TERROIR OF THE FINGER LAKES OF NEW YORK

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INTRODUCTION

Geology is more than the study of rocks as inanimate objects. Some of the oldest and most interesting applications of geology involve interactions between people and the noble grape, *Vitis vinifera*. Mounds of grape seeds in prehistoric caves testify that early people had more than a passing acquaintance with wine (McGovern, 2003). Grapes naturally ripen to high sugar levels and, left on the vine, they will begin to ferment from the action of native yeasts on the skins. Perhaps our early ancestors plucked such fermenting fruit and, with a smile, plucked a few more.

Regardless of how people came to appreciate the joys of the grape, there is ample evidence in the earliest written documents that they were making and enjoying wine. The records of the ancient Egyptians and Greeks also contain observations that certain regions seemed to produce better wine than others. This observation carries through to modern times where the question is brought to a sharp focus by the rather simple occurrence of two vineyards, side by side, that share most obvious aspects of climate, slope and viticulture, yet produce crops that are vastly different. As documented in James Wilson's classic book on the geology of French wines, property boundaries dating back centuries in many cases mirror underlying faults, facies changes, and other geological variations.

This is the essence of *terroir* (pronounced tehr-wahr), that geology can be used to understand and explain the mysteries of the grape. An explosion of recent studies has documented the terroir of important viticultural areas in North America (Haynes, 1999, 2000; Meinert and Busacca, 2000, 2002; Jones et al., 2004; Swinchatt and Howell, 2005).

Our Keck project focused on the terroir of the Finger Lakes of central New York. Within the Finger Lakes region there are microclimates, paleodeltas, and glacial features that allow some vineyards to stand out from their neighbors. We selected seven vineyards for detailed study: Dr. Konstantin Frank's Vinifera Wine Cellars, Fox Run Vineyards, Lamoreaux Landing, Shalestone Vineyard, Sheldrake Point Vineyards, Silver Thread Vineyard, and Standing Stone Vineyard (Fig. 1). Individual student research focused upon clay mineralogy, climate, sedimentology, soil acidity, vine vigor, and water chemistry related to these vineyards. Although the study areas were vineyards rather than mountain ranges or quadrangles, the geology of each vineyard was mapped and sampled using classical geological techniques.

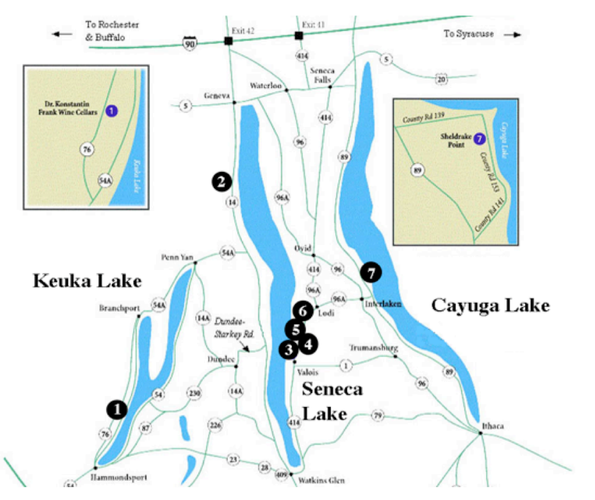

Figure 1. Location of studied vineyards in the Finger Lakes AVA. 1) Dr. Konstantin Frank, 2) Fox Run, 3) Standing Stone, 4) Shalestone, 5) Silver Thread, 6) Lamoreaux Landing, and 7) Sheldrake Point.

The Finger Lakes AVA

The Finger Lakes AVA encompasses roughly 940,000 hectares (2.3 million acres) and is named for the 11 Finger Lakes (Conesus, Hemlock, Canadice, Honeoye, Canandaigua, Keuka, Seneca, Cayuga, Owasco, Skaneateles, and Otisco Lakes, from west to east).

Wine making in the Finger Lakes dates back to 1829 when William Botswick planted vines in his rectory garden. The region contains the first winery in the United States, US Bonded Winery #1, now called Great Western. The Finger Lakes was granted American Viticulture Area (AVA) status in 1987. AVAs are appellations of origin for American wines as designated by the Alcohol and Tobacco Tax and Trade Bureau (TTB) formerly called the Bureau of Alcohol, Tobacco and Firearms (BATF).

New York State ranks third in vinifera wine production in the United States behind California (>90% of all US wine) and Washington State. If V. labrusca grapes and hybrids are included, for wine, juice, and eating, then New York ranks second in the nation, behind only California.

The Finger Lakes AVA is the leading producer of wine in New York State. Table 1 summarizes wine production from V. labrusca, V. vinifera, and hybrid grapes from the Finger Lakes region. In addition to vintage variations, the amount of wine made from V. labrusca grapes varies annually with prices and demand from the juice and table grape markets. In contrast, most V. vinifera and hybrid grapes are used solely for wine production. It is difficult to obtain accurate statistics about wine production in New York because historical practice and state law allow importation and mixing of bulk wine from other states, amelioration of wine with up to 25% water and/or sugar, and other practices which are not common in other wine-producing states (Baxevanis, 1992). Table 2 shows a detailed listing of acreage and tonnage for Finger Lakes V. vinifera and hybrid grapes.

Grape variety	2002 tons	2003 tons	2002 $/ton	2003 $/ton
V. labrusca				
Catawba	2,916	3,141	$237	$242
Concord	6,865	8,950	$266	$187
Delaware	592	464	$284	$284
Ives	118	178	$302	$349
Elvira	3,243	4,061	$259	$264
Niagara	5,895	5,879	$246	$207
Total/average	19,629	22,673	$266	$256
Hybrid				
Aurora	4,073	3,493	$245	$260
Baco Noir	870	1,174	$362	$388
Cayuga	767	524	$415	$394
DeChaunac	584	250	$321	$342
Rougeon	625	512	$315	$313
Seyval Blanc	425	393	$533	$452
Total/average	7,344	6,346	$365	$358
V. vinifera	2,291	2,695	$1,454	$1,264
Grand total	29,264	31,714		

Table 1. 2002-3 Wine grape production in the Finger Lakes AVA and prices for all New York. Note: All V. vinifera and hybrid grapes assumed to be used for wine production. V. labrusca use estimated from reported juice and wine data. Modified from www.nass.usda.gov/ny/08aug/win0804.htm.

GEOLOGY OF THE FINGER LAKES AREA

Middle to Upper Devonian rocks are widespread across New York State. The rocks exposed in the Finger Lakes region are part of the Late Devonian clastic wedge that was deposited west of the Acadian mountains in a shallow inland sea. Broadly interpreted, the lithofacies exposed in the Finger Lakes region represent shallower water marine conditions (Hamilton Group) with an abrupt change to deeper water marine environments (Genesee Group). The Hamilton Group consists of gray to black shale, mudstone, and siltstone with a variety of brachiopod, bivalve, trilobite, and echinoderm fossils. There are also several thin but widespread clay-rich limestone beds. The formation reflects deposition of fossiliferous to unfossiliferous black, fissile shale on the open shelf. A prominent erosional surface separates the Hamilton Group from the overlying Tully Limestone. The Tully Limestone is a biomicrite containing coral, brachiopod, crinoid, and trilobite fossils and is only found in central and western New York. The unit pinches out between Seneca and Keuka Lakes. The Tully Limestone reflects a period of reduced siliciclastic influx and increased deposition of authigenic carbonate and biogenic carbonate. There is a sharp contact between the Tully Limestone and the overlying Geneseo Shale, a black fissile shale that lacks benthonic or infauna that was deposited in relatively deep water far from the continental edge under anoxic conditions.

Variety	**Acres**	**Tons**
Chardonnay	418	1,476
Riesling	340	1,069
Baco Noir	262	1,316
Seyval Blanc	235	938
DeChaunac	143	748
Pinot Noir	137	348
Cabernet Franc	136	300
Vidal Blanc	103	348
Ventura	96	592
Rougeon	84	428
Ravat 51	73	202
Cabernet Sauvignon	61	127
Marechal Foch	57	225
Merlot	52	110
Gewürztraminer	46	150
Isabella	39	103
Moores Diamond	36	95
Chambourcin	27	49
Other	449	1,198
Total	9,124	41,403

Table 2. 2001 Production of V. vinifera and hybrid grape varieties in the Finger Lakes AVA. Data from www.nass.usda.gov/ny.

Acadian tectonism contributed to the deepening of the basin and relative sea level rise. The Penn Yan, Sherburne, and Ithaca Formations are composed of fine-grained sandstone and dark gray siltstone and shale. The bases of some sandstone beds are marked by brows and groove and, rarely, flute casts. Sandstone and siltstone beds contain ripples and climbing ripples. Sandstone beds grade into shales. The Genesee Group reflects deposition by dilute, relatively slow-moving turbidity flows (Woodrow and Isley, 1983).

A thick veneer of Pleistocene glacial deposits in the Finger Lakes region covers the Devonian bedrock. Deglaciation of the Laurentide ice sheet is recorded by moraines, till, and glacial outwash, and the excavation and infilling of the Finger Lakes. The Valley Heads Moraine and much of the infill of the Finger Lakes was deposited at ~14.4-14.9 ka 14 C yr BP (Mullins et al., 1996). The Valley Heads Moraine dams each Finger Lake at its southern margin, is restricted to the valleys, and reveals evidence for deposition by moving water.

The modern Finger Lakes formed as a result of the combination of glacial scoring and the action of high-pressure sub-glacial meltwater (Mullins and Hinchey, 1989). Further evidence for erosion by large volumes of subglacial meltwater includes the overdeepened, V-shaped bedrock valleys that the Finger Lakes occupy. In Seneca Lake, the depth to bedrock is up to 306 m below sea level. Up to ~270 m of sediment fills the valleys. Mullins et al. (1996) attributes most of this sediment infill to deglaciation. Initially, deposition occurred mostly from the north, consistent with a glacial outwash origin. Much of the sedimentation likely occurred in proglacial lakes that filled the valleys. At this stage, the proglacial lakes were local and confined to areas adjacent to the ice sheet and were impounded by the Valley Heads Moraine to the south. Progressive northward retreat of the Laurentide ice sheet allowed for lake expansion and lakes overflowed into adjacent, lower valleys (Fairchild, 1899). As new lake outlets opened to the east and/or west, lake levels dropped, which produced a series of distinct proglacial lakes (Fig. 2) and left behind hanging deltas and evidence for ancient shorelines (e.g., terraces). A reversal in the direction of inwash into the proglacial lakes occurred around ~ 13.9 ka 14 C yr BP, which is inferred to reflect a significant lake level drop to modern conditions (Mullins et al., 1996). The evolution of the proglacial lakes was rapid; they existed only between ~14.9 to ~13.9 ka 14C yrs BP. Post-glacial-Holocene lacustrine sediment infill in the Finger Lakes is minor, only ~5-12 m are recorded in modern lakebed cores (Mullins et al., 1996).

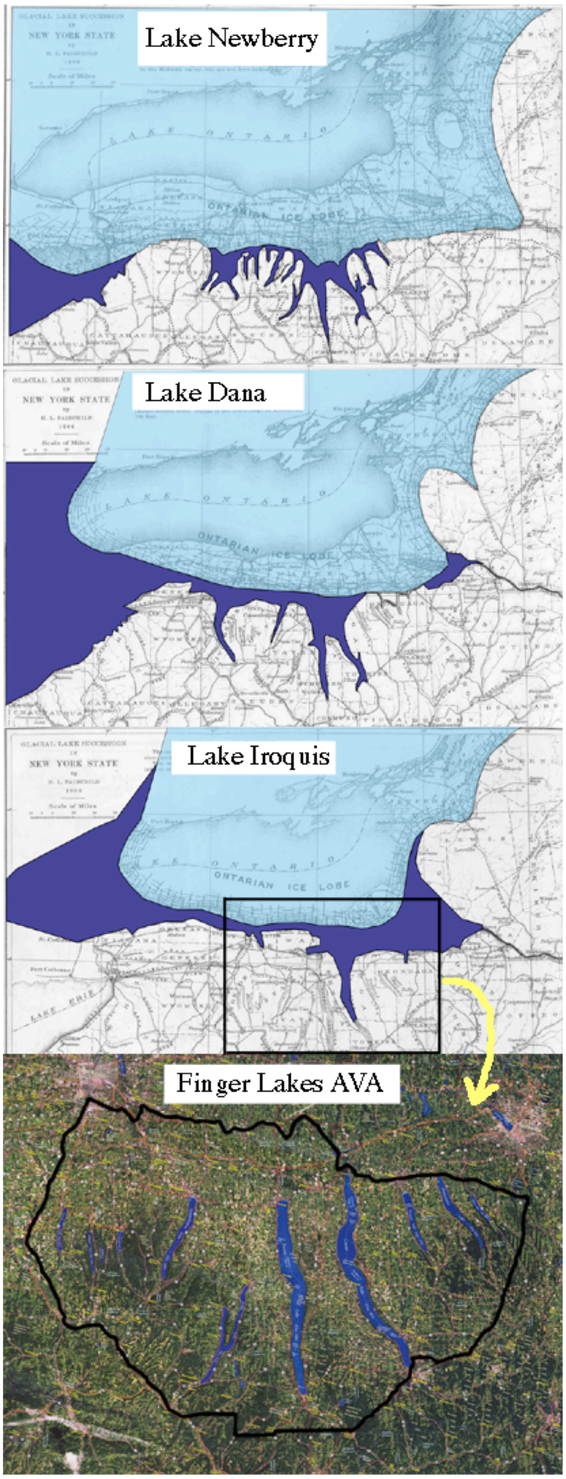

Figure 2. Formation of Finger Lakes and proglacial lake sediments by episodic glacial retreat (after Fairchild, 1899).

Paleodeltas

The glacial sediments deposited during and after glaciation have been reworked by post-glacial rivers to form a variety of fluvial deposits including modern and paleodeltas. The paleodeltas formed at higher lake levels and thus are now present as hanging deltas exposed on hillsides adjacent to the modern lakes. Paleodeltas have a different grain size distribution than adjacent glacial till and thus cause dramatic changes in vineyard soil characteristics with locally sharp boundaries. Paleodeltas have been identified at both Fox Run (cf. Martin, this volume) and Sheldrake Point (cf. Cavatorta, this volume) vineyards and are undoubtedly present in other vineyards as well. The proglacial clay distal fringes of these deltas can cause problems with vineyard drainage whereas the proximal fluvial parts of the deltas can provide ideal drainage conditions. Thus, location of paleodeltas can have a significant effect on vine vigor and performance as documented by Cavatorta (cf., this volume).

Soils of the Finger Lakes Area

Soils of the Finger Lakes belong to several different soil series. The major differences among these soil series are grain size distribution (texture) and protolith composition, especially the presence of clay and/or limestone in the subsurface or constituting a significant percentage of glacial clasts in till or reworked fluvial sediments. Grain size and texture mainly affect drainage, a critical parameter of vineyard performance. Limestone affects both Ca content and pH, whereas clay affects the availability of Ca, Mg, and K, all essential vine nutrients. In addition, the clay mineralogy varies in different geologic settings as a function of both protolith and weathering (time), thus affecting vineyard performance (cf. Mayer, this volume).

One of the most important factors influencing nutrient availability to plants is soil pH. Grape vines grow best and receive the most nutrients at optimum pH levels (White, 2003). Many macronutrients are best absorbed at approximately neutral pH for V. vinifera although V. labrusca can tolerate and thrive at lower pH (Pool, 2001). Linhoff (cf., this volume) studied soil pH in Sheldrake Point, Silver Thread, Dr. Konstantin Frank's, and Standing Stone vineyards and determined that with soil amendments all were close to neutral pH.

Climate of the Finger Lakes Area

The lakes not only give the Finger Lakes AVA its name but also play an important role in the region's climate. The mean temperature of much of central New York is too low for vinifera wine production with several areas below 2000 growing-degree days (Fig. 3). Most of the vineyards in the Finger Lakes AVA are located close to the lakes, particularly the deeper ones such as Seneca Lake (Fig. 4), because of their moderating effect on temperature and precipitation, known informally as the "lake effect." The effect is twofold, causing warmer minimum temperatures in winter and cooler maximum temperatures in summer. The study by Whitesell (cf., this volume) documents the lake effect in general and shows that in the warmest region on the southeast side of Seneca Lake known locally as the "banana belt," the minimum temperature in winter is up to 5.1°F warmer and the maximum temperature in summer is up to 2.1°F cooler than areas away from the lake.

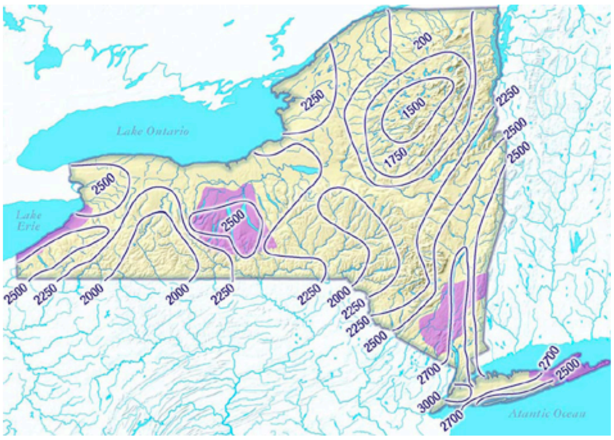

Figure 3. Growing degree days (temperatures above 50°F during the growing season) in New York state (after Dethier and Vittum, 1967). Areas in pink are major grape-growing regions.

CONCLUSIONS

The Finger Lakes region of New York state has a long history of wine production and continuing improvements in viticultural and enological techniques combined with a better understanding of terroir for vineyard site selection bode well for a healthy industry in the future. A fundamental control on the wine industry in New York is the glacial history of the region (Meinert, 2004). The glacial history includes formation of the Finger Lakes themselves and also a complex series of geological materials including tills, erratics, paleodeltas, and proglacial lake sediments that form the substrate for vineyards and soil development. The lakes also affect the mesoclimate of the region by moderating both winter and summer temperatures.

Within this general glacial environment there are specialized geological settings such as paleodeltas and buried proglacial clay layers that directly affect vineyard performance. Highest quality grapes appear to be associated with substrates that limit nutrients and moisture so as to avoid excessive vine vigor. The coarse-grained and consequently well-drained proximal parts of fluvial paleodeltas appear to be particularly amenable to controlling vine vigor in combination with controlled application of supplemental irrigation (Lakso et al., 2003; Lubick, 2004).

ACKNOWLEDGMENTS

Our studies of the terroir of the Finger Lakes region of New York would not have been possible without the help of many people. First, we must acknowledge our great debt to those who established the basics of our geological and viticultural understanding of the Finger Lakes, starting with Harold

Fairchild more than a century ago and continuing to the present day with the fine research conducted at the Cornell University New York State Agricultural Experiment Station at Geneva, New York. We have greatly benefited from the advice and support of the owners and workers at numerous vineyards throughout the Finger Lakes. In particular, we want to thank Fred Frank and Morton Hallgren of Dr. Konstantin Frank's Vinifera Wine Cellars, Scott Osborn and Peter Bell at Fox Run, Mark Wagner and Kelley O'Neil at Lamoreaux Landing, Richard Figiel and Steve Devaney at Silver Thread Vineyard, Tom & Marti Macinski at Standing Stone Vineyards, Rob Thomas at Shalestone Vineyards, and Bob Madrill and Dave Wiemann at Sheldrake Point Vineyard. Fred Frank and Bob Madrill were also instrumental in organizing a research mini-symposium in Fall, 2004 where we presented the preliminary results of our research. Finally, we would like to express our heartfelt thanks to Susan Spence of the New York Wine & Grape Foundation who was a continuing source of information and good cheer.

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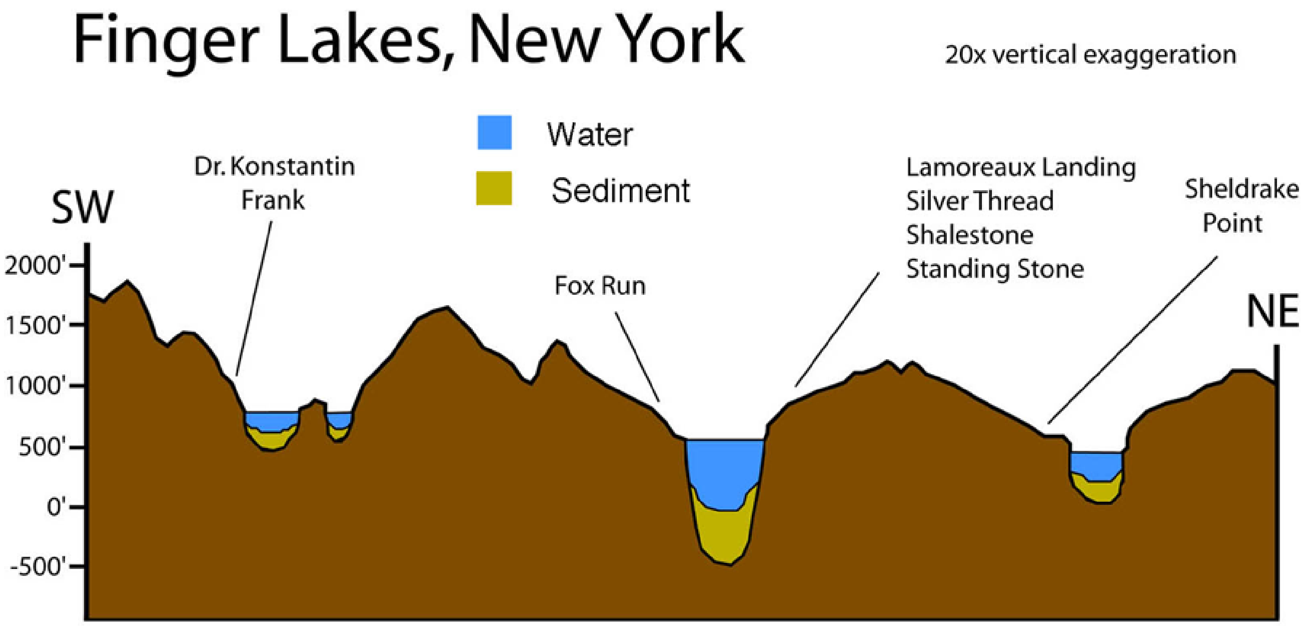

Keuka Lake
Surface: 714'
Max water depth: 187'
Max erosion below lake level: 633'

Seneca Lake
Surface: 445'
Max water depth: 610'
Max erosion below lake level: 1450'

Cayuga Lake
Surface: 382'
Max water depth: 433'
Max erosion below lake level: 1175'