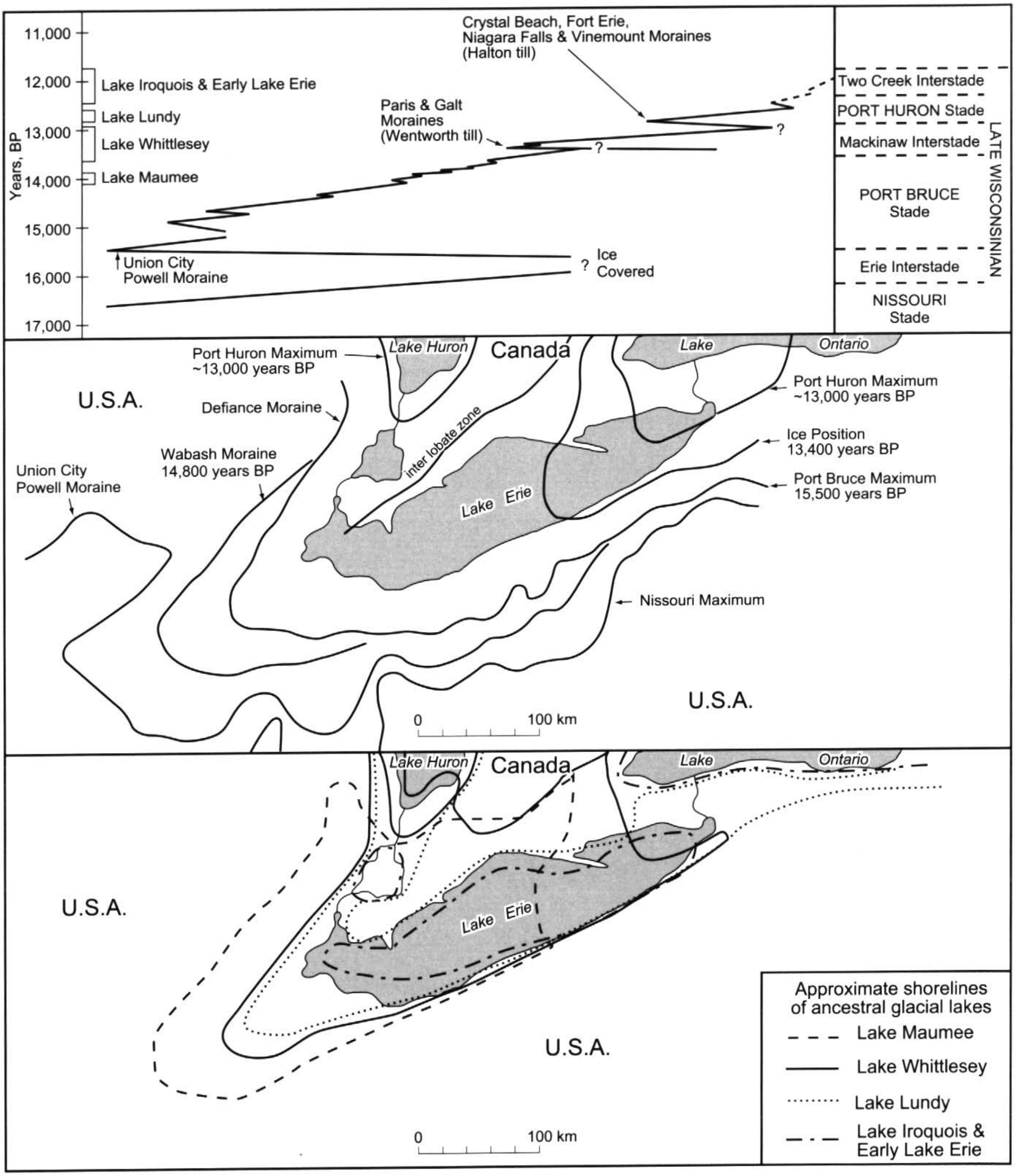

Figure 3 Generalized geochronology of glacial retreat and advance events in southern Ontario (after Barnett, 1985, 1992; Menzies, 1994.)

Sea reached its maximum extent about 11,000 years BP, but its level had fallen considerably by the beginning of the Holocene (about 10,000 years BP). At about this same time in the Niagara Peninsula, much of the area on either side of the Niagara River south of Niagara Falls, which had been inundated by northeastward-flowing waters connecting Lakes Wainfleet (that drained water from Lake Erie) and Tonawanda (whose water had drained over the escarpment at three spillways in New York and at the position of the present Niagara River) was differentially uplifted in the east, caused drainage to reverse to the west (Tesmer, 1981; Tinkler, 1994). Originally, the Niagara River had flowed through a pre-glacial gorge (the buried St. David's Gorge) that during Late Wisconsinan glaciation became filled with glacial sediment (Hobson and Terasmae, 1969; Tesmer, 1981). At the close of glaciation and the beginning of the Holocene, the Niagara River cut a new path from the pre-existing Lake Tonawanda spillway over the Escarpment back along its present path to intersect the old gorge and form a right angle bend to create the famous Whirlpool about 5000-6000 BP (Tinkler *et al.*, 1994). This was about the same time as the earliest records of cultivation of grapes for wine in the Middle East; where later, in the ancient Persian empire, official government policy dictated that (Buckley, 1994), "government ministers used to take important decisions when drunk, in the belief that the divine influence of wine would guide them."

GEOLOGY AND PHYSIOGRAPHY OF THE NIAGARA PENINSULA DVA

South of an east-west line through Niagara Falls, there is no commercial production of grapes, and the Haldimand Clay Plain (Fig. 5) is underlain, progressively southward, by the Upper Silurian Guelph, Salina and Bertie/Bass Islands formations (Fig. 4), and stops at the Onondaga Escarpment, which is capped by the Lower Devonian Bois Blanc and Middle Devonian Onondaga formations (Figs. 4, 5). North of Niagara Falls, there is commercial production of *Vitus labrusca* grapes on the Haldimand Clay Plain, the Vinemount Moraine, and the Fonthill Kame (Fig 5). These are underlain by the Middle Silurian Eramosa Member, the upper part of the Lockport Formation (Figs. 4, 5, 6), the only exposure of which is at the crest of the upper Niagara Gorge (Fig. 7a).

The principal area of *Vitus vinifera* grape wine production is located in the northern Niagara Peninsula, from the Vinemount Moraine across the Niagara Escarpment to Lake Ontario (Figs. 5, 6). Detailed descriptions of the geology, physiography and geomorphology of the Niagara Escarpment and the northern Niagara Peninsula are included in Bolton (1957), Brett *et al.,* (1994), Cheel (1991), Feenstra (1981, 1984), Haynes and Fraser (1994), Haynes (1995a,b), Hobson and Terasmae (1969), Johnson *et al.* (1992), Kingston and Presant (1989), Menzies and Taylor (1998), Tesmer (1981), Tinkler (1994), Tinkler *et al.* (1994), Tiplin and Seibel (1988), and Tovell (1992). Chemistry of ground-

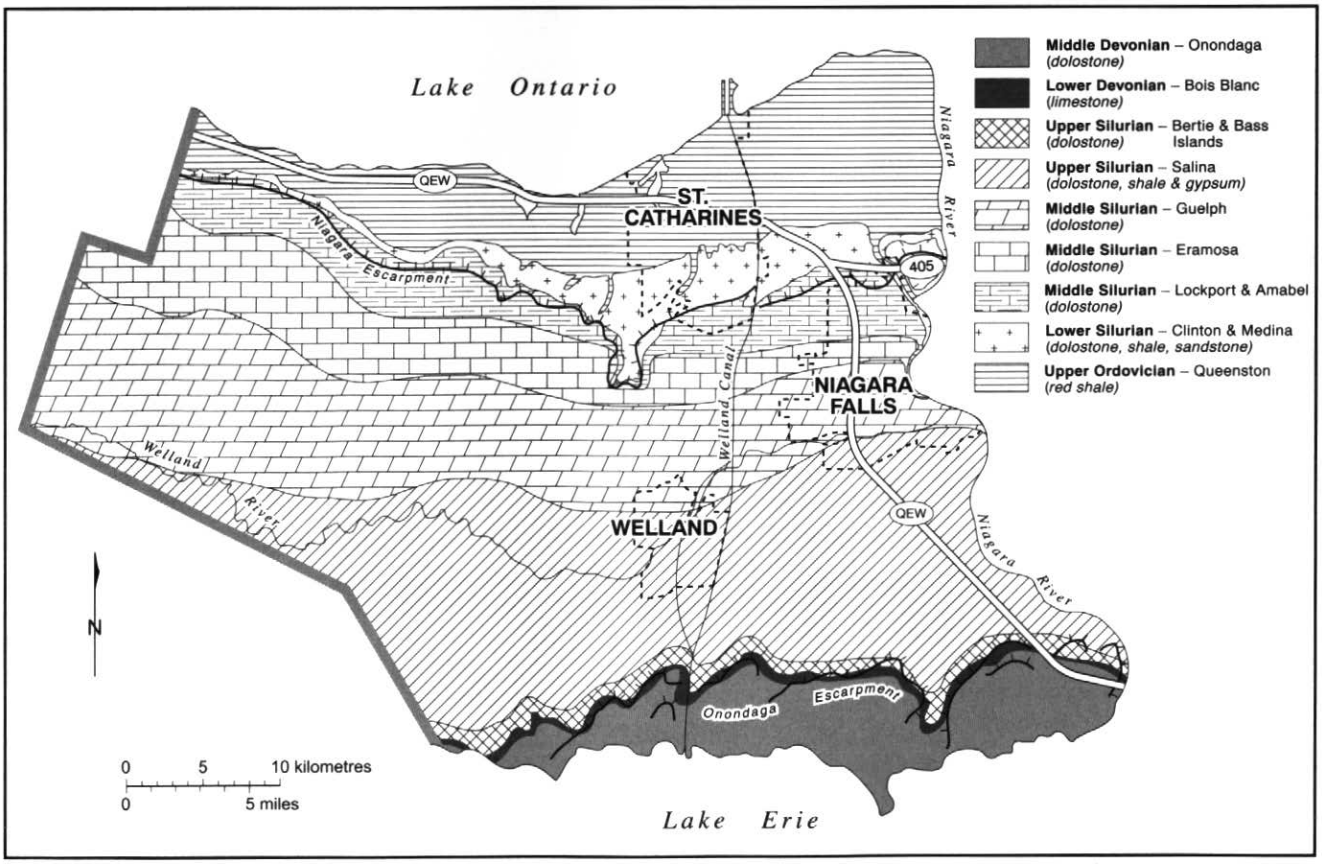

Figure 4 Bedrock geology of the Regional Municipality of Niagara (modified from Ontario Geological Survey, 1991; Haynes, 1992; Menzies and Taylor, 1998.)

waters in the Lockport Formation has been studied by Haynes and Mostaghel (1982).

The most complete vertical exposures of the Paleozoic bedrock forming the Niagara Escarpment are located at the Niagara Gorge and at the St. Catharines hydro-electric power station (Fig. 7). Here, the Escarpment forms a cliff about 90 m in height, of Lower and Middle Silurian strata (comprising, from top to bottom: 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 (Figs. 6, 7).

On the face of the Escarpment, two terraces (Bell and Irondequoit, Fig. 6) are locally wide enough to support cultivation of *Vitus vinifera*. As they are above the Lake Iroquois shorebluff, they have been termed collectively by Haynes (1994b), the Lake Iroquois Bench (Fig. 5). The plain below that extends to Lake Ontario has been been termed by Haynes (1994b) the Lake Iroquois Plain (Fig. 5). At the base of the Niagara Escarpment, the Bell Terrace (Tiplin and Seibel, 1988) lies above the prominent north-facing bluff of gravels (Fig. 6) that marks the shoreline of Lake Iroquois. Although narrow in the east and west parts of the Region Niagara, the Bell Terrace widens to about 3 km between the Welland Canal and 15-Mile Creek (Fig. 5). West of 16-Mile Creek (Fig. 5), the Escarpment is lower (about 62 m high) and, here, the Lake Iroquois Bench has been termed (Haynes, 1998; Haynes *et al.*, 1998) the Vineland Double Bench, as it comprises two broad terraces: the Bell Terrace at the base, and the higher Irondequoit Terrace (Haynes, 1994b) above the scarp of Irondequoit limestone (Fig. 6). Here, the 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. 5) 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 and Queenston) that underlie the two resistant sequences of dolostones (Lockport-Decew), and carbonates (Irondequoit-Reynales) overlying sandstones (Thorold-Grimsby) (*see* Fig. 6). The two terraces of the Vineland Double Bench have formed over 1) an upper, thick, ledge of Irondequoit and Reynales dolomitic and argillaceous limestones underlain by Thorold and Grimsby sandstones, and 2) a lower, thin ledge of Whirlpool sandstone, at the base of the Escarpment, that often coincides 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,

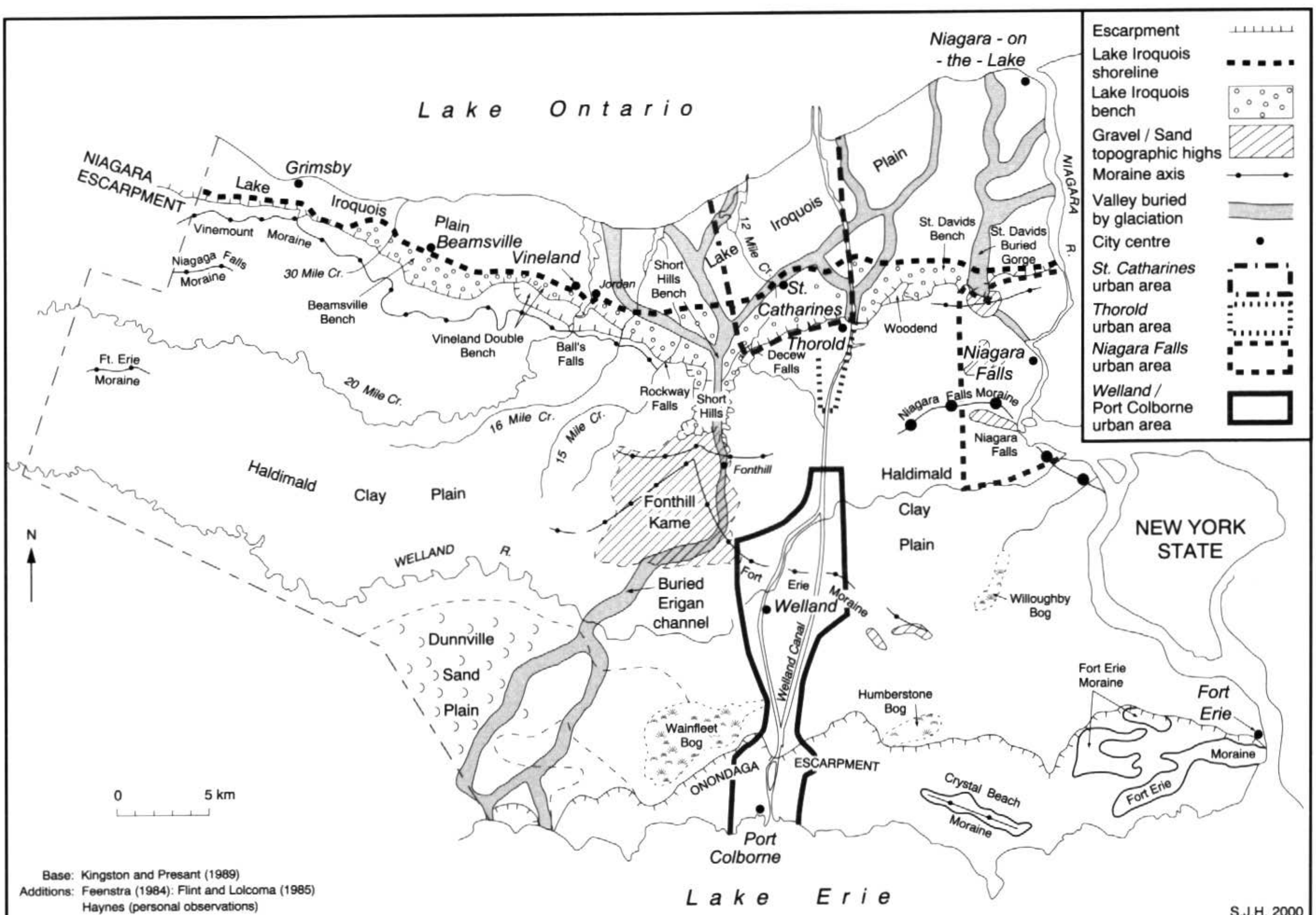

Figure 5 Major physiographic features and surface geology of the Regional Municipality of Niagara (modified from Haynes, 1994b).

toward Beamsville, the Irondequoit Terrace recedes back to the Escarpment scarp, while the Bell Terrace widens to about 1.5-2 km to form the Beamsville Bench (Fig. 5). On both Bench terraces, bedrock is overlain by a ramp of Halton till and other Quaternary glacigenic sediments (Fig. 6). Owing 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. The glaciolacustrine deposits on the Bell Terrace and Iroquois Plain vary from massive clay to silt to sand, with sands more common nearer Lake Ontario, suggestive to Menzies and Taylor (1998) of ice-proximal fluctuations of the ice front in the Lake Ontario basin.

The eastern end of the Vineland Double Bench is truncated by the 2-km wide, 4-km long reentrant of the Short Hills 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 gorge of the Erigan Channel, which used to connect Lake Erie with Lake Ontario (Flint and Lolcama, 1985). To the south, the Short Hills are terminated by the Fonthill Kame (Fig. 5), an irregular square hill, which stands 67 m above the surrounding plain of Haldimand clay, and is characterized by a steep convex-upward northern slope (ice-contact side) and shallower concave-upward southern, eastern and western slopes formed of stratified, well-washed sands and gravels.

NIAGARA PENINSULA *TERROIRS*

A French AOC *appellation* is based on the meterological (climate), physiographic (landform), viticultural (grape-growing practices), pedological (soil) and geological (subsoil) factors that constitute the *terroir* of that particular *appellation*; such that change of any factor within any one of these groups in an adjacent area could constitute reasons for designation of a separate *appellation* (see Haynes, 1999b). However, outside France, geological (and even physiographic) factors are largely ignored, and pedological factors are often restricted to soil texture.

Wine *terroirs* are, in fact, only a sub-group of the Tender Fruit category within the overall suitabilities of Niagara Peninula lands for all types of agriculture (Chapman, 1994; Fraser and Haynes, 1994). This in turn is part of a much larger framework of changing and competing land uses within the dynamics of a rapidly expanding population that is sensitive to land-use needs such as aggregates and recreational areas (Haynes and Fraser, 1994). Indeed the exact legal definition of the Niagara Escarpment and its land uses is open to debate (Haynes, 1995b), as is its position as a United Nations Biosphere Preserve (Haynes, 1995a).

In the Niagara Peninsula, no

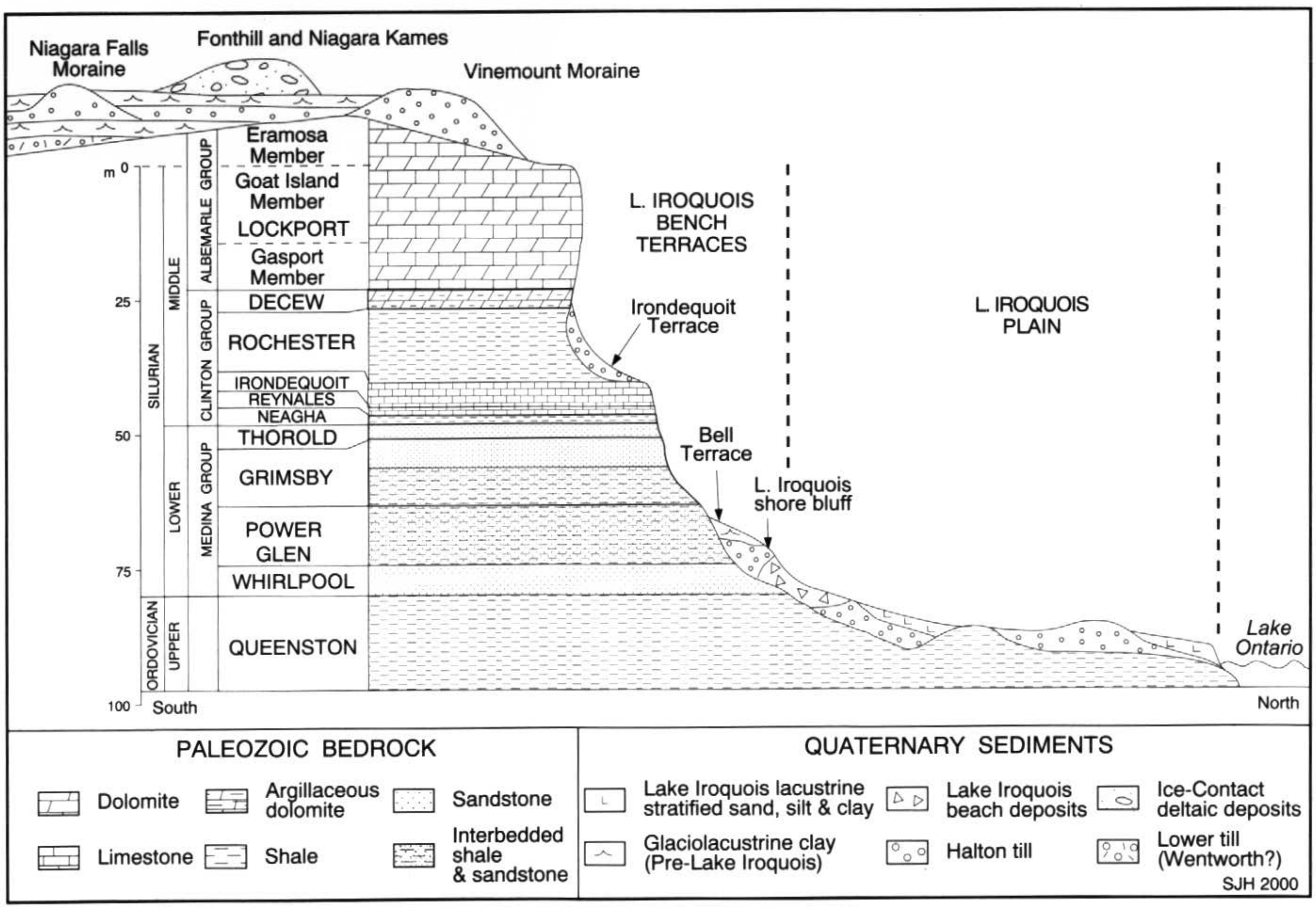

Figure 6 Composite north-south section of the geology and physiography across the Niagara Escarpment, in the Niagara Peninsula (modified from Haynes, 1994b, 1995a.)

previous comprehensive attempt to define *terroirs* has been published. Sayed (1992) presented vineyard site suitability maps that were based on a compilation of the climate zones of Wiebe and Anderson (1977) and the soil maps of Kingston and Presant (1989). Unfortunately, this study appears to have ignored both the geological reality of several of Kingston and Presant's soil types (see below) and the excellence of wines produced from several award-winning estate wineries whose vineyards were assigned poor site-suitability ratings.

Currently, the Niagara Peninsula DVA is divided into climate zones controlled by the physiography. These are discussed below and then related to physical geology and soil factors to define *terroirs*.

Niagara Peninsula Climate Zones and Physiography

Niagara's climate on and below the Niagara Escarpment is dominated by the moderating effect of its position between the large water masses of Lake Ontario and Lake Erie that, in winter, contribute to warmer-than-normal temperatures, resulting in a mean annual daily temperature of ~9°C, an average coldest monthly temperature (January) of ~ -4.7°C and a warmest (July) of 21.4°C, and the highest number of days with rainfall in spring and fall (Shaw, 1994, 1996). The relation of the average monthly temperatures at St. Catharines to those in several French wine districts (Ziraldo, 1995) is presented in Figure 8.

In addition, a study of the different effects of air flow over the eastern Niagara Escarpment (narrow terraces) and western Escarpment (wide terraces), coupled with an airborne thermal imagery study of infrared radiation along a single north-south traverse of the northern Niagara Peninsula through Vineland at an altitude of 5000 m in 1976 (Stewart *et al.,* 1977), allowed Wiebe and Anderson (1977) to propose the seven separate climate zones in the Niagara Peninsula DVA shown in Figure 8 (top). Unfortunately, this study is open to question as it was only flown in the spring months of 1974, 1975 and 1976 at different altitudes below 5000 m, and was not flown over other traverses. Notwithstanding these problems, each of Wiebe and Anderson's (1977) zones constitutes a separate possible climate *terroir*. In the zone of "level area above the Escarpment," and including the Fonthill Kame, the virtual absence of lake effects results in fewer numbers of frost-free days in spring and colder winter temperatures below -20°C, causing severe damage to the vines, and thus restricting plantings to *Vitus labrusca* varieties. North of the Escarpment, the physiography of the landforms and proximity of Lake Ontario control the air-flow pattern, such that distance north of the Escarpment is the determining climate factor in vineyard site selection in terms of the likelihood of temperatures below -20°C that cause severe damage to the vines, and hard frosts in April that cause severe bud damage (Sayed, 1992). 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. 8). Moderate cold-injury danger is

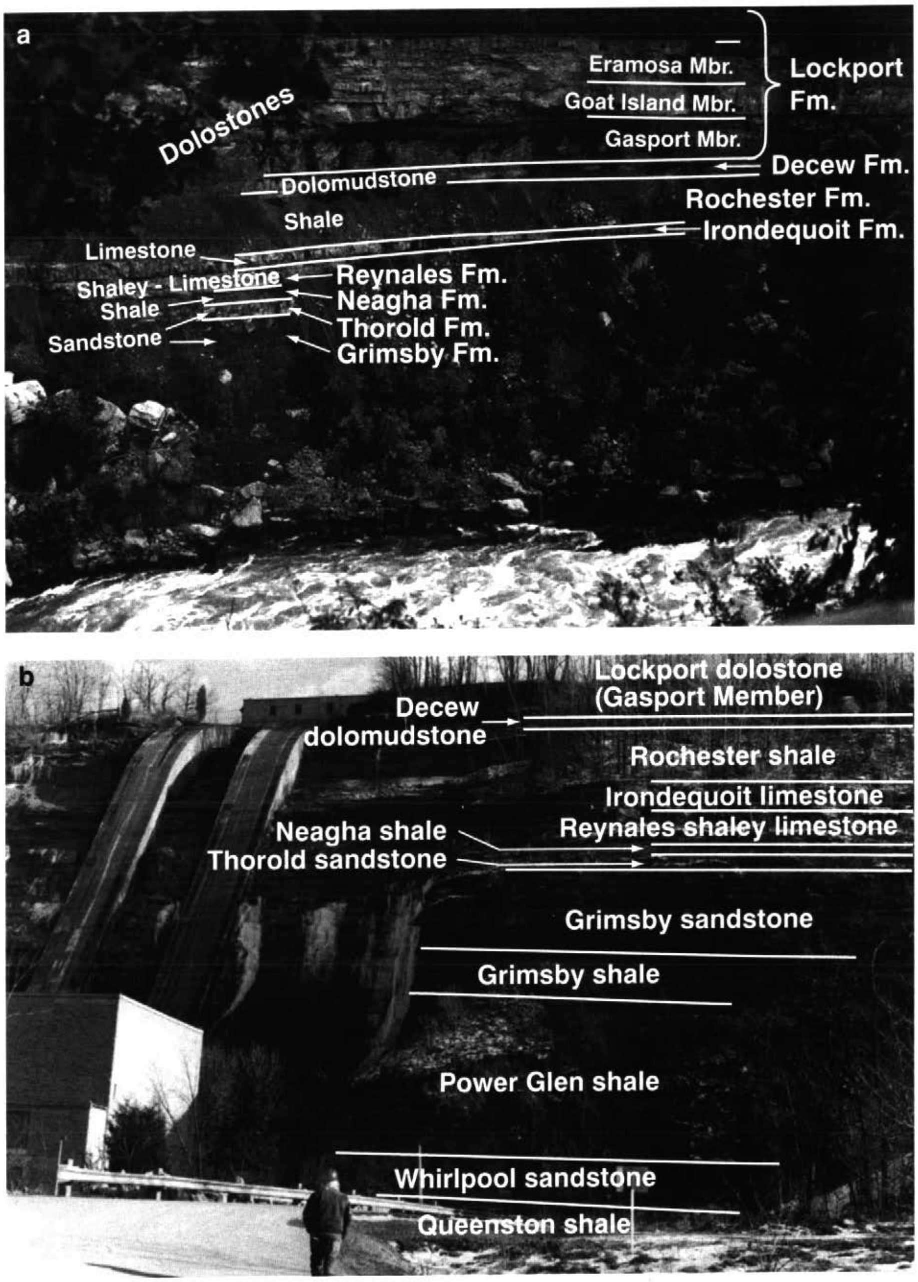

Figure 7 The sequence of Silurian strata exposed in (**a**) the Niagara River Gorge above the Whirlpool, and (**b**) the 12-mile Creek at the Power Glen hydro-electric power plant, St. Catharines.

experienced in the "Lakeshore effect zone" (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" (Fig. 8). Interestingly, the flat "Lake plain between escarpment and lake" zone, which widens considerably in the eastern Niagara Peninsula, is at greater frost risk than the other zones below the Escarpment because it is furthest from both the Escarpment and Lake Ontario. However, four wineries and numerous vineyards are located in the northern half of this zone, east of the Welland Canal (reason enough for a rigorous climate study).

Physical Geology and Soil *Terroir* Factors

In terms of physiography, drainage, bedrock, glacial drift and soils, two distinctly different *Vitus vinifera terroirs* are present in the Niagara Peninsula (Fig. 9): 1) the Lake Iroquois Plain (the area between Lake Ontario and the Lake Iroquois shoreline bluff), and 2) the Escarpment (the terraces of the Lake Iroquois Bench and locally slopes above the Niagara Escarpment, north of the Vinemount Moraine). Topographically, the Lake Iroquois Plain has mainly gentle slopes, grading to both north and south, whereas the Lake Iroquois Bench terraces of the Escarpment grade consistently north, often with moderate to steep slopes (Figs. 6, 9). Thus, topography and climate zones indicate at least two major divisions of the Niagara Peninsula DVA.

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, which, in the vineyards, are usually thicker than 3 m (personal observations). From 1:20,000 scale mapping, Kingston and Presant (1989) demonstrated that the soils and their equivalent Pleistocene-Holocene subsoils include a large number of types that exhibit rapid lateral changes. Because they took samples to a depth of only 1 m, the soil profile penetrated by the roots of older grapes may be much more complicated, as older grape roots commonly penetrate the glacial soils by 1.5-3 m in the Niagara Peninsula (Sayed, 1992). Also, although their study has helped considerably to refine the 1:50,000 map of the Quaternary geology (Feenstra, 1984), they have imported many soil names from outside the Niagara Peninsula and in some cases have used the same soil name for soils with similar appearance but totally different Quaternary settings (*e.g.,* although the type areas of Beverly and Toledo soils are the glaciolacustrine silty clays of the Haldimand Clay Plain above of the Niagara Escarpment, they are also mapped as glaciolacustrine silty clays on the Lake Iroquois Bench; notwithstanding the *circa* 60-m vertical difference in elevation of the lake beds). However, these differences aside, the soils do exhibit a general south-to-north zonation (Fig. 9). On the Lake Iroquois Bench, Oneida soils are developed on Halton clay till, and Brantford, Beverley, Toledo (also, Cashel, Peel) soils are developed on glaciolacustrine clays and silty clays overlying Halton till. On the Lake Iroquois Plain, Chiguacousy, Peel and Jeddo soils overlie the ridges of Halton till clay, whereas fertile Grimsby, Tavistock, Vineland and Vittoria soils overlie the stratified sands silts and clays of the Lake Iroquois lakebed.

Because *Vitus vinifera* grapes hate "wet feet" good drainage is essential, so the steeper Escarpment slopes are favoured both for excellent slope drainage, as well as good groundwater drainage through the Oneida silty clay soils on the Beamsville Bench and Vineland Double

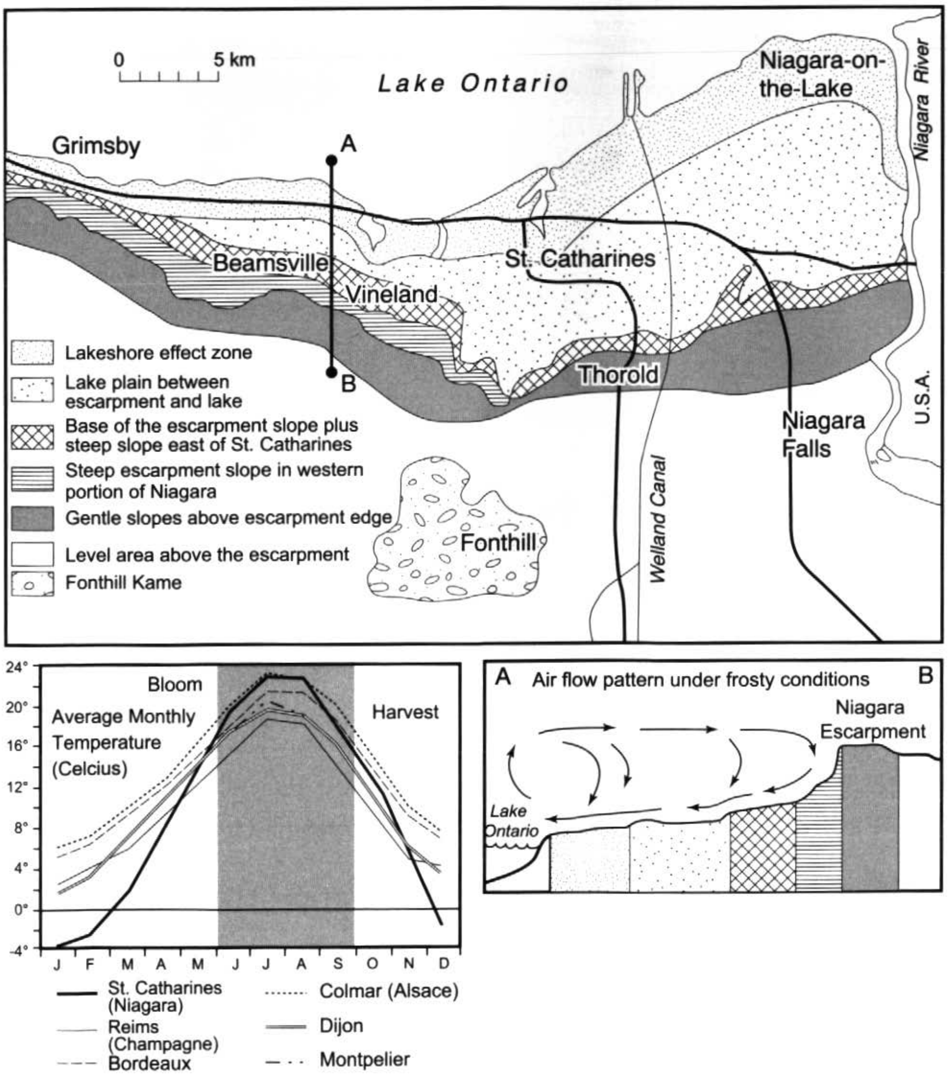

Figure 8 Plan and section of grape climatic zones in Niagara (modified from Wiebe and Anderson, 1977), and comparison of Niagara (St. Catharines) with the average monthly temperatures of French wine regions (from Ziraldo, 1995).

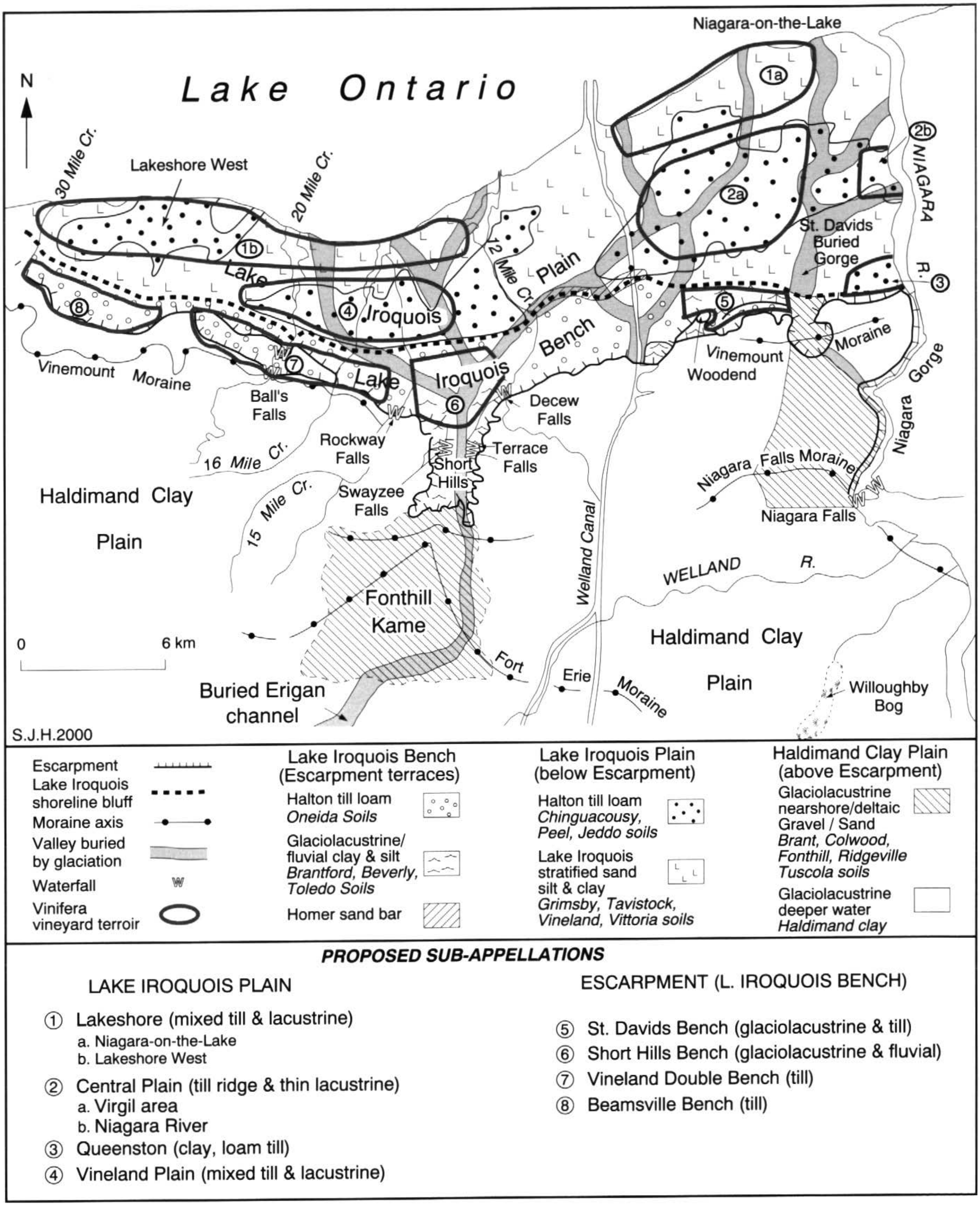

Figure 9 Relation of surface geology, generalized soil types, and physiography to *Vitus vinifera* vineyard *terroirs* and proposed sub-*appellations* of the northern Niagara Peninsula (based on Feenstra, 1984; Kingston and Presant, 1989; Haynes, 1998.)

Bench, and mixed till and lacustrine silty clay soils on the St. David's Bench (Fig. 9). However, this is partly offset by the fact that today, all the vineyards employ extensive regrading of the natural topography and sub-drainage installations. Thus, successful vineyards can be located in heavy clay soils on the relatively flat Lake Iroquois Plain.

POTENTIAL *APPELLATIONS* AND SUB-*APPELLATIONS* IN REGION NIAGARA

The recognition of wine *terroirs* can be made at progressively smaller levels depending on the information available (Table 1). The largest level is a wine region (*e.g.,* Burgundy), which is the scale of southern Ontario. The next smaller is the macro-level of a French regional *appellation* (*e.g.,* the Côte de Beaune), which is a readily identifiable area of maximum contiguous viticulture. I consider that this is equivalent to the entire Niagara Peninsula viticulture area of commercial production of both *Vitus vinifera* (on and north of the Escarpment) and *Vitus labrusca* (essentially the entire area shown in Fig. 9) grapes.

At the meso-level of an *appellation,* the Côte de Beaune is divided into four separate areas on the basis of differences in physiography, geology and soil. Although these four divisions (Table 1) are today ranked separately for Chardonnay and Pinot Noir grapes in terms of quality (*Grand Cru* is highest), this is not directly applicable to the Niagara Peninsula as the Burgundian appellations have had many centuries to define the best wine grapes and the best wine-growing areas. However, these would be the *terroir* equivalent of dividing the Niagara Peninsula into four areas (Fig. 9) comprising: the roughly circular area of the Fonthill Kame; and the three longitudinal segments of the Lake Iroquois Plain (between Lake Ontario and the Lake Iroquois shoreline), the Niagara Escarpment (from the Lake Iroquois shoreline to the Vinemount Moraine), and the Haldimand Clay Plain (south of the Vinemount Moraine). Others may consider that these divisions are sub-*appellations* of a Niagara Peninsula *appellation,* there being no rules on size, nor on exact definitions.

The next smaller level (Table 1) is the mini-level of a sub-*appellation* (communal *appellation* in Burgundy) such as Aloxe-Corton or Savigny-lès-Beaune, which are village areas roughly 3-5 km along the strike of the Côte de Beaune. Previously these have not been defined in Niagara, but it is proposed that the present *Vitus vinifera* viticultural areas (Lake Iroquois Plain and Niagara Escarpment *appellations*) can be divided into a minimum of eight sub-*appellations* (see below).

The absolute smallest level of a *terroir* is the micro-level of a vineyard for a specific varietal wine. In the Côte de Beaune, this varies from tiny 1-3 hectare vineyards in the *Grand Cru appellations* to large multi-hectare vineyards in the Villages and Hautes Côtes *appellations.* In the Niagara Peninsula DVA, it is still unknown which are the best varietals, let alone which are the best vineyards: it will be many years before we can even begin to consider Niagara Peninsula *Crus* designations.

On combining the differences in the climate, landform physiography, and soil (taking into account relative stratigraphic position of the Quaternary precursor) the Lake Iroquois Plain can be provisionally subdivided into four, and

Table 1 Terroir nomenclature: comparison of Niagara Peninsula with Côte de Beaune.

Level	Name	Canada	France
Regional	Wine Region	Southern Ontario	Burgundy
Macro Level	Regional *Appellation* (DVA in Canada)	Niagara Peninsula	Côte de Beaune (south part of Côte d'Or)
Meso Level	*Appellation*	Proposed in this paper Four *appellations* 1. Lake Iroquois Plain 2. Niagara Escarpment 3. Haldimand Pland 4. Fonthill Kame	Designated by INAO as *Appellations Contrôlée* 1. Côte de Beaune Grand Cru 2. Côte de Beaune Premier Cru 3. Côte de Beaune-Villages 4. Hautes Côte de Beaune
Mini Level	Sub-*appellation* (Communal *Appellation*)	Proposed in this paper a minimum of eight for Lake Iroquois Plain and Niagara Escarpment *Appellations*	Communes in *appellations* 1 to 4 1. *e.g.,* Corton Grand Cru 2. *e.g.,* Aloxe-Corton 3. *e.g.,* Savigny-lès-Beaune 4. Not defined individually
Micro Level	Specific vineyard site (*Climat* in France)	Not yet defined	Grand Cru Corton divided into 20 *climats*: *e.g.,* Les Renardes Les Bressandes

the Escarpment into four, separate *terroirs* or sub-*appellations* (Fig. 9). In general, these correspond with those recently proposed by winemaker J-L. (Jean-Laurent) Groux of Hillebrand Estate Winery (oral presentation, September 1999, Niagara Grape and Wine Festival seminar on "*Terroir,*" at Brock University). Groux 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 data base, which has been more than 10 years in the making, has allowed him to distinguish nine different *Vitus vinifera terroirs* (sub-*appellations*). However, as there are many vineyard areas that are not represented by estate wineries (and which I have not visited), and/or which have not supplied J-L. Groux with grapes, other terroirs (and new sub-*appellations*) are likely to emerge on further study.

Discussion of my eight proposed *vinifera terroirs* (sub-*appellations*) and their relation to the nine proposed sub-*appellations* of J-L. Groux follows.

Lakeshore Sub-*appellation*

This *terroir* corresponds to the "Lakeshore effect" climate zone (Fig. 8). Slopes are very gentle. It is split by the urban area of St. Catharines into Lakeshore West and Niagara-on-the-Lake (1a,b, Fig. 9). In both areas, a wide variety of lacustrine sandy, silty and clay loam soils derived from glaciolacustrine nearshore and deltaic sand and silt are present in the vicinity of the lakeshore of Lake Ontario (Tavistock, Vineland, Peel and Vittoria soils), as well as low mounds or ridges of Halton till clay soils (Chinguacousy, Peel, and Jeddo). Also, newer vineyards are planted on good, sandy loam soils in competition with tree fruits (Sayed, 1992).

J-L. Groux considers my Lakeshore subdivisions (1a,b, Fig. 9) to be two separate sub-*appellations*. Also, he extends his Lakeshore sub-*appellation* further east than my Lakeshore West (1b, Fig. 9). His Niagara-on-the-Lake sub-*appellation* expands much further south than mine (1a, Fig. 9) to include, of my Central Plain sub-*appellation* (see below), all of my Niagara River *terroir* (2b, Fig. 9) and the eastern part of my Virgil area *terroir* (2a, Fig. 9). He considers his Lakeshore sub-*appellation* to be one of the best in Niagara for Chardonnay varietal wines, as they exhibit a floral profile and a long aftertaste, and are especially suited for "Champagne-style" sparkling wine. Merlot is good here, while Gamay is good in his Niagara-on-the-Lake sub-*appellation*. Niagara-on-the-Lake is the site of Konzelman Estates, Niagara's most northerly winery and vineyards (located next to Lake Ontario), a producer of excellent German-style wines.

Although there are no clear geological or climatic reasons for separating this sub-*appellation* into separate Niagara-on-the-Lake and Lakeshore West sub-*appellations*, the different physiographic separation of these two areas from the Niagara Escarpment (Fig. 9) may, in future, govern their distinction as separate *terroirs*.

Central Plain Sub-*appellation*

This *terroir* (2, Fig. 9) corresponds to the part east of the Welland Canal of the "Lake plain between escarpment and lake" climate zone (Fig. 8). Gentle slopes grade north and south from an east-west striking low ridge-like mound of Halton Till. I have divided it into the Virgil area and Niagara River *terroirs* (2a,b, Fig. 9) along the line of the buried river channel that links south to the St. Davids Buried Gorge that marks the pre-Late Wisconsinan ancestral Niagara River. Not only is this a natural "geologic break" but also, the vineyards close to the Niagara River (2b, Fig. 9) are subject to the moderating effects of the large body of moving water such that the climate is similar to that of the Lakeshore effect zone (Fig. 8). Thus the till soils and very gentle slopes are major factors in making this *terroir* famous for the fine wines of Inniskillin, Marynissen Estates and Reif Estates.

J-L. Groux includes the eastern part of my Virgil area, and all of my Niagara River *terroirs* in his Niagara-on-the-Lake sub-*appellation* (see above). The western part of my Virgil area (2a, Fig. 9) is included in his Grantham sub-*appellation*, which he recognizes as an area of very heavy clay soils only recently used for vineyards after installation of extensive sub-drainage. J-L. Groux claims that these heavy clay soils create wines with more depth and are good for red Pinot Noir and Merlot, and white Chardonnay and Sauvignon Blanc.

Queenston Sub-*appellation*

This *terroir* (3, Fig. 9) was first distinguished by J-L. Groux. It is located in the far south-eastern part of the "Lake plain climate zone," and is the farthest *terroir* from Lake Ontario and its moderating influence, which results in the warmest summers but cold winter vine damage. It has heavy clay soil (Halton Till exposed in the lakebed of Lake Iroquois) and slopes are gentle to the north. Groux considers that the Chardonnay wines from here are superb.

Vineland Plain Sub-*appellation*

This is the western part (4, Fig. 9) of the "Lake Plain" climate zone (Fig. 8), and slopes are gentle to the north. It is underlain by Halton till and a variety of Lake Iroquois lake and deltaic sediments. Although recognized also by J-L. Groux, it is not well known as a sub-*appellation* and does not appear to produce wines of distinction.

St. Davids Bench Sub-*appellation*

This (5, Fig. 9) is the widest part of the "steep slope east of St. Catharines" climate zone (Fig. 8). Slopes are all northward and range from steep in the south to moderate in the north. Soils are clay loams derived from pre-Lake Iroquois glaciolacustrine silty clays overlying Halton till that merge to the east with nearshore and deltaic sands (Fig. 10). The Irondequoit Terrace is present but is only 100-200 m wide. The main part of the St. Davids Bench viticultural area extends from the top of the Thorold sandstone, at the base of the low scarp of Irondequoit limestone, north across Highway 81 toward the Lake Iroquois shore bluff (Fig. 10). This is the preserve of Paul Bosc and his family, who developed the St. Davids Bench viticultural area from scratch, and named it. This is the premier example in Ontario of a French-trained viticulturist and winemaker deliberately choosing a virgin *terroir*, testing the climate, soils and drainage, buying the property, then developing (with sub-drains and surface-regrading) flagship vineyards (Château des Charmes) that produce award-winning wines. Paul Bosc tells me he was struck by the similarity of the topography and limestone geology to Burgundy, and how the groundwater underflow from the Escarpment irrigates his vines in hot summer months. However, it wasn't until I visited Burgundy in 1999 that I realized how much the shape and orientation of the hill of Woodend at the end of the St Davids Bench (Fig. 10), separating this *terroir* from the other Escarpment bench *terroirs*, resembles the hill of Corton at the end of the Côte de Beaune, separating the southern from the northern part of the Côte d'Or (Haynes, 1999: Figs. 1, 2 and cover photograph).

A wide variety of good wines are produced here. Paul Bosc has pioneered commercial development of different varieties, including two little-known but classical white grape varieties from northern France: Auxerrois, from Alsace; and Aligoté from Burgundy. The latter is often referred to as "that other white wine" because, except for the village of Bouzeron where it is a fine wine with its own *appellation* (Bourgogne Aligoté-Bouzeron), it is relegated to the highest and lowest slopes of the Côte d'Or (although it preceeded Chardonnay on the Hill of Corton in times past). J-L. Groux considers the St. Davids Bench is very good for Chardonnay, Cabernet Franc and Cabernet Sauvignon.

Paul-André Bosc (son of Paul Bosc) has his own ideas on *terroir*, which he presented at the 1999 seminar on "*Terroir*" at Brock University. This included the first scientific evidence for the existence in the Niagara Peninsula of *terroirs* at the micro-level of a vineyard. This evidence consisted of differences in both the flavour profiles (from the tastings we conducted) and analytical data (Table 2) of two Chardonnay wines produced from similar grapes grown in vineyards on the north side (Toledo clay loam) and south side (Beverly silty clay loam) of Highway 81 (*see* Fig. 10). Except for different spacings of the sub-drain (5-m separation for the Beverly soils, and 2.5-m for the Toledo soils), which is a reflection of the differences in soil texture, porosity and permeability, all other viticultural and wine-making factors were the same for both vineyards. As the climate cannot be significantly different across a road, only differences in the soil parentage and/or ground water chemistry

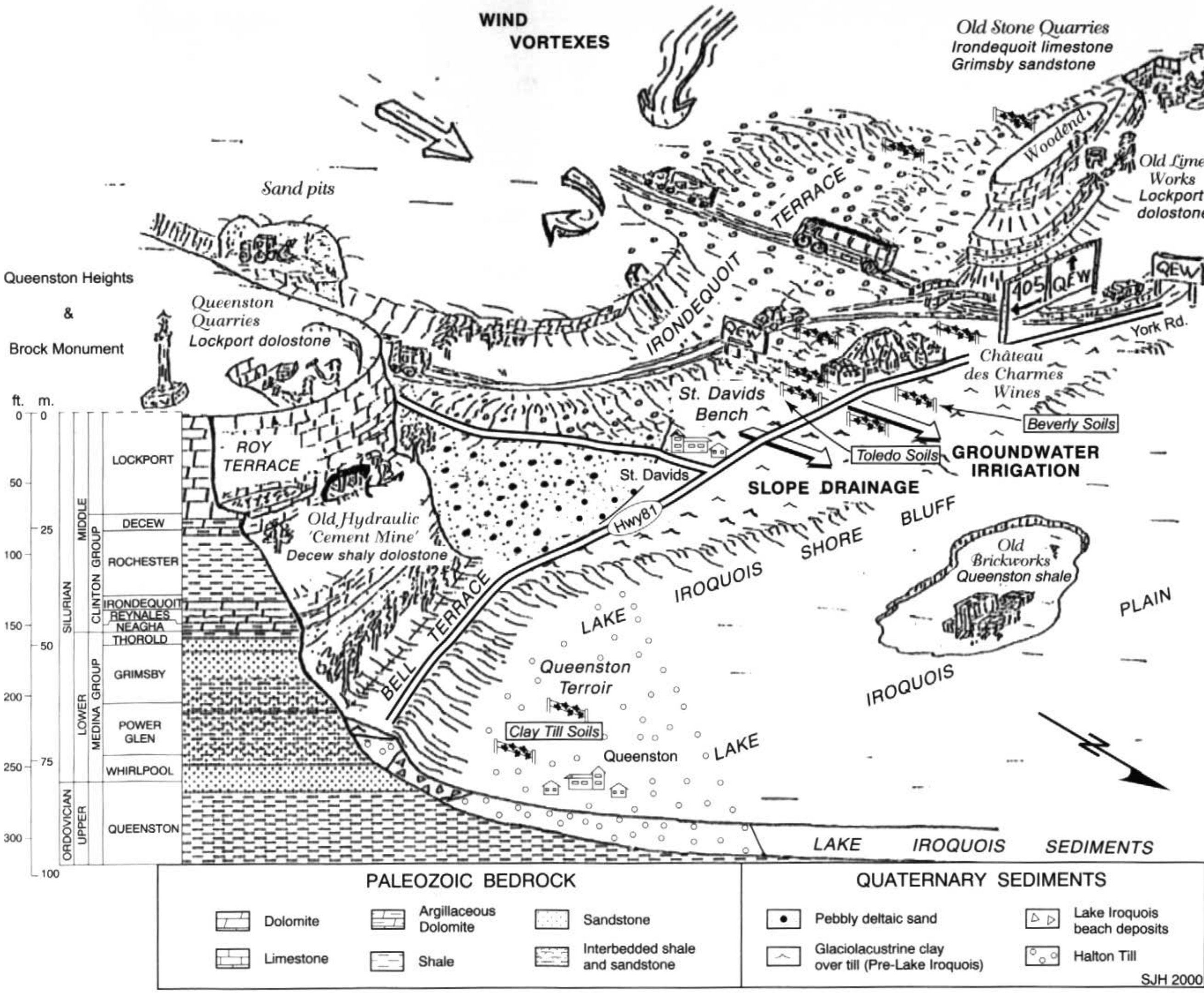

Figure 10 Simplified geological sketch of the Niagara Escarpment between Queenston Heights and Woodend, illustrating the relation of geology to the St. Davids Bench and Queenston sub-*appellations* (modified from Haynes, 1994b).

and flow rate can account for the differences presented in Table 2 between both the grape juice and the wine from the two vineyards.

Paul-André Bosc considers that the numerous different clones of specific grape varieties need to be tested for all the different soils. Interestingly, a mutant Gamay (the grape for Beaujolais) grew on the original Bosc home farm from cuttings Paul Bosc Sr. brought from Europe. Cuttings from this mutant now occupy several acres, and the first commercial quantities were produced in 1999. Paul-André Bosc informs me (oral communication, and imbibing, March 2000) that the clone is now recognized by the official body in France so this will be, in a sense, the first Canadian vinifera. Certainly, "tank-tasting" (opening the tap

Table 2 Comparison of Chardonnay juice and wine from adjacent Toledo and Beverly soil vineyards at Château des charmes.

	St. David's Bench Vineyard	Paul Bosc Vineyard
Vineyard Location	North of Highway 81	South of Highway 81
Soil Name	Toledo	Beverly
Juice		
Total acidity	8.55	9.30
PH	3.37	3.37
Brix (sugar)	23.5	23.2
Wine		
PH	3.32	3.47
Total acidity	7.13	7.58
Alcohol	13.50%	13.50%

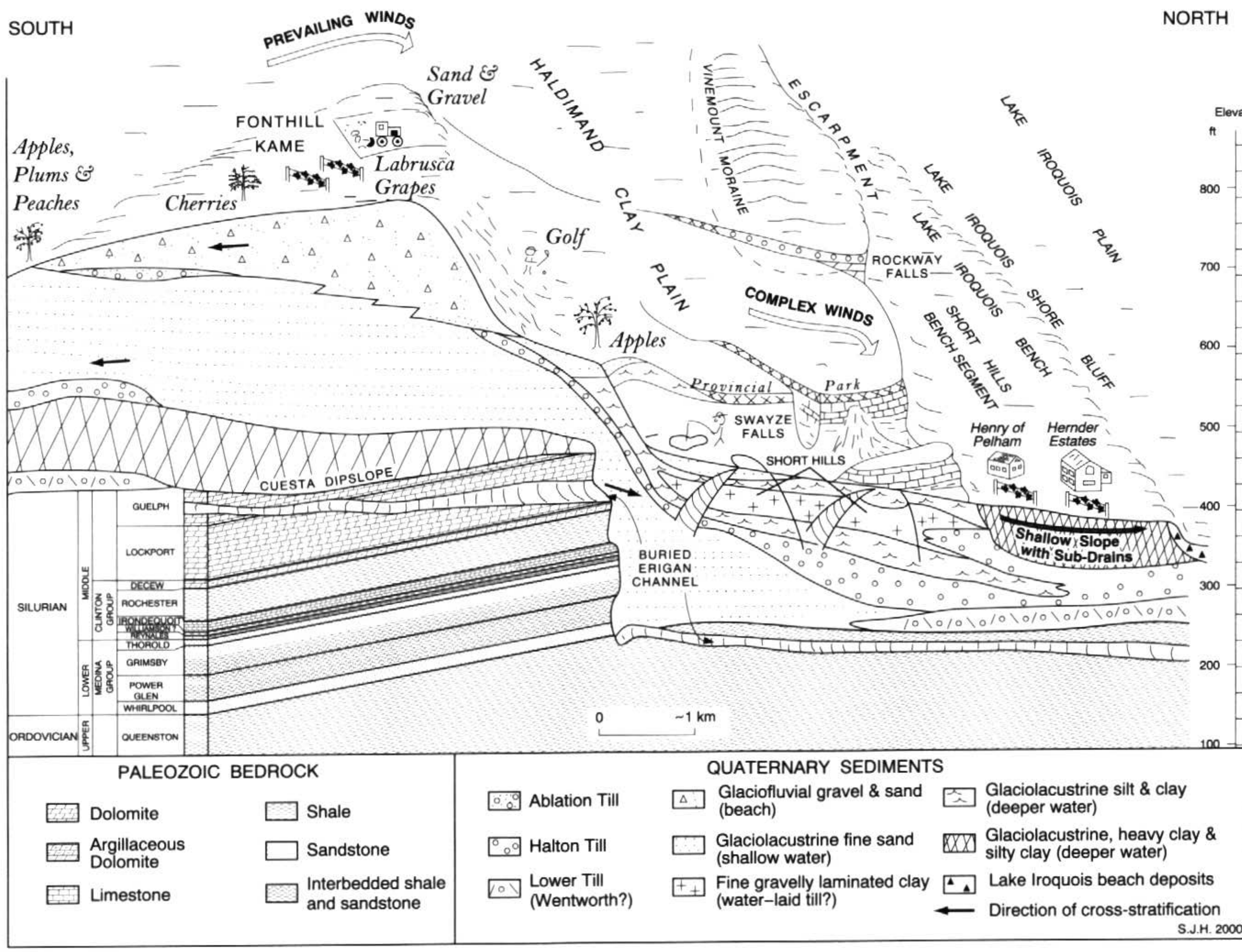

Figure 11 Simplified north-south cross-section of the geology, physiography and land uses in the Short Hills-Fonthill Kame segment of the Escarpment and their relation to wineries on the Short Hills Bench sub-*appellation* (modified after Haynes, 1994b and from data of Feenstra, 1981; Kingston and Presant, 1989.)

of the maturation tank and drawing off a quantity to be tasted) of the 1999 vintage indicates a full-bodied wine of exceptional character.

J-L. Groux recognizes a separate sub-*appellation*, Iroquois Lakeshore, along the Lake Iroquois shore bluff that is good for Cabernet Franc and Cabernet Sauvignon. I have included this as the northern part of the St. Davids Bench as the geology, and apparently the wines, are not significantly different.

Short Hills Bench Sub-*appellation*

This is situated at the mouth of the Short Hills Reentrant, on the west side of 12-Mile Creek (6, Fig. 9). This is the most unusual of the Escarpment *terroirs* as the landforms, climate and Quaternary sediments and soils are all products of the development of the Fonthill kame-delta above one of the world's largest waterfalls, that dwarfed Niagara Falls, at the head of a *circa* 2-km wide, 90-m deep, pre-Late Wisconsinan gorge now completely buried in its southern part by glacigenic sediments (Fig. 11). Within the actual Short Hills reentrant itself, the Late Wisconsinan glaciogenic sediments have been carved down about 50-60 m during the Holocene by 12-Mile Creek and its tributaries into a series of flat-topped, conical hills (hence the name, Short Hills). This flat-top surface can be traced from the top of the Lake Iroquois shore bluff south of the Escarpment back about half way to Swayze Falls (Figs. 9, 11) as a very gentle north-facing slope. North of the Short Hills reentrant, this slope is underlain by more than 43 m of very heavy, massive, blue-tinted brown, locally colour-banded lacustrine clay (personal on-site observations of Waterloo University core, summer 1999 drilling project) that represents a pre-Lake Iroquois lakebed. To the south, the slope of this north-facing surface increases, apparently in response to a change to fluvial-deltaic deposition of coarser-grained facies (fine, gravelly laminated clay, then fine sands) as it approaches the Fonthill kame-delta and its upper coarser sand and gravel units (Fig. 11). Here, the deep valleys trap the cold air from Fonthill, creating a southward bulge in the cold "Lake Plain" climate zone (Fig. 8). In front, and to the west side of the Escarpment edge of the Short Hills reentrant, a northward bulge of the warmer "Base of the escarpment slope" and "Steep escarpment slope" climate zones (Fig. 8) is contained between the Short Hills reentrant and 15-Mile Creek (Figs. 8, 9). Here, the gently north-sloping ancient lake-bed surface, now regraded and sub-drained, is the site of Henry of Pelham's Estate vineyards (Fig. 12).

This sub-*appellation* was not recognized by J-L. Groux, because he has not made wine from here, but it is adjacent to his West St. Catharines sub-*appellation*, which, although well-known as a producer of *Vitus labrusca* grapes for juice and jam, has few *Vitus vinifera* vineyards due to the effect of cold air channelling down 12-Mile Creek. The Reserve Chardonnay from Henry of Pelham's very thick, heavy glaciolacustrine clay vineyard (which I confirmed by digging a 2.5-m pit with their backhoe) is excellent and a great medal winner, the clay making the wine of depth and characteristic strong flavour. Also, this is one of only a few places in eastern North America to produce a good Baco Noir.

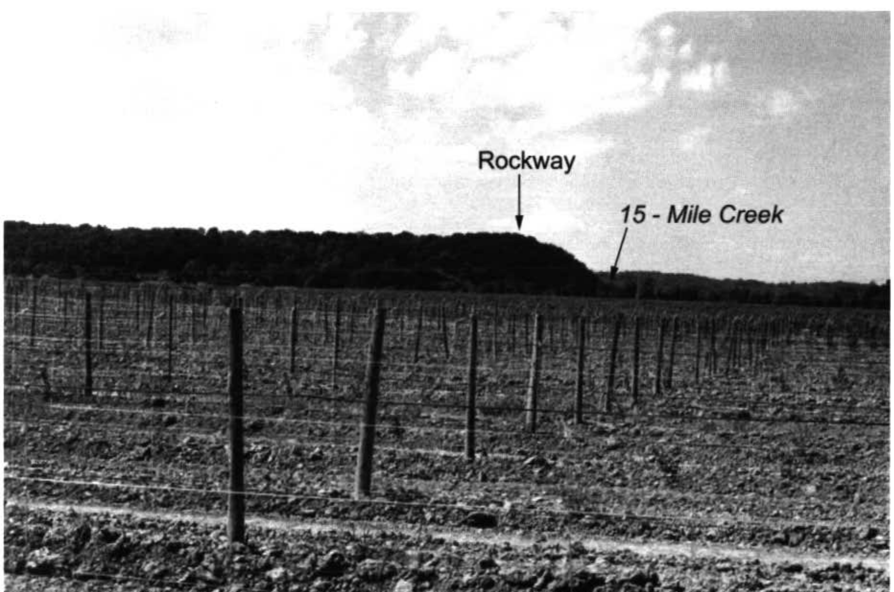

Figure 12 View southwest across Henry of Pelham Estate vineyards on the Short Hills Bench to the steep high scarp of the Niagara Escarpment at Rockway.

Vineland Double Bench Sub-*appellation*

This *terroir* (7, Fig. 9) is located about the town of Vineland and village of Jordan (Fig. 5) between Rockway Falls and an unnamed headland of the Escarpment west of Vineland. It is characterized by picturesque vineyards and waterfalls sited on the moderate northward slopes of both the *circa* 1-2 km wide upper (Irondequoit) and lower (Bell) terraces (Figs. 13, 14). Because the steepest slope of the Escarpment is here the scarp face of the Irondequoit Terrace, cartographers refer to this as the Niagara Escarpment, rather than the subdued scarp of Lockport dolostone to the south. This has influenced the climate zones (*i.e.*, the topographic base for the map of Wiebe and Anderson, 1977), such that the upper Irondequoit Terrace is in the moderate cold-injury danger "Gentle slopes above escarpment edge" climate zone, while the lower Bell Terrace is in the slight cold-injury danger "Steep escarpment slope in western portion of Niagara" zone (Figs. 5, 8, 9).

On both terraces, Oneida and Chinguacousy light and heavy till loam soils overlie Halton till (Fig. 13). Also, both terraces are well slope-drained and the loam soils experience summer irrigation by ground waters flowing north from the Escarpment. Wind vortexes, created by the interplay of the prevailing wind from Lake Erie with winds from Lake Ontario, break up spring frosts.

Riesling in all of its delightful styles is king in this *terroir*, not least because of the viticultural and wine-making skills of the Schmidt family, who pioneered the growing of wine grapes on the Irondequoit Terrace and brought their German wine experience to the creation of Vineland Estates winery (the new sparkling Riesling wines and icewines are a "must try"). J-L. Groux groups, as do most people, the Vineland Double Bench with the Beamsville Bench, as the soils and general setting on the Escarpment are the same (see below). He considers that this whole zone yields excellent Riesling and Gewurztraminer with the required high acidity (high acidity makes these German varietal wines "steely," which is much appreciated by wine connoisseurs), and Chardonnay with higher acid and more floral tones compared to the other *terroirs*. On the Bell Terrace, Ed and Lorraine Gurinskas of Lakeview Cellars Estate winery have pioneered Cabernet Sauvignon and a great Pinot Gris. Both terraces are sites of many new vineyards and wineries.

Beamsville Bench Sub-*appellation*

Although the Beamsville Bench (8, Fig. 9) is usually attributed to the whole of the "Steep escarpment slope in western portion of Niagara" climate zone, from Grimsby to the Short Hills reentrant (Fig. 8), I consider that it should be restricted to the bay-like reentrant of both the Escarpment and this climate zone, immediately south of the town of Beamsville (Figs. 5, 8, 9). Here, the Irondequoit terrace has merged with the face of the Escarpment, and the generally northerly Escarpment face presents a mixture of landforms, with a variety of micro-climates due to differing east through west exposures. In the east, a sheer northwest-facing cliff of exposed strata from the Grimsby to the Lockport (Fig. 6) has formed by presently-active erosion as fissure caves (the location of the Cave Springs) along regionally predominant northeast-striking joints, parallel to the cliff. On the moderate slopes of the Bell Terrace below, Cave Spring Cellars vineyards, under owner Len Pennachetti and winemaker Angelo Pavan, are renowned for their Chardonnay and for pioneering efforts to establish the Beamsville Bench as one of the top quality *terroirs*. In the central and western parts of the Bench, opposite Beamsville (Fig. 5), the Escarpment face is more subdued as it is covered by a concave-upward ramp of Halton till. This part is therefore higher than the main Bell Terrace to the north and has steep-to-moderate slopes that were incised during the Holocene by numerous streams, creating an intricate network of picturesque hills and valleys now favoured by many of the newer wineries.

CONCLUSIONS

Although *Vitus labrusca* grapes are grown on the Haldimand Clay Plain and the Fonthill Kame, south of the Niagara Escarpment, the area of the Niagara Peninsula that can support commercial *Vitus vinifera* viticulture is on and north of the Escarpment. This is governed by the fact that *V. labrusca* grapes are able to withstand temperatures down to about -29°C, whereas *V. vinifera* grapes suffer vine injury if winter temperatures fall consistently below -20°C, and spring bud damage in frost-prone areas. The area of *Vitus* cultivation is termed, by the Vintners Quality Alliance (VQA), the Niagara Peninsula Designated Viticultural Area (Niagara Peninsula DVA), which corresponds to the macro-level of a regional *appellation* in France.

At the meso-level of a French *appellation*, clear differences in climate, physiography, Paleozoic bedrock lithology, and Quaternary drift geology/pedology dictate that the Niagara Peninsula DVA can be divided into two *Vitus vinifera appellations* and two *Vitus labrusca appellations*. The two *V. vinifera appellations* comprise:

1. Lake Iroquois Plain: the area between the shore of Lake Ontario and the base of the Lake Iroquois shoreline;
2. Niagara Escarpment: from the top of the Lake Iroquois shoreline, southward over the Escarpment terraces of the Lake Iroquois Bench to the Vinemount Moraine.

The two *V. labrusca appellations* comprise the Haldimand Clay Plain and the

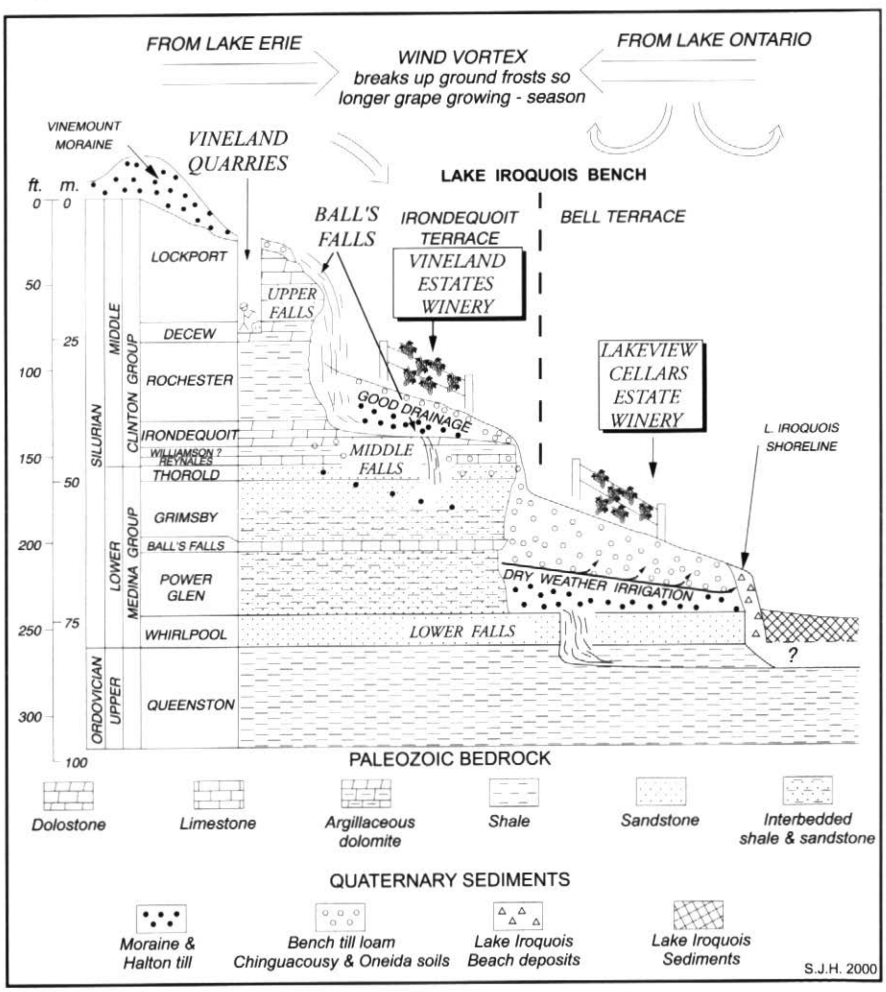

Figure 13 Simplified stratigraphic section of the Vineland Double Bench showing relation of geology to the vineyards on the Irondequoit and Bell Terraces and the waterfalls of 20-Mile Creek at Ball's Falls (modified from Haynes, 1994a).

Fonthill Kame, and are not considered in this article as they do not commercially produce wine. However, in future, it is likely that these will support the new varieties of *V. vinifera* that have been developed to be more cold-resistant, particularly should the warm winter climate-trend of the past decade continue. In spite of this, predictions of their success must be tinged with caution as temperatures below -20°C are common here, and even the Vineland research station, in the warm lakeshore climate zone about Lake Ontario, recorded -26°C on Christmas Eve, 1980.

At the mini-level, at least eight, and possibly 10, distinctive geological-pedological-physiographic *terroirs* define sub-*appellations* that are in general agreement with similar areas distinguished by J-L. Groux, winemaker at Hillebrand Estates, on the basis of grape variety suitability and differences in wine flavour profiles. These comprise:

1. Four (possibly six) sub-*appellations* of the Lake Iroquois Plain *Appellation*: a) Lakeshore (which may constitute two separate sub-*appellations* of Lakeshore West and Niagara-on-the-Lake); b) Central Plain (which may constitute two separate sub-*appellations* of Virgil and Niagara River); c) Queenston; d) Vineland Plain.
2. Four sub-*appellations* of the Niagara Escarpment *Appellation*: a) St. Davids Bench; b) Short Hills Bench; c) Vineland Double Bench; d) Beamsville Bench.

Distinction of micro- *terroirs* at the vineyard level is limited by lack of data, and is a fertile field for future research. The physical-chemical distinction of juice and wine (produced under identical viticultural and oenological conditions) from two neighbouring vineyards with different soils at Château des Charmes indicates to the owners, the Bosc family, the validity of the concept that geological *terroirs* play a major role in determining the flavour profiles of Niagaran wines.

Worldwide, many famous vineyards are on poorly consolidated silty-to-gravelly soils, so the till and clay soil vineyards of Niagara are unusual. However, it is the combination of these unusual soils and climate that give Niagara wines their distinctive character and, particularly the icewines, increasing medal-winning international recognition. Eventually, a time may come when it is possible to define the best places to plant the most suitable grape varieties to produce the very best wines. However, since there are many years of work ahead in accurately defining the mini-geology and mini-climate of Niagaran *terroirs* at the sub-*appellation* level, and even more work at the micro-level of a vineyard, it is worth heeding the following justification of such analysis, by Paul-André Bosc (oral presentation, September 1999, Seminar on "*Terroir*" Brock University),

> *Terroir*: it wouldn't be interesting unless people were interested in it; *terroir* is the future.

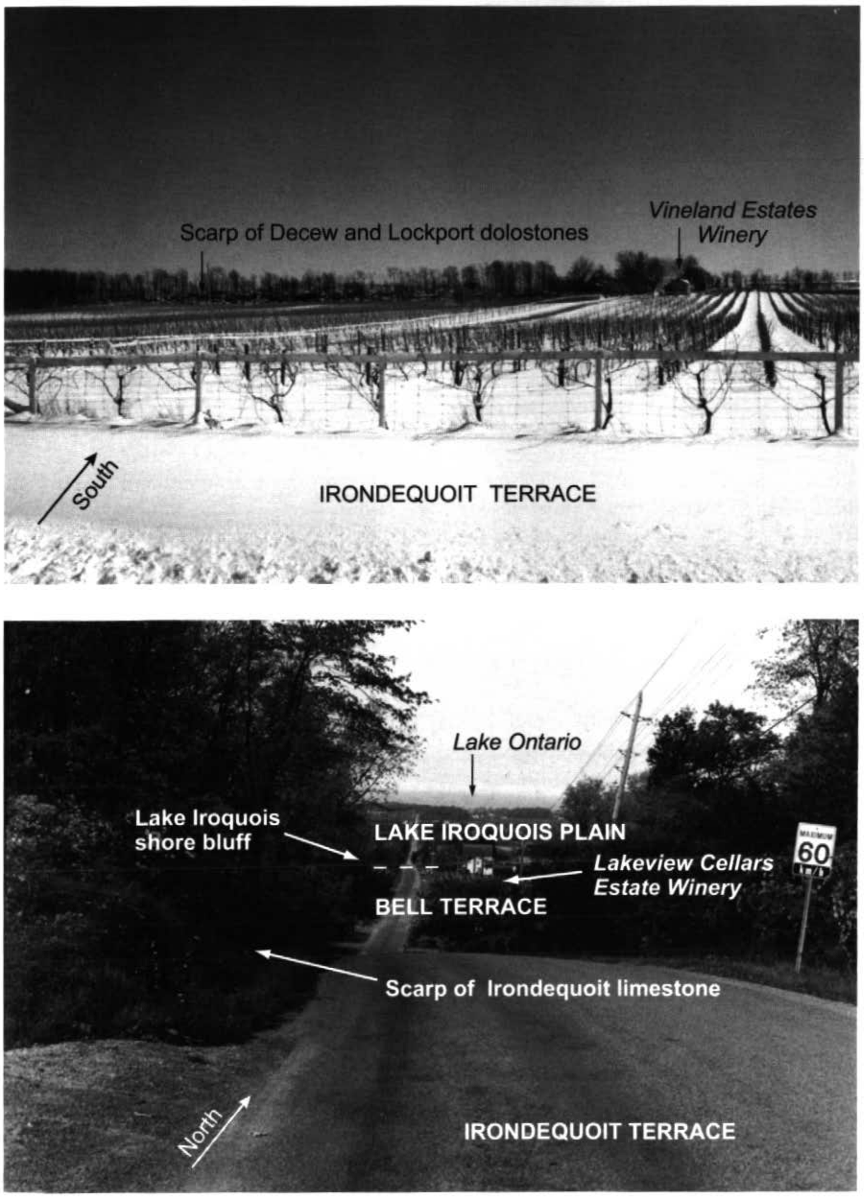

Figure 14 The Vineland Double Bench of the Lake Iroquois Bench. (**Top**) View north across Vineland Estates vineyards, on the Irondequoit terrace, to the low scarp of Decew and Lockport dolostones. (**Bottom**) view south from the Irondequoit terrace across Lakeview Cellars Estate vineyards, on the Bell Terrace, to the Lake Iroquois Plain.

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