The Dahlonega Wine and Gold District: Geology and Terroir of Viticulture in Northeastern Georgia

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48TH ANNUAL FIELD TRIP OF THE GEORGIA GEOLOGICAL SOCIETY
DAHLONEGA, GEORGIA, OCTOBER 11-13, 2013

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The Friday night social plays an integral part of the Georgia Geological Society mission with appreciation going to those who sponsored it. The Georgia Geological Society was founded to bring together people who are interested in the geology and geologic history of the State of Georgia. Its members, approximately 350 of them, include Geoscience professionals from academia and industry as well as students and knowledgeable geology enthusiasts. The society encourages the study of Georgia geology in a variety of ways including the presentation of awards for the best grade school and high school student presentations in geology at the Georgia Science and Engineering Fair and the best graduate and undergraduate presentations in the Earth Science Division of the Georgia Academy of Science. The Annual Meeting and Field Trip, typically held in the Fall of each year, brings together a wide range of geologists and geology enthusiasts for the study and debate of important geological problems in the state... and we have a good time doing it.

We thank the Dahlonega Visitors Center and in particular Jay Markwalter, who enabled contacts with the regional wineries and landowners. Robert C. Fuller at North Georgia College and State University kindly arranged for access to a campus parking lot, which during the peak of the fall foliage season is hard to find. Brannon Boegner at Wolf Mountain Vineyards and Winery, Doug Paul at Three Sister’s Vinyards, Raymond Castleberry at Cavender Creek Vineyard and Winery, and Elizabeth Bucks at Montaluce Winery and Estates were all wonderful for allowing the field trip access their properties.

Finally, the term Terroir defined as “the environmental conditions, especially geology, soil, and climate, in which grapes are grown and that give a wine its unique flavor and aroma” implicitly includes the human factor, because it is people who sense attributes of the fruits, the labor that go into viticulture, and the taste of wine. Thanks to all the people (students, professionals, family, and friends) that truly make the Georgia Geological Society a fun and learned society.

Paul A. Schroeder
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A BRIEF HISTORY OF VINIFERA WINE GRAPE PRODUCTION IN GEORGIA

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Although numerous native grape species were found in Georgia when the first colonists arrived, there was initially great confusion over the potential for grape production. Earlier colonists in Virginia, North Carolina, and elsewhere had been greeted at the seashore by grape vines. Many of these had huge trunks, and the vines covered the lush forest and reached to the tops of the largest trees. Among the native grapes found in Georgia were Vitis aestivalis (summer grape), Vitis cinerea (graybark grape), Vitis rotundifolia (muscadine grape), Vitis vulpina (frost grape), and Vitis labrusca (fox grape). There is no evidence that eastern Indians had ever produced fermented drinks of any kind, so there was literally no wine production until the arrival of European colonists. Colonists first assumed that the New World grapes would produce wine in similar fashion to the Old World grapes, and if not, the Old World grapes would easily produce wine in the new lands. Neither of these assumptions was correct.

The first reference to wine production in the Southeast was either that produced by a Huguenot colony in Florida (1565) or a Spanish fort at Paris Island, South Carolina. Regardless of who was first, the quality of the wine is in doubt. Colonists in Virginia and elsewhere quickly determined that native grapes were inferior, by European standards, as to fruit taste and wine production. John Wesley, one of the original Georgia colonists and the man who largely founded the Methodist movement with his brother Charles, described the native grapes of Georgia in one of his journals: “The common Wild-Grapes are of two sorts, both red: the fox-grape grows two or three only on a stalk, is thick-skinn’d, of a harsh taste, and of the size of a small Kentish Cherry. The cluster-grape is of a harsh taste too, and about the size of a white currant.” The wine produced was often described as having a “foxy” taste, which is a terrible descriptor; more meaningful descriptors would include wet horsehair, musky, or barnyard, all of which bring to mind the interaction of negative smells with taste on the palate. England greatly desired development of a thriving source of European-style quality wine, since they could only readily obtain such wine from their oft competitors and/or enemies – Spain, Portugal, France and other European nations. Native grapes obviously were a disappointment.

Prior to Columbus, there was essentially only one grape species used to make wine, Vitis vinifera, and the use of this grape was historically tied to the Mediterranean region and nearby nations of the Middle East, having been initially used for wine as long ago as 8000 BC (Neolithic period) in the Caucasus region. The original wild grape was Vitis vinifera subsp. sylvestris, with the domesticated grape being V. vinifera subsp. vinifera. The domesticated
vine has hermaphrodite flowers (self-fertile), whereas the wild vine is dioecious, meaning that male and female flowers are on separate plants and pollination is required. Over time, ancient viticulturists selected for the self-pollinating *V. vinifera* as it was more fruitful, and self-pollination allowed the planting of grapes in areas with limited insect pollinators. Dual mutations further allowed for *V. vinifera* white grapes, and there were literally thousands of red and white *V. vinifera* varietals/clones developed through selections from the Mediterranean region and eventually Europe. Over thousands of years, wine production methods improved, as did the quality of the end product. By the time the colonial powers first crossed the Atlantic, European viticultural and enological techniques were similar to those we would recognize today – including barrels and corked glass bottles.

With General James Oglethorpe as its leader, Georgia was established as a colony in 1733 (Fig. 1), and the successful introduction of European grapes was considered to be of utmost importance to the charter – along with mulberries for silk worms and olives for oil. Conceptually, there was some discussion of using the mulberry trees to physically support (trellis) the wine grapes, a practice that was conducted in Italy with trees and wine grapes till relatively recent times. The settlement at Savannah was one of the first, if not the first, sites to truly “experiment” with production of *Vitis vinifera* wine grapes in what would become the United States. Two years after General Oglethorpe landed in Savannah, The Trustees Garden was established for the development of wine grapes and other commodities; it was also developed as an experiment station, purportedly the first in the Western Hemisphere, for development of tropical and Mediterranean plants, such as wine grapes and white mulberry trees (used for silk) (Fig. 2).

On numerous occasions, wine grapes were planted either at the Trustees Garden or in select sites near Savannah, and even though vineyards were established, the vines either died outright, or fruit were not produced. Oglethorpe, as late as 1738, was still optimistic: “There is great hope, nay, I may say, no doubt, that both Silk and Wine will in a very short time come to perfection.” This proved to be a false assumption for a number of reasons; chief among these were insects and diseases which attacked the European grapes but for which resistance or tolerance were observed in the native grape species. Though descriptions of dying grapes from that time period do not provide adequate evidence of the cause of death, we now know potential culprits were: (1) fungi that cause powdery mildew (*Uncinula necator*), downy mildew (*Plasmopara viticola*), and black rot (*Gnidaria bidwellii*), (2) the bacterium that causes Pierce’s disease (*Xylella fastidiosa*), and (3) the Phylloxera insect (*Daktulosphaira vitifoliae*). Any of these would have independently made production of wine from *V. vinifera* an impossibility in Georgia, and it is possible that all were involved in the demise of the Savannah plantings. By the time of the American Revolution, there was virtually no interest in establishing European grapes in Georgia – due strictly to negative experiences and numerous failed attempts. For at least a hundred years hence, production of wine in Georgia was limited of necessity to that provided by native grapes, and production was very limited. However, the pathogens and insects that decimated the European vines in Georgia were not content to remain in the New World. It is at this point that the history of wine grape production in Georgia becomes intimately tied to the history of wine grape production in the Old World.
Figure 1. General Oglethorpe meets with the Creek Indians. Though native grapes abounded in Georgia, the Native Americans had never developed fermentation, so wine or any fermented drink was unknown to them (Hargrett Rare Book and Manuscript Library, University of Georgia Libraries).

Figure 2. Engraving (1732) of the establishment of Savannah, GA. The Trustees Garden, an experiment station for development of tropical and Mediterranean plants for the New World, is shown as the large cleared area in the background. Wine grapes, imported from Europe, were planted in this garden on multiple occasions, but they were never successfully grown due to diseases and insects for which they had no or limited natural resistance (Hargrett Rare Book and Manuscript Library, University of Georgia Libraries).
Wine grape had been a staple in the Mediterranean regions and eventually much of Europe since biblical times. The economic impact of wine production was among the greatest of the agricultural commodities in these regions. Though references in the Bible do point to mildews of grape, the European grape was generally at home in its environment, and it did not have substantial fungal or insect enemies; otherwise, production would have been extremely limited. However, the balance between the *V. vinifera* vine and its enemies started to change in the 1800s.

In 1845, powdery mildew was introduced to Europe. The spread was rapid, and the impact was devastating to the economies of the region. French wine production was rapidly reduced from 39 million hectoliters to 11 million, and wine prices soared. Frederick Cozzens, a wine merchant, stated in 1854 that: “Nature can do no more, and in sorrow and poverty, the peasant must turn to face other employments. So far the northern countries have been less affected, but in the south of France, Spain and Portugal, in Madeira and Italy, prospects seem to favor the conclusion that in the course of a few years, these famous wines will be at an end.” Fortunately, sulfur, already known to have disease-curing properties, was found to provide substantive control of powdery mildew. In 1857, the Academia de Geogofila of Florence reported that an American vine, when grafted on an Italian rootstock, was resistant to powdery mildew. There was absolutely no understanding that the importation of American vines to Europe had resulted in the delivery of powdery mildew. In fact, the understanding of disease and the association of pathogens with disease was a new concept at that time.

It is difficult for one to remember how little was known about diseases at the time of the powdery mildew introduction to Europe. It was not until the period of 1860-1863 that Louis Pasteur, the French scientist best known for pasteurization and development of vaccines, helped to prove that microorganisms arise from preexisting microorganisms and not from spontaneous generation. Prior to this, though microorganisms had been observed in diseased tissues, they were assumed to be a result of the disease, as opposed to the cause. Coincidentally, it was Heinrich Anton de Bary, known as the father of plant pathology, who in 1861 firmly established that the fungus *Phytophthora infestans* was the cause of the disease known as late blight of potato. The European wine grape, in part due to its economic value, would soon serve as a field laboratory for disease management; other New World threats remained, and these had not yet been established in Europe. However, before that could happen, much needed to be learned about insect management, and the vineyards of Europe would provide the appropriate laboratory for this need as well.

In 1862, American grapes were delivered from New York to an obscure wine merchant in Roquemaure, a small town in southern France; he had a small walled garden behind his establishment, and it was ground zero for one of the worst agricultural disasters ever witnessed for an individual commodity. The next summer, vines started dying in nearby vineyards. This time the culprit was Phylloxera, an insect with a complicated life cycle, which includes an aboveground leaf gall stage and a belowground root-feeding stage. It is the belowground stage that causes plant death; the European grape had no natural defenses against this insect, so it essentially destroyed the vast majority of the grape vines in Europe over the next 20 years. Initial solutions were expensive, such as flooding
vineyards or injecting carbon bisulfide or potassium carbonate into the ground to kill the insects. In 1874, Henri Bouschet displayed a $V. \text{vinifera}$ vine grafted to an American rootstock at the Congres Viticole in Montpellier. Soon thereafter, it was determined that American or American/European hybrid rootstocks would provide protection against Phylloxera, and the wine that was produced was of excellent quality. Phylloxera, destroyed almost all European grapes with a tremendous economic impact, but the replanting of vines with American rootstocks was pursued in earnest. A side benefit of the rootstock research was the fact that many rootstocks, if allowed to grow and produce fruit, could be utilized for wine production; these were the initial basis for what has been termed French-American hybrids. French-American hybrids produce wines with unique qualities, such as those of ‘Vidal Blanc’, ‘Chambourcin’, and ‘Seyval’ – all of which are now found in Georgia vineyards. Phylloxera is generally less destructive in sandy soils, so it may not have been the cause of death of vines in colonial Georgia, but if not, still other diseases were available to fill the void.

In 1878, yet another disease was introduced to Europe – downy mildew. Downy mildew is more prevalent in warm, wet weather, and under these conditions, whole grape clusters are destroyed and complete defoliation can occur. In 1882, Alexis Millardet observed that vines that were treated with copper sulfate and lime to deter grape thieves were devoid of downy mildew, while nearby untreated vines leaves were diseased. Based on this observation, Millardet developed what came to be known as Bordeaux mixture (a compound of copper sulfate, slaked lime, salt and water), which he patented in 1885. For more than 50 years, this was the standard in disease management for numerous plant diseases. Black rot was also later introduced to Europe, but since Bordeaux mixture likewise suppressed black rot, it was never considered to be a major issue in Europe. However, if $V. \text{vinifera}$ grapes are not sprayed with fungicides in Georgia, black rot is the primary disease, and it would often result in 100% losses in wet years.

Though horrible to behold, the unfortunate demise of grapes in Europe was a Godsend to production of $V. \text{vinifera}$ grapes in the United States. If “necessity is the mother of invention,” the economic impact of the destruction of European wine grapes necessitated solutions, and thankfully, inventions were found to overcome both diseases and insects that had prevented successful $V. \text{vinifera}$ wine grape production in Georgia. However, there is yet one more devastating disease that could be exported to Europe, and that is Pierce’s disease. Even now, Pierce’s disease limits the production of $V. \text{vinifera}$ grapes to elevations in Georgia above 1300 feet. As mentioned previously, Pierce’s disease is caused by a bacterium, $X. \text{fastidiosa}$, that colonizes and results in blocked xylem tissue. Like Phylloxera, Pierce’s disease kills the vine completely, and there is no cure for infected vines. Cold winter temperatures are currently the only full-proof solution to Pierce’s disease, and there is a danger that global warming will make less and less of Georgia lands available for $V. \text{vinifera}$ wine production. Though insecticide application to manage the vectors, namely leafhoppers and spittlebugs, does suppress the spread of the disease, there is no ideal solution at this time other than cold temperatures. At the time of Oglethorpe’s landing, Pierce’s disease would have ultimately killed the vines within a few years of his arrival. Though we can now control fungal diseases and Phylloxera, thanks to the 19th century European introductions and solutions, we
still can’t grow \textit{V. vinifera} grapes in Savannah or any lower elevations in Georgia.

Until the late 1800s, limited and sporadic wine production appears to have been the norm in Georgia. However, in 1886, Ralph Spencer, a land developer, established three winemaking communities in Haralson County (west of Atlanta and near the Alabama line). He convinced ~200 Hungarian families to move from the coalmines of Pennsylvania to establish Budapest, Georgia (four miles from Tallapoosa) in 1893. Also, Tokaj, named after a famous winemaking region in Hungary, and Nyitra, named after an ancient Hungarian fortress, were started as smaller communities. Spencer established the Georgia Fruit Growing and Winery Association, and these immigrants started production of wine grapes as a major endeavor. Information relative to the species of grape utilized by these Hungarians is not available, so it is not known whether the grapes were native or European grapes. However, by 1893, due to the European experiences with diseases and Phylloxera, the technology would have been available for production of \textit{V. vinifera} in this area (Fig. 3), and based on description, it is at least possible that \textit{V. vinifera} wines were produced in part if not in whole. Assuming that the winters were colder at that time, it is possible that Pierce’s disease may not have been as prevalent, so use of rootstocks, sulfur, and Bordeaux mixture may have in fact allowed for \textit{V. vinifera} production. However, though this is a tantalizing thought, it is currently speculative to assume that any other than native grapes were grown by these immigrants. Whatever the species of grape, the industry expanded, and by 1896, nearly 13,000 acres of grapes were planted in Haralson County alone. By 1900, it is estimated that >20,000 acres of grapes were planted, and Georgia possessed the sixth largest viticultural region in the United States. Georgia wine was distributed throughout the Southeast for one dollar per gallon.

Unfortunately for the Hungarians, the advent of significant wine production in Georgia was short-lived. The temperance movement of the late 19\textsuperscript{th} and early 20\textsuperscript{th} century was particularly strong in Georgia. As a result, alcohol restrictions and prohibition came early to Georgia, being voted in on 1 January 1907 by the Georgia legislature – twelve years ahead of the federal law. However, Georgia’s bill only impacted 13 counties, as 135 were already “dry” at the time of its enactment. In 1919, the 18\textsuperscript{th} amendment to the U.S. Constitution established prohibition on a national level. In 1920, the Volstead Act was implemented by Congress, which made manufacture or consumption of alcohol an illegal act. Whatever the state of Georgia’s wine grape industry was by the beginning of the 20\textsuperscript{th} century, it was decimated by prohibition. Though prohibition was short-lived, ending in 1933, the impact of the temperance movement and prohibition continued for at least another 50 years. In part, the influences are felt even today, as farm wineries still struggle with a negative association of excessive alcohol use and its established dangers – often resulting in local political opposition to development of new vineyards and wineries.

Despite the obvious challenges from both man and nature, the “second wave” of Georgia wine production started approximately 30 years ago, with the vast majority of the growth-taking place in the last 15 years. Gay Dellinger is said to have been the first pioneer, planting a five-acre \textit{V. vinifera} vineyard near Cartersville, Georgia in 1979, followed by another three acres in 1982. In 1983, her Pinot Blanc received a silver medal at the Eastern Grape Growers Association annual meeting in Washington,
D.C. In 1983, Tom Slick established the Habersham Winery, the first true winery, soon to be followed by Chateau Elan in 1984. There are now more than 30 wineries which sell predominantly *V. vinifera* wines in the foothills of the North Georgia mountains, and the number continues to grow yearly, with several new wineries in the planning and building stages.

There is no way that General Oglethorpe could have understood the challenges of *V. vinifera* production at the time of his landing in Savannah. Even today, *V. vinifera* production is limited to the upper elevations, due to Pierce’s disease. However, with modern rootstocks, and an arsenal of fungicides, insecticides, herbicides, etc., high quality *V. vinifera* wines can be produced in at least a portion of the original Georgia colony – too late for an export to England but just in time for enjoyment by native Georgians and visitors alike.

Figure 3. Spraying grapes, date unknown. (UGA Extension Georgia Mountain Research and Education Center, Blairsville, GA).
REFERENCES CITED


THE DAHLONEGA GOLD BELT

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INTRODUCTION

The Dahlonega gold belt, named for the town of Dahlonega, Georgia, is a narrow zone of highly sheared rocks containing numerous gold deposits that is traceable from near the Georgia-Alabama state line northeastward to the Georgia-North Carolina state line, a distance of approximately 152 miles (243 km) (Figure 1). The belt attains its greatest thickness of approximately 10 kilometers in the immediate Dahlonega area, but generally has an average thickness of less than five kilometers.

For over 100 years this area was one of the major gold-producing regions in Georgia, following the discovery of gold there in 1829. For the next 20 years following this discovery, Georgia was one of the leading gold-producing states (Yeates and others, 1896; Jones, 1909). However, after gold discoveries in California in 1849 and the Civil War, production steadily declined and then essentially ceased in 1935 (Pardee and Park, 1948). Increases in the price of gold in the 1980’s and further large price increases currently have spurred a small resurgence of interest in the area. The Dahlonega belt probably accounted for the bulk of Georgia’s recorded production of just over one-half million ounces (Pardee and Park, 1948). However, given the incompleteness of production records, actual production, most likely, was considerably more. Although the Dahlonega belt formerly was a significant gold-producing region, when compared to world-wide production, individual mines elsewhere have been much more productive.

This article presents a brief summary of the various interpretations of the geology of the Dahlonega belt. Revised interpretations and unpublished data from the author based on observations at individual mines since the late-1980’s are incorporated and help provide a “status report” of our understanding of the Dahlonega belt.

STRATIGRAPHY

Rocks of the Dahlonega belt have been characterized as an intact stratigraphic sequence (Gillon, 1982; McConnell and Abrams, 1984; German, 1985; 1988, 1989), and as a purely tectonostratigraphic sequence (Albino, 1990; Higgins et al, 1988). Regardless of interpretation, the Dahlonega belt possesses an internal mapable stratigraphy that is traceable from Paulding County in west-central Georgia northeastward to Rabun County in the extreme northeastern corner of the state (McConnell and Abrams, 1984; German, 1985; 1988; 1989) and into North Carolina (Hatcher, 1988; Hopson et al, 1989).

Rocks interpreted to be the oldest rocks of the Dahlonega belt are those of the Pumpkintvne Creek Formation (McConnell, 1980; McConnell and Abrams, 1984; German, 1985), which also have been called the Ropes Creek Metabasalt (Higgins et al, 1988). These rocks consist of amphibolite, biotite-muscovite-quartz-plagioclase gneiss
± hornblende (Galts Ferry Gneiss Member), muscovite-biotite-plagioclase-quartz gneiss (Barlow Gneiss Member) and manganiferous magnetite quartzite (iron formation). Structurally overlying the Pumpkinvine Creek Formation is the Canton Formation, which consists of graphitic garnet-biotite-muscovite-quartz schist, amphibolite and muscovite-biotite-plagioclase-quartz gneiss (metagraywacke) in the southwestern part of the Dahlonega belt. In the northeastern part of the belt, the Canton Formation is divisible into four members: the Proctor Creek Member (muscovite-garnet-biotite-quartz schist), the Palmer Creek Member (garnet-hornblende-biotite-quartz schist), the Chestatee Member (amphibolite and quartzofeldspathic gneiss) and the Helen Member (garnet-biotite-muscovite-quartz schist and biotite-plagioclase-quartz gneiss with minor amphibolite and magnetite quartzite). Structurally overlying the Canton Formation
is the Univeter Formation, which consists of amphibolite, quartzofeldspathic gneiss, magnetite quartzite and muscovite-biotite-quartz schist.

The Dahlonega belt also contains a number of metamorphosed extrusive and intrusive bodies. Some of the quartzofeldspathic gneisses (for example, the Barlow Gneiss and the Galts Ferry Gneiss) have been interpreted as pre- to syn-metamorphic intrusive bodies that have been intensely deformed during the deformational history of the Dahlonega belt (Pardee and Park, 1948; Albino, 1990).

These also have been interpreted as metavolcanic rocks (McConnell, 1980; McConnell and Abrams, 1984; German, 1985; 1988, 1989). The exact origin of these is still somewhat unresolved, but current interpretation suggests an intrusive origin. Other rock bodies are clearly intrusive in origin. These include sericitized mica-bearing and hornblende-bearing trondhjemitic plutonic bodies in the vicinity of Dahlonega (Cook et al, 1984; German, 1985). Deformational features and crosscutting relationships of these trondhjemitic bodies indicate intrusion late in the tectonic history of the Dahlonega belt (German, 1985).

Rocks within the Dahlonega belt have been referred to as the New Georgia Group (McConnell and Abrams, 1984; German, 1985; 1988), the Helen Group (Gillon, 1982; Nelson and Gillon, 1985) and the Otto Formation (Hatcher, 1987; Hatcher and Goldberg, 1991; Settles et al, 2002; Thigpen and Hatcher, 2009). Rocks described by Settles et al, 2002 northwest of Dahlonega, although clearly part of the Dahlonega belt, have not been subjected to the intense shearing and gold mineralization of rocks at Dahlonega and to the south. Rocks of the Dahlonega belt also have been compared to rocks of the Ocoee Supergroup of the western Blue Ridge (Hatcher and Goldberg, 1991), which they structurally overlie. Based on stratigraphic relationships and chemistry of the mafic metavolcanic rocks within the belt, rocks of the Dahlonega belt were interpreted to record the formation and filling of a rift basin (Gillon, 1982) or back-arc basin (German, 1985, 1988, 1989) in the Late Proterozoic or early Paleozoic. More recent age determinations for the Barlow and Galts Ferry Gneisses (466 Ma and 463 Ma, respectively) (Thomas, 2001), the Cane Creek Gneiss northwest of Dahlonega (482 Ma) (Settles et al, 2002) and correlative metadacite from the Hillabee Greenstone in Alabama (470 Ma) (McClellan et al, 2007) strongly indicate that rocks of the Dahlonega belt formed in an arc terrane outboard of Laurentia in the Early to Middle Ordovician (McClellan et al, 2007).

**STRUCTURE AND METAMORPHISM**

The recognition of the Dahlonega belt as a distinct zone (characterized by pervasive shearing) has been reported by numerous workers (Crickmay, 1952; Bowen, 1961; Gillon, 1982; Cook and Burnell, 1983; German, 1985; 1988; 1989; Albino, 1990; Higgins and others, 1996). The Dahlonega belt is bounded by major faults along most of its strike length. Forming the southeastern boundary is the Chattahoochee/Dahlonega Fault (McConnell and Abrams, 1984; German, 1985; 1988; 1989; Hatcher and Goldberg, 1991; Nelson, 1992; Nelson and others, 1998). Along this fault, rocks of the Tallulah Falls thrust sheet were thrust over those of the Dahlonega belt (Helen thrust sheet of Nelson, 1992; Nelson and others, 1998). Movement along this fault is characterized by early ductile deformation (near the peak of metamorphism) and later post-peak brittle deformation (Bowen, 1961; McConnell and Costello, 1980; Gillon, 1982; Nelson, 1992).
Part of the northwestern boundary of the Dahlonega belt is formed by the Allatoona Fault in the southwestern portion of the belt and the Hayesville/Soque River Fault in the northeastern portion. Along the Allatoona Fault, rocks of the Dahlonega belt were thrust over rocks of the Ocoee Supergroup. The Allatoona Fault appears to be a pre- to syn-metamorphic fault (Settles et al., 2002) with post peak-metamorphic reactivation in the vicinity of Canton where it truncates portions of the Canton Formation (German, 1985). Northeast of Dahlonega, most of the northwestern boundary of the Dahlonega belt is formed by the Hayesville/Soque River Fault. Movement along this fault is believed to be pre- to syn-metamorphic (Nelson, 1992; Hatcher and others, 1988). Along this fault, rocks of the Hayesville thrust sheet were thrust over those of the Great Smoky thrust sheet (Nelson, 1992; Nelson and others, 1998).

Rocks of the Dahlonega belt have experienced multiple deformation. As many as four deformational events are recognizable (McConnell and Abrams, 1984; German, 1988; 1989). The major structural feature within the belt is the Auraria antiform, a regional second generation fold. This fold is a northwest-vergent, asymmetrical, isoclinal fold that is traceable for at least two-thirds of the length of the belt. Minor folds are generally northwest vergent southwest of Dahlonega but have been rotated to a southeastern vergence northeast of Dahlonega. Earlier deformation of rocks of the Dahlonega belt has been overprinted by an intense episode of dextral shearing that produced a strongly-developed mylonitic foliation. Shear indicators include rotated garnets exhibiting deformed cores (Fig. 2), augen-textured quartzofeldspathic gneisses (Fig. 3), sheath (?) folds and ribbon quartz features in the more quartzose schists and some ore bodies (Fig. 4) (German, 1985; Albino, 1990). Recent characterization of the Dahlonega belt as the “Dahlonega fault zone” (Higgins and others, 1996) was also accompanied by speculation of dextral displacement along the shear zone on the order of tens of kilometers.

Rocks of the Dahlonega belt were metamorphosed to staurolite and kyanite zones (German, 1985; 1988), and possibly sillimanite zone (Gillon, 1982; Albino, 1990), of regional amphibolite grade in the Late Devonian (Acadian) (Dallmeyer, 1978; 1988). Degree of regional metamorphism generally increases along the belt from southwest to northeast. Coincident with later shearing are retrograde effects that are observable throughout the belt, consisting largely of partial replacement of amphiboles and biotite by chlorite.

**GOLD DEPOSITS**

Mining activity in the Dahlonega belt began in most instances as placer mining of alluvial deposits. Placer mining generally evolved into hydraulic mining of saprolite when it was discovered by the miners that the source of the gold was quartz veins in the underlying bedrock. At many mines after the depletion of surface deposits, underground mining methods were employed on significantly large and continuous ore bodies. These endeavors, however, met with mixed success due to insufficient reserves or inability to extract the gold from unoxidized ore.

Ore bodies are divided into two general categories: veins and mineralized zones (Pardee and Park, 1948). Veins are less numerous than the mineralized zones and are generally restricted to more competent rocks. These are generally well-defined bodies of wide-ranging size. The mineralized zones, on the other hand, are
Figure 2 – Photomicrograph of rotated garnet in schist of the Canton Formation in cross polarized light (above) and plane-polarized light (below). Note rotated, deformed core with subsequent euhedral, undeformed overgrowth, indicating temperature and fluid mobility remained high post-deformation. Field of view is 5.36 mm.
Figure 3 – Barlow Gneiss. Note intensely sheared appearance with augen porphyroclasts consisting of blue quartz and plagioclase.

Figure 4 - Sheared ore from the Franklin-Creighton Mine, Cherokee County consisting of quartz, large pyrite crystals, fine interstitial pyrrhotite, biotite, and amphibole. Note stretched inclusions of amphibolite host rock and macro ribbon quartz in the lower portion of the sample.
Figure 5 - Example of alteration associated with gold ore at the Franklin-Creighton Mine, Cherokee County consisting of quartz, carbonate (ankerite?), tourmaline, chlorite and muscovite. Note undeformed appearance of the assemblage.

much more common and are characterized by their discontinuous occurrence and irregular shapes. The mineralized zones are generally composed of several small quartz stringers (or lenses) and may be several tens of feet wide. This feature made them easily mineable by techniques that exploited the entire zone as one single ore body, but it was not generally profitable to mine individual quartz stringers. Veins and quartz stringers of the mineralized zones may be parallel or sub-parallel to the foliation of the host rocks.

The mineralogy of the ore bodies varies widely. Quartz is by far the most abundant mineral, occurring as massive aggregates of interlocking grains. Occurring with the quartz are locally abundant concentrations of gold, pyrite and pyrrhotite with lesser amounts of silver, galena, chalcopyrite, sphalerite and arsenopyrite. The ore bodies commonly are banded as a result of the presence of stretched and sheared inclusions of the host rock (Fig. 4). Locally, crosscutting or bordering the ore
bodies are slightly deformed to undeformed alteration masses consisting of carbonates, tourmaline, epidote, garnet, chlorite, biotite, hornblende, muscovite and, rarely, kyanite (Fig. 5). These alteration masses locally contain visible gold (Lindgren, 1906; German, unpublished data). Extensive alteration most commonly occurs where the ore bodies lie within amphibolite, with less alteration associated with metasediments and felsic intrusive/extrusive rocks (Albino, 1990). Alteration assemblages associated with amphibolite host rock indicate these mineral assemblages were deposited by CO\textsubscript{2} -enriched fluids containing various base and precious metals. The wide variation in alteration within the Dahlonega belt indicates alteration was strongly controlled by host rock mineralogy. Local occurrences of ore bodies rich in elements (such as lead, arsenic or tellurium) not found in the majority of the deposits also may suggest a highly variable chemistry of the mineralizing fluids or distinct, episodic mineralizing events.

The association of the gold deposits with a major shear zone, the crosscutting nature of many ore bodies and the composition of the alteration assemblages indicate that the ore bodies were deposited by fluids emanating from deep within the crust during shearing. The highly deformed nature of most ore bodies, yet undeformed nature of local alteration assemblages indicate that mineralization occurred late in the deformational history of the Dahlonega belt and continued for a time after major deformation ceased (Fig. 2, Fig. 5). These characteristics strongly suggest an Alleghanian age for the shearing and mineralization of the Dahlonega belt. The exact mechanism of gold deposition is not yet fully resolved. German (1985, 1988, 1989), observing the close association of the majority of the deposits with rocks of volcanic affinities, especially with exhalative horizons (iron formation), proposed a syngenetic origin for the gold and a lateral secretion mechanism for its concentration in veins. Albino (1990), citing the occurrence of gold and gold-silver tellurides in many deposits, proposed that gold deposition was linked to the presence of sufficient aqueous tellurium to cause gold saturation in the mineralizing fluid resulting in gold deposition and based on geothermometric and geobarometric modeling proposed that mineralizing fluids were >500°C with pressure on the order of 5 kb. A syngenetic model does not sufficiently account for those deposits not directly associated with volcanic rock or iron formation nor the mechanism for local mobilization followed by local deposition from fluids that were clearly out of equilibrium with the host rocks as subsequent observations by the author at individual mines have shown (German, unpublished data). Although Albino’s (1990) pressure-temperature values are very plausible, his model does not sufficiently account for the fact that many, if not the majority, of deposits do not contain tellurium, nor does it account for the close association of numerous gold deposits with iron formation, possibly indicating interaction of the mineralizing fluids with iron-rich host rock caused gold saturation and deposition. The variation in the mineralogy (particularly metal content) of ore bodies may indicate a highly variable mineralizing fluid or distinct mineralizing events. Additional research is needed to adequately address all potentially applicable models.

**SUMMARY**

The Dahlonega gold belt is a narrow zone of highly sheared rocks containing numerous gold deposits that is traceable across northern Georgia. For over 100 years
the Dahlonega belt was one of the major gold-producing regions of the southeast. Rocks of the belt are interpreted to record the formation and filling of a rift basin or back-arc basin in the Early to Middle Ordovician. Faults form the boundaries of the belt along most of its length, and rocks within the belt have experienced at least four deformational events. Rocks of the Dahlonega belt were regionally metamorphosed to amphibolite grade during the Acadian orogeny. Subsequent shearing produced widespread retrograde effects and was coincident with the emplacement of numerous auriferous quartz veins at amphibolite grade metamorphic temperatures and pressures. Mineralization and shearing are interpreted to be Alleghanian in age.

**REFERENCES CITED**


Location map for Geology stops #1 and #2. The geologic map of the Dahlonega area (German, 1985) shows units of the Pumpkinvine Creek, Canton and Univeter Formations. Numbered dots are locations of abandoned gold mines. Map Scale is 1:100,000

**STOP #1 - DESCRIPTION**

At this stop, we will examine saprolite exposures of felsic gneiss, amphibolite and button schist of the Univeter Formation and garnet mica schist, metagraywacke and amphibolite of the Canton Formation within excavations for businesses at the northwest corner of the intersection of State Routes 400 and 60 and at a roadcut along State Route 60 immediately to the west. Both the Univeter and Canton Formations are host for numerous gold deposits, and at least two massive sulfide deposits, within the Dahlonega Gold belt.

After exiting the buses, first we will examine saprolite exposures of the Univeter Formation behind the convenience store. Note the sheared nature of the felsic gneiss and amphibolite. Thin amphibolites converge a short distance to the northeast indicating they are limbs of isoclinal folds. The points of convergence, unfortunately, are now obscured by parking lots northeast of the convenience store. After examining these exposures, proceed northwest across the vacant lot, noting saprolite exposures of button schist in contact with the felsic
gneiss. Micaceous rocks like this schist tend to develop distinct shear features (SC mylonite fabrics) within the Dahlonega belt. Across the vacant lot from the convenience store are roadcuts within the Canton Formation, but the contact with the Univeter Formation is obscured. The roadcut exposes garnet mica schist, metagraywacke and amphibolite of the Canton Formation. Chemical analyses of amphibolites within the Dahlonega belt indicate they are metabasalts with mid-oceanic ridge or volcanic arc affinities. They are interlayered with metasediments throughout the Dahlonega belt, strongly suggesting formation in a back-arc basin. Note the repetitive nature of the mica schist and metagraywacke. Could these represent turbidite deposits?

Location Map for Stop 2 – Findley Ridge on the south side of Dahlonega (see German 1985, 1989; Cook et al, 1984).
STOP #2 – DESCRIPTION

At this stop, we will examine a sequence of rocks on Findley Ridge on the south side of Dahlonega along a roadcut traversing the ridge. If permission is granted by the landowner, we also will examine briefly abandoned workings of the Crown Mountain Mine. The sequence of rocks forming this prominent ridge consists of amphibolite; manganiferous, magnetite quartzite (iron formation); sericite schist; and felsic gneiss and is host for at least thirteen abandoned gold mines.

After exiting the buses, we will walk to the roadcut across the ridge along Alicia Street. Unfortunately, nearly all exposures of this sequence of rocks are highly weathered, greatly obscuring many features of the various rock types. One of the most striking features of this sequence is the presence of manganiferous, magnetite quartzite, which is locally banded, resembling typical banded iron formation. The thickness of the iron formation varies from less than one meter to as much as five meters, but may be thickened by folding. Early investigations of this site describe two separate iron formation zones. The iron formation is interpreted to represent chemical precipitation in the vicinity of a submarine volcanic vent.

At this and other locations along Findley Ridge, gold occurs in quartz veins and stringers parallel to sub-parallel to the foliation of the host rock. Early descriptions of the deposits state that the highest concentrations of gold occurred in rich shoots formed by small flexures in the veins and foliation. Thickness of individual veins varies widely from as thin as a centimeter to meter thickness, the majority, however, being less than 20 centimeters or so.

Did the iron-rich lithologies along Findley Ridge provide favorable sites for the deposition of gold from gold-bearing metamorphic fluids, or was the gold a primary constituent of these rocks that was laterally secreted into veins during metamorphism and deformation?
**Introduction**

Cultivation of grapes and production of wine is a rapidly growing industry in northeastern Georgia. The greatest concentrations of vineyards operations are in the vicinity of Dahlonega, seat of Lumpkin County, and Cleveland, the seat of White County (Figure 1). On this field trip we will visit four vineyards in the Dahlonega region, a center of major US gold production from the early 19th century into the early 20th century. Today the gold of the region is not mined but grown on vines, and is harvested, fermented, and bottled by skilled winemakers and consumed by wine lovers and increasing numbers of agri-tourists, making this emerging industry a significant contributor to the area’s economy. Three of the vineyards we will visit are located in the Dahlonega gold Belt province, and one lies just to the north in an adjacent geological feature - the Cowrock Terrane. Not only will we see basic bedrock geology that controls gold deposits, but we will also see how the area’s geology plays a major role in the cultivation of grapes by its influence on climate, including temperature and precipitation, length of growing season, slope and aspect of terrain, solar insolation, and soils, all environmental factors that are often referred to collectively by wine enthusiasts as the region’s ‘terroir.’

In shopping for wines I often read labels on the bottles and am always been fascinated by the descriptions of terroir that are used. Most of these emphasize the uniqueness of the environment in which the grapes were grown; many sound decidedly mysterious and romantic, which always leads me to wonder if there is any scientific evidence for some of the more poetic claims. In this short analysis I cannot give any definitive answers as to the influence of terroir on wine quality. I will, though, use the Dahlonega region to discuss a few of the important environmental characteristics that are critical to grape cultivation and show how these can be evaluated by geospatial analysis.

My methodology utilizes publically available and cost-free geospatial datasets, such as satellite imagery, aerial photography, digital elevation models, field-based climate measurements and gridded climate normals, georeferenced raster maps, and vector versions of published maps, all processed and interpreted with commercial Geographic Information System (GIS) software. This approach can give the user a regional view that reveals environmental relationships not easily discernable from ground-based field work alone and is a good place to start in evaluating potential new vineyard sites.
LOCATION OF ANALYSIS AREA

The four vineyards we will visit are Three Sisters, Wolf Mountain, Cavender Creek, and Montaluce, all located in Lumpkin County (Figure 1). In making a regional geospatial analysis of a broad region I feel it is important to confine the analysis area to naturally occurring environmental units, especially when making comparisons of regions. I consider a watershed to be such a unit, as it is physiographically enclosed and thus may have different environmental characteristics from surrounding watersheds. For this analysis I have used three 10-digit watersheds (Dicks Creek, Yahoola Creek and Upper Etowah River) that include the four vineyards that we will visit (Figure 1). These watersheds are defined in the USGS Watershed Boundary Dataset, which is part of the National Hydrography Dataset. The Dicks Creek and Yahoola Creek watersheds belong to the Upper Chatahoochee basin, while the Upper Etowah River watershed is a part of the Etowah basin. After analyzing a number of factors in each of these watersheds separately, including climatic and geomorphic characteristics, I have concluded that the three areas are very similar, and therefore I have analyzed them together as a single unit, which I refer to informally as the ‘Dahlonega wine region.’ Since the separate watersheds are adjacent, occur at the same latitude, share the same stratigraphy and geological structure, and are subjected to the same meteorological trends, it seems intuitively obvious that they should have similar environmental characteristics. It is likely that adjacent watersheds are also similar, but I have restricted the present analysis to the three that include the field trip stops.

GEOLOGICAL SETTING AND PHYSIOGRAPHIC SETTING

The Dahlonega wine region watersheds are aligned northwest-southeast and lie perpendicularly across parts of four major geological provinces (Figure 2) as defined by Thigpen & Hatcher (2009) and described extensively by R. D. Hatcher and his colleagues (Hatcher, et al., 2005; Hatcher et al., 2007): the Tugaloo terrane, the Dahlonega gold belt, the Cowrock terrane and the Western Blue Ridge. The complex geological and geomorphic evolution of this area, which has included multiple events of deformation, metamorphism and regional uplift, has juxtaposed a wide variety of structures and lithologies that have produced a varied topography and physiography.

Digital elevation models (DEMS) from the USGS’s National Elevation Dataset illustrate the physiographic setting of the Dahlonega wine region, which is located on the southeastern slope of the Blue Ridge mountains where they begin their southwest plunge towards the Gulf Coastal Plain (Figure 3). A detailed view of the digital elevation data (Figure 4) shows the physiographic complexity of the three watersheds. Elevations increase from 997’ at the lowest spill point of the Upper Etowah River watershed to 4449’ at the highest point in the Dicks Creek watershed. The dendritic drainage pattern of the higher elevations contrasts with the trellis pattern.

1 http://nhd.usgs.gov/wbd.html
2 There are vineyards within these watersheds that are not part of our field trip stops, but I have included these vineyards as part of the analysis. I have not included vineyards that fall outside the three watersheds in the analysis, but do show them on the various maps for sake of regional context.
Figure 1. Location map of the northeastern Georgia wine region.
Figure 4. Detailed view of topography of the Dahlonega wine region.
seen at lower levels, and there are examples of radial drainage and evidence of deranged patterns. Hypsometric analysis of the separate and composite watersheds shows that all three have classic equilibrium stage profiles (Figure 5), with the majority of the terrain (63%) lying above 1100’ and below 1800’. The greater area of the watersheds thus forms a narrow plateau between the Blue Ridge to the northwest and the Western Inner Piedmont province to the southeast. This plateau has been recognized and mentioned in the past literature and referred to as the ‘Dahlonega Plateau’ (LaForge, 1925) and the ‘Dahlonega Uplands’ (Alhadeff et al., 2001), though no definitive definition of the boundaries has ever been proposed.

The Cowrock terrane, which outcrops along the northwest boundaries of the three watersheds, forms the highest elevations in the Dahlonega wine region (Table 1), ranging up to 4449’. The southeastern boundary of the watersheds is formed by outcrops of the Tugaloo terrane, while the Dahlonega gold belt and the Western Blue Ridge, lying between the Cowrock and Tugaloo provinces, form areas of intermediate elevation. The topographic variation caused by the juxtaposition of four quite different geological features, is critically important to the Dahlonega area’s viticulture; it is a major control of the area’s climate, which, in my opinion, is the single most important factor for successful grape cultivation.

**CLIMATE: TEMPERATURE AND PRECIPITATION**

The National Climatic Data Center (NCDC)\(^4\) lists only three active weather-monitoring stations in the immediate Dahlonega region that were used in generating its 1981-2010 climate normals\(^5\): Dahlonega, Cleveland and Sautee. The Cleveland and Sautee stations do not fall within the wine region, but are close to the eastern boundary of the Dicks Creeks watershed. The Dahlonega station alone falls within the boundaries of the Yahoola Creek basin. These three stations do not provide the density of coverage necessary to evaluate the climate situation of an area as large as the Dahlonega watersheds, so I have used the gridded 1981-2010 climatic normals produced by the PRISM Climate Group at Oregon State University.\(^6\) This data combines observations at measurement stations with climate-influencing factors, such as longitude, elevation, slope and aspect, to interpolate a continuous field of temperature and precipitation values at 800-meter (approximately one-half mile) intervals. It thus presents a more complete picture of the distribution of macroclimatic and mesoclimatic conditions than can be surmised from a few widely scattered ground stations.

Mean monthly temperatures for the Dahlonega area watersheds were calculated by converting the raw PRISM data for each month to raster format for the entire US and extracting the area of the watersheds from each of these images (see Figure 6 for an example). As is normal for the northern hemisphere, January is the coldest month with a mean temperature of

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\(^4\) [http://www.ncdc.noaa.gov/](http://www.ncdc.noaa.gov/)

\(^5\) Produced every 10 years by the US National Climatic Data Center, climate normals are 30-year averages of climatological variables, including temperature and precipitation. The most recent normals were released in 2012 and are for the period 1981-2010.

\(^6\) PRISM Climate Group data is the official climate data used by the US Department of Agriculture and is funded by that agency’s National Resource Conservation Service, the USDA Forest Service and by the NOAA Office of Global Programs. PRISM data can be accessed through the group’s website at [http://www.prism.oregonstate.edu/](http://www.prism.oregonstate.edu/).
39.2°F and July the warmest, with a mean temperature of 75.3°F (Figure 7).

The relationship of temperature to elevation is well-established worldwide, with temperature decreasing at higher elevations. To evaluate this relationship for the Dahlonega region the PRISM temperature rasters for January and July were combined with elevation values from the DEMs data for the three watersheds. The resultant file relates each temperature point to an elevation value. A plot of this data indicates that temperatures in January decrease at a rate of about 3°F/1000’ (Figure 8), while the decrease in July is approximately 2.4°F/1000’ (Figure 9). Interim months vary between these values.

Table 1. Elevation ranges of geological features in the Dahlonega wine region.

<table>
<thead>
<tr>
<th>Geological Province</th>
<th>Elevation (feet above msl)</th>
<th>Elevation (feet above msl)</th>
<th>Elevation (feet above msl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cowrock terrane</td>
<td>1319</td>
<td>4448</td>
<td>2866</td>
</tr>
<tr>
<td>Dahlonega gold belt</td>
<td>997</td>
<td>2159</td>
<td>1577</td>
</tr>
<tr>
<td>Western Blue Ridge</td>
<td>1047</td>
<td>1906</td>
<td>1470</td>
</tr>
<tr>
<td>Tugaloo terrane</td>
<td>1017</td>
<td>3130</td>
<td>2002</td>
</tr>
</tbody>
</table>

Figure 5. Hypsometric curve of the three Dahlonega wine region watersheds.
Figure 6. Gridded climate normals for mean January temperatures. Data from the PRISM Climate Group, Oregon State University.

Figure 7. Mean monthly temperatures derived from gridded 1981-2010 climate normals.
Figure 8. Mean January temperatures vs. elevation.

Figure 9. Mean July temperatures vs. elevation.
The importance of temperature for viticulture is that it determines the length of the growing season (period of frost-free days), a critical factor in producing grapes with sufficient sugar content to ferment to an appropriate alcohol level. The mean frost-free period is calculated for some of the NCDC monitoring stations used in the 1981-2010 climate normals. A plot of values for stations in the vicinity of the Dahlonega wine region demonstrates that the number of frost-free days decreases with increasing elevation (Table 2 and Figure 10), as would be expected from the temperature-elevation relationships established above. Because the data from the monitoring stations is so scattered, both in values and geographically, I am reluctant to draw a trendline through it; it would be more satisfying to have additional observation points that are within the watershed areas or closer to it before doing so. We do have some general guidelines, though, from experienced viticulturalists. Poling (2006) suggests a minimum growing season of 165 days for proper ripening of grapes. Other viticulturalists recommend at least 180 days as a safer minimum (Dr. Sarah Spayd, personal communication, NC State University, 2013). Comments from vineyard operators in the Dahlonega region suggest that the growing season there may be greater than 185 days, which makes the area a good one for many *Vitis vinifera*, French-American hybrids and native American varieties. All experts do emphasize that the minimum growing season will vary according to the varieties of grapes being grown.

Though we lack a good way of extrapolating length of growing season to unmeasured areas the Heat Summation or Winkler Scale method can be a good substitute and is useful for determining the varieties of grapes appropriate for a region’s temperature conditions. The method was developed by A. J. Winkler (Amerine and Winkler, 1944) for California grape regions, but has subsequently been applied worldwide; it divides geographical areas into five categories (Table 3) based on the average number of degrees that exceed 50°F in a month’s mean temperature, that being the generally assumed temperature at which grapes begin to grow. In the northern hemisphere this threshold temperature applies for the period from April 1 through October 31. The analysis presented above of mean monthly temperatures confirms that the threshold temperature criterion applies to the Dahlonega region. The Winkler scale is based on the number of growing degree days in the growing season. This number is calculated by summing the product of the number of degrees in each month from April through October that exceed 50°F and the number of days in the month. Using the PRISM group’s gridded 1981-2010 temperature normals I have calculated Winkler zones for 100-foot elevation increments throughout the three Dahlonega watersheds (Figure 11). The analysis indicates that the Dahlonega wine region comprises Winkler zones II-V, with all of its present vineyards falling within Winkler zone IV (Table 4 and Figure 12).

Elevation is not only a determinant of temperature patterns but of precipitation, which I have also analyzed using the PRISM group’s 1981-2010 gridded climate normals. Mean annual precipitation throughout the Dahlonega wine region is 62.4” with a range of 55.5” to 79.8”. As in many mountainous areas, precipitation in the Dahlonega region shows a direct relationship to elevation, increasing at the rate of approximately 11”/1000’ (Figure 13 and Figure 14). Variation in mean monthly precipitation shows a more complex pattern than temperature, with highest levels
Figure 10. Frost-free days (growing season length) vs. elevation from weather monitoring stations in northeastern Georgia.

Table 2. NCDC weather monitoring stations in the vicinity of the Dahlonega wine region.

<table>
<thead>
<tr>
<th>Station Name</th>
<th>Elevation (Ft)</th>
<th>Mean Frost-Free Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clayton 1SSW</td>
<td>1939</td>
<td>177</td>
</tr>
<tr>
<td>Dahlonega 1W</td>
<td>1562</td>
<td>189</td>
</tr>
<tr>
<td>Sautee 3W</td>
<td>1591</td>
<td>187</td>
</tr>
<tr>
<td>Jasper</td>
<td>1463</td>
<td>215</td>
</tr>
<tr>
<td>Gainesville</td>
<td>1171</td>
<td>234</td>
</tr>
<tr>
<td>Toccoa</td>
<td>1010</td>
<td>222</td>
</tr>
<tr>
<td>Alto</td>
<td>919</td>
<td>211</td>
</tr>
</tbody>
</table>

Table 3. Winkler zone boundaries and representative regions and grape varieties.

<table>
<thead>
<tr>
<th>Winkler Zones</th>
<th>Growing Degree Days</th>
<th>Representative Regions</th>
<th>Typical Grape Varieties</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>2500 or less</td>
<td>Côte d’Or, Champagne, Rhine Valley, Willamette Valley</td>
<td>Chardonnay, Pinot Noir, Riesling</td>
</tr>
<tr>
<td>II</td>
<td>2501 – 3000</td>
<td>Bordeaux</td>
<td>Cabernet Sauvignon, Sauvignon Blanc, Cabernet Franc, Merlot</td>
</tr>
<tr>
<td>III</td>
<td>3001 – 3500</td>
<td>Rhône Valley</td>
<td>Sauvignon Blanc, Sémillon, Syrah, Zinfandel</td>
</tr>
<tr>
<td>IV</td>
<td>3501 – 4000</td>
<td>Spain</td>
<td>Port, Barbera</td>
</tr>
<tr>
<td>V</td>
<td>Greater than 4000</td>
<td>North Africa</td>
<td>Muscat, Verdelho</td>
</tr>
</tbody>
</table>
Figure 11. Winkler scale curve for the Dahlonega wine region.

Figure 12. Winkler scale zonation of the Dahlonega wine region.
Figure 13. Mean annual precipitation in the Dahlonega wine region.

Figure 14. Mean annual precipitation vs. elevation.
occurring in January and July (Figure 15). As a general rule mature grapevines require about 24-30” of rainfall per year (Poling, 2006). Mean annual precipitation within the Dahlonega region far exceeds this requirement, and all of the present vineyards have estimated mean annual precipitation levels of 60”-65”. Excessive rainfall and snow in the three watersheds, especially at higher elevations, can have a detrimental effect on vineyards, as heavy precipitation in late winter can delay budbreak and spring pruning, which can lead to late harvest, which can be further affected by early fall frost. Excessive rainfall during the growing season also generates high humidity, a common condition in the southern Appalachians that promotes fungal diseases, excess leaf vigor, and attracts insects.

**SLOPE, ASPECT AND SOLAR RADIATION**

In areas such as the Dahlonega region that have wide ranges in elevation and contrasts in topography, terrain slope and aspect are critical factors in selecting vineyard sites that are not excessively steep and have sufficient exposure to sunlight. I have calculated slopes and aspects from the DEMs data of the three watershed areas and have attempted to see what relationship they might have to the amount of solar insolation received in the region during the growing season.

Terrain slopes in the Dahlonega region vary from 0° to 49° (Figure 16), with a mean value for the entire region of 10.5°. Slopes greater than 15° can be dangerous to work mechanically and are more difficult to work manually, therefore are considered by many US viticulturalists to be the maximum for safety and economics. Slopes steeper than 15° also have a greater propensity for loss of soil due to erosion. Highest slope angles in the Dahlonega wine region occur generally at the highest elevations formed by the Cowrock terrane and along the prominent strike valleys that occur in the southeastern parts of the Dahlonega gold belt province.

Aspect is especially important in siting a vineyard for optimum exposure to sunlight. As in all mountainous areas there is terrain with every aspect in the Dahlonega region (Figure 17), but the most common orientations have azimuths of 67.5° – 247.5° (Figure 18).

Sunlight is a critical factor in grape cultivation as it is the driving force behind photosynthesis and controls the length of the growing season. The total calculated direct and diffuse solar insolation in the Dahlonega region during the period from April 1 through October 31 is 2.18E+11 watt-hours.\(^7\) The level of solar insolation varies

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\(^7\) To put this number in perspective, it is equivalent to the amount of energy produced by burning 659,053,638 barrels of crude oil.
Figure 15. Mean monthly precipitation from gridded 1981-2010 climate normals.

Figure 16. Distribution of slopes in the Dahlonega wine region.
Figure 17. Distribution of aspects in the Dahlonega wine region.

Figure 18. Aspect frequency in the Dahlonega wine region.
considerably over the region (Figure 19), ranging from a high of $1.22E+06$ watt-hours/m² to a low value of $6.55E+05$ watt-hours/m². The highest values occur on the south-facing high peaks of the Cowrock terrane, while some of the lowest values occur on the Cowrock’s north-facing slopes and in its mountain-shadowed, dendritic valleys. Low values are also common along the strike valleys of the southeastern part of the Dahlonega gold belt. The Western Blue Ridge area has the least variation in elevation and large areas of high solar insolation. All of the operational vineyards in the Dahlonega region are situated in excellent sites for sun exposure and all are receiving approximately equivalent amounts of solar insolation (Table 5).

To test which aspect receives the highest solar insolation I have compared the Cowrock terrane and the Dahlonega gold belt. In both cases the highest mean sun exposure is for south-facing slopes, followed by those facing southeast and southwest (Figure 20). The least exposure is for slopes facing north.

Using the Western Blue Ridge area I extracted all south-facing slopes and analyzed which slope angles receive the highest solar insolation. Slopes in the range of 10°-20° appear to have the optimum inclination for sun exposure in that area (Figure 21). The highest solar insolation in the entire Dahlonega wine region is located at the highest elevation in the three watersheds (highest point in the Dicks Creek watershed); it has a slope of 10° and an aspect of 180°.

SOILS

Soils supply vines with water and essential nutrients and provide the substratum in which grapevines root. The inorganic components of soils are derived from weathering of an area’s lithologies. In the Dahlonega region the juxtaposition of four complexly evolved geological provinces has provided a variety of rock types (Table 6) that have produced an even more complex variety of soil types. Detailed soil mapping has been carried out in the region by McIntyre (1972) and is available in digital format through the US Department of Agriculture’s GeoSpatial Data Gateway. The soil series that have been mapped are in such fine detail that it is impossible to show them legibly for the entire Dahlonega region at the scale of the maps in this publication. I have analyzed, though, the soils on which the existing vineyards of the Dahlonega wine region are planted and have made individual maps of vineyards showing the soil distribution in each (Figure 22).

The most common soil that occurs in existing vineyards is also the most commonly occurring soil throughout the area of Lumpkin, Dawson and White Counties – the Hayesville series (Table 7). Five subunits of the Hayesville make up 77 acres of the approximately 100 acres of existing vineyards. The second most common soil by area is the Toccoa series with 19 acres, and the Tallapoosa series makes up 17 acres. The remaining three series – Hiwassee, Mussella and the Massada – account for less than six acres of the total.

The characteristics of soils that occur in existing vineyards are important to note. The Hayesville and Toccoa are both deep, well-drained, with moderate permeability, and are low in natural fertility and organic matter content with deep root zones. These are all considered to be excellent characteristics of good vineyard soils (White, 2009). Depth is important for vines to extend their roots in periods of drought. This is especially important for *V. vinifera*...
Figure 19. Total calculated solar insolation for the growing season in the Dahlonega wine region.

Figure 20. Comparison of aspect vs. solar insolation in the Cowrock terrane and Dahlonega gold belt.
Figure 21. Comparison of slope vs. solar insolation in the Western Blue Ridge province.

Table 5. Mean solar insolation for vineyards of the Dahlonega wine region.

<table>
<thead>
<tr>
<th>Vineyard</th>
<th>Mean Solar Insolation (watt-hours/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blackstock</td>
<td>1066467</td>
</tr>
<tr>
<td>Cavender Creek</td>
<td>1087296</td>
</tr>
<tr>
<td>Frogtown</td>
<td>1083390</td>
</tr>
<tr>
<td>Montaluce</td>
<td>1090927</td>
</tr>
<tr>
<td>Montaluce satellite</td>
<td>1073670</td>
</tr>
<tr>
<td>Three Sisters</td>
<td>1095716</td>
</tr>
<tr>
<td>Wolf Mountain</td>
<td>1087442</td>
</tr>
</tbody>
</table>

Table 6. Lithologies of geological features in the Dahlonega wine region.

<table>
<thead>
<tr>
<th>Geological Feature</th>
<th>Dominant Formation</th>
<th>Main Lithologies</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cowrock terrane</td>
<td>Coleman River Fm.</td>
<td>Metasandstone and schist, with some mafic and ultramafic bodies</td>
<td>Hatcher et al., 2005</td>
</tr>
<tr>
<td>Dahlonega gold belt</td>
<td>Otto Fm., Lake Burton Mafic-Ultramafic Complex</td>
<td>Metasandstone, muscovite schist, calcareous and muscovite quartzite, aluminous schist, gneisses amphibolites, manganiferous magnetite quartzites, with a number of meta-igneous intrusive and extrusive bodies</td>
<td></td>
</tr>
<tr>
<td>Tugaloo terrane</td>
<td>Ashe-Tallulah Falls Fm.</td>
<td>Metasandstone, pelitic schist, aluminous mica schist, with varying amounts of amphibolite and some basement rocks</td>
<td>German, 2013</td>
</tr>
<tr>
<td>Western Blue Ridge</td>
<td>Great Smoky Group</td>
<td>Massive-bedded, unsorted and graded sandstones and argillites of the Rich Butt sandstone and a lower dark, pyritic and carbonaceous argillite</td>
<td>Thigpen and Hatcher, 2009</td>
</tr>
</tbody>
</table>
varieties, which are the most widely grown grapes in the Dahlonega region, since they are long-lived and have a natural tendency to root deeply. Excessive precipitation that occurs in the Dahlonega region requires well-drained soil to remove surface water quickly and prevent waterlogging of roots. Low fertility soils, with low organic-matter content, are considered best for vineyards, as they prevent excessive vegetative growth (referred to as ‘vigor’) during the growing season, redirecting the plants energy to production of berries rather than leaves.

With the great variety of rock types that occur in the Dahlonega wine region there are doubtlessly other soils with good viticultural potential. Hayesville and Toccoa soils of the existing vineyards appear, though, to be ideal and serve as models for future vineyards.

Table 7. Main soil series in vineyards of the Dahlonega wine region.

<table>
<thead>
<tr>
<th>Soil Series</th>
<th>Mapping Units</th>
<th>Description of Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hayesville</td>
<td>HIB (Hayesville sandy loam 2–6% slopes) HIC (Hayesville sandy loam 6–10% slopes) HIE (Hayesville sandy loam 10–25% slopes) HIE3 (Hayesville sandy clay loam, severely eroded 6–10% slopes) HIE3 (Hayesville sandy clay loam, severely eroded 10–25% slope)</td>
<td>Moderately deep to deep, well-drained soils. Formed in materials weathered mainly from gneiss, but, in places, partly from schist, granite, quartzite and some basic material. Cover medium-sized to large areas on very gently sloping to sloping, medium to moderately wide ridgetops and on sloping to steep hillsides that have a dendritic drainage pattern. Permeability is moderate. Natural fertility and the content of organic matter are low. Available water capacity is medium. Root zone is moderately deep to deep. Strongly acidic. Well suited to farming. Most extensive soils in the Dawson, Lumpkin and White Counties area.</td>
</tr>
<tr>
<td>Hiwassee</td>
<td>HSC (Hiwassee loam 2–10% slopes)</td>
<td>Deep, gently sloping to steep, well-drained soils that formed in old alluvium and colluvium. Material derived from weathered basic and acidic metamorphic rocks, such as hornblende gneiss, diorite, and hornblende schist. Occur in small areas on old stream terraces, on foot slopes, in saddles, and around drainage heads along larger streams. Permeability is moderate. Fertility is medium to low. Organic content is low. Available water capacity is medium. Acidic. Deep root zone. Well suited to farming.</td>
</tr>
<tr>
<td>Masada</td>
<td>MoC2 (Masada fine sandy loam, eroded) 6-10% slopes</td>
<td>Deep, well-drained soils that developed in old alluvium washed soils derived from weathered igneous and metamorphic rocks, such as granite, gneiss and schist. Occurs in small to medium-sized areas on old stream terraces. Slopes are moderately long. Low in natural fertility and organic matter content. Strongly acidic. Permeability is moderate. Available water capacity is medium. Root zone is deep. Well suited to farming.</td>
</tr>
<tr>
<td>Mussella</td>
<td>MCE (Mussella cobbly loam) 6–25% slopes MuE2 (Mussella gravelly clay loam, eroded) 10–25% slopes</td>
<td>Moderately deep, well-drained soils on uplands. Formed in materials weathered from diorite, schist and hornblende gneiss. Occur in small to medium-sized areas. Slopes range from 6-70%. Permeability is moderate. Low in natural fertility and organic matter content. Strongly acidic. Available water capacity is generally low. Shallow to moderately shallow root zone. Suitability to farming is limited due to depth of the effective rooting zone and a cobbly surface layer.</td>
</tr>
<tr>
<td>Tallapoosa</td>
<td>TDG</td>
<td>Well-drained to excessively drained soils that formed in materials weathered from mica schist, quartzite and mica gneiss. Occur in the lower mountain ranges, on narrow, long and broken, sloping to steep ridgetops and on short, broken, steep to very steep hillsides. Low in natural fertility and organic-matter content. Strongly acid to very strongly acid. Permeability is moderate. Low available water capacity. Shallow root zone. Not well suited to farming because of shallow root zone and occasional steep, broken surfaces.</td>
</tr>
<tr>
<td>Toccoa</td>
<td>ToC</td>
<td>Deep, well-drained soils. Occur on narrow to moderately wide flood plains, generally along moderately rapid to rapid stream that have channels more than four feet deep. Low in natural fertility and organic-matter content. Medium acid. Permeability is medium rapid. Available water capacity is medium. Root zone is deep.</td>
</tr>
</tbody>
</table>
Figure 22. Soil types in Dahlonega wine region vineyards.
CONCLUSIONS

In this short analysis I have illustrated the use of geospatial analysis to uncover a number of key elements in the Dahlonega wine region that are important for the area’s viticulture and that are not readily discernible from the usual data types, such as hardcopy topographic maps and widely separated NCDC weather stations. Most vineyard operators know intuitively or through experience that temperature and precipitation vary with elevation and season, but not many know to what degree they vary. Using the PRISM group’s gridded climate normals we have been able to make an estimate of the rate of change and how that rate varies from month to month. By calculating a Winkler zonation for the Dahlonega region we have devised a method of estimating the elevations at which different grape varieties can be cultivated. And using digital elevation models we have calculated slopes, aspects and solar insolation for the region and now have a better idea as to the best areas for maximum sunlight exposure and know the optimum slope and aspect for a future vineyard. We have ascertained the soil types that have been successful for the present vineyard operators and know the types of soils to look for in our own ideal vineyard site. And we have done all this using free data and some fairly inexpensive but powerful software.

I would, though, like to offer one word of caution. I have emphasized the importance of climate as the most critical factor in viticultural success, and in evaluating potential vineyard sites we almost always use climate data as our first criterion. What could be more satisfying than 30-year climate normal data? It has the benediction of the best scientists who have measured the data, processed and published it with the approval, support and full backing of our government weather agencies. And so we use the climate data from these agencies and find our ideal site. And then several years into our new venture comes the late spring frost after budbreak, or the early fall frost before harvest, or the hail storm, or tornado, or the winter that is too warm, or the summer that is too dry, all unpredicted by our latest climate normals. It reminds me of a quote from Mark Twain: “Climate is what we expect, weather is what we get.”
REFERENCES CITED


McIntyre, C. L., 1972, Soil Survey of Dawson, Lumpkin, and White Counties, Georgia: US Department of Agriculture in Cooperation with the University of Georgia, 105 pages.


APPENDIX – The pages that follow contain descriptions of the four vineyard stops.
Vineyard Stop 1

Location: Long. 83° 58’ 44.392”W, Lat. 34° 35’ 39.935”N (Tasting room)
Address: 180 Wolf Mountain Trail
Dahlonega, GA 30533
Owner/Operator: Karl Boegner
Winemakers: Karl Boegner, Steve Boegner
First Planting: 2000
Vineyard Size: 10.0 acres. 5000 vines
Elevation: Average 1592’ (1526’ – 1666’)
Orientation: Lots run east-west with south-facing slopes
Geology: Cowrock terrane. Coleman River Formation: Interlayered metasandstone, quartz-feldspar gneiss, and pelitic schist with minor caleisiclate quartzites and amphibolite.
Soils: Hayesville sandy loam (10-25% slopes), and Tallapoosa series
Grape Varieties: 7 varieties of *V. vinifera* (Cabernet Sauvignon, Malbec, Mourvedre, Syrah, Tannat, and Touriga Nacional)
Trellising: Vertical Shoot Positioning to provide maximum sun and spray penetration. Vines trained up to four foot fruiting wire to take advantage of mountain-top air circulation, which helps combat excessive rainfall and high humidity.
Yields: 3 – 5 tons/year. Operator keeps yields low by green harvesting early in growing season in order to produce limited quantities of high-quality grapes.
Production: 3500-4000 cases/year at present.
Wines: 15 *vinifera* styles. Also produces 4 styles of sparkling wines by traditional Methode Champenoise using 100% Georgia grown Chardonnay and Syrah.
Vineyard Stop 2

Location: Long. 83° 52’ 45.963”W, Lat. 34° 36’ 32.928”N (Tasting room)
Address: 439 Vineyard Way
Dahlonega, GA 30533
Owner/Operator: Doug and Sharon Paul
Winemakers: No official winemaker – Wine produced by consensus
First Planting: 1998
Vineyard Size: 20.4 acres
Elevation: Average 1695’ (1692’ – 1750’)
Orientation: General trend of property is east-west with mainly south-facing vineyard slopes
Geology: Otto Formation: Metasandstone, light to dark-gray, fine to medium-grained and quartz dominant with locally abundant staurolite.
Soils: Hayesville sandy loam (10-25% slopes), and Hayesville sandy loam (6 – 10% slopes)
Trellising: Vertical Shoot Positioning used for the European varieties. Geneva Double Curtain used for the native American variety. Also use Kniffen Renewable.
Production: 3500-4000 cases/year at present.
Wines: 1 100% estate grown grapes and wines. 5 blends from vinifera, hybrid and American grapes, 2 vinifera varietals (Chardonnay and Merlot) and an ice wine (made from frozen Vidal Blanc grapes).
Vineyard Stop 3

Location: Long. 83° 54’ 32.917”W, Lat. 34° 33’ 26.926”N (Tasting room)
Address: 3610 Cavender Creek Road
          Dahlonega, GA 30533
Owner/Operator: Raymond and Donna Castleberry
Winemaker: Raymond Castleberry
First Planting: 2007
Vineyard Size: 4.0 acres
Elevation: Average 1547’ (1528’ – 1564’)
Orientation: Vineyard lots oriented northeast-southwest. Topography of lots is almost flat with
gentle slopes to northwest and southeast
Geology: Otto Formation: Metasandstone, light to dark-gray, fine to medium-grained and
quartz dominant with locally abundant staurolite.
Soils: Hayesville sandy loam (2 - 6% slopes), and Hayesville sandy loam (6 – 10% slopes) and
Hayesville sandy loam (10 – 25%). The property was formerly a farm, and the vineyard lots are located in an old pasture. The farm raised chickens
and for many years the manure was deposited over the pasture. The soil is thus
over-fertile and produces excess vigor in the vines.
Grape Varieties: 5 varieties of V. vinifera (Cabernet Franc, Cabernet Sauvignon, Petit Manseng,
Touriga Nacional, Viognier), 1 native American variety (Cynthiana-Norton).
Trellising: Modified Lyre
Wines: 9 styles at present
Vineyard Stop 4

Location: Long. 84° 04’ 0.533”W, Lat. 34° 33’ 52.177”N (Tasting room)
Address: 946 Via Montaluce
Dahlonega, GA 30533
Owner/Operator: Toll Brothers/Gibraltar Group
Winemaker: Maria Peterson
First Planting: 2006
Vineyard Size: 12.0 acres
Elevation: Main lots: av. 1471’ (1401’ - 1533’). Satellite lots: av. 1472’ (1458 – 1493’).
Orientation: Main vineyard lots are oriented northeast-southwest and slope south. Satellite
vineyard is oriented northwest-southeast and slopes southwest.
Geology: Lake Burton Mafic-Ultramafic Complex. Main vineyard lots are located partially
on two units – a metagabbro and amphibolite unit and a felsic gneiss and
amphibolite unit. The satellite vineyard is located entirely on the felsic gneiss and
amphibolite unit.
Soils: The main vineyard lots are mainly on Tallapoosa soils, with small marginal
patches of Hayesville sandy loam (10-25% slopes). The satellite lots are entirely
on Hayesville sandy loam (10-25% slopes). Some reported problems with low
zinc and magnesium in soils.
Grape Varieties: 7 varieties of V. vinifera (Cabernet Franc, Chardonnay, Malbec, Merlot, Petit
Verdot, Pinot Gris, Sangiovese) and 2 French-American hybrids (Seyval Blanc
and Vidal Blanc). Cabernet Sauvignon was recently removed due to poor
performance.
Trellising: Single Curtain
Wines: 11 styles at present. 4 vinifera blends, 2 hybrid blends, 2 hybrid varietals, 3
vinifera varietals, and a mead (honey wine).
WINE PRODUCTION AND THE LOCAL CLIMATE OF DAHLONEGA, GEORGIA

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Northeast Georgia, including Dahlonega, is broadly classified within the Humid Subtropical climate type of the well-known Koeppen system. However, within this macroclimate, there are many local or micro-climates formed by factors such as aspect, location on a slope, or land-use / land-cover. Microclimate information is an important consideration for a vineyard as it aids in the selection of the particular cultivars and products. The Three Sisters Vineyards, one of the several vineyards that will be visited on the field trip, has an automated observing station as part of the Georgia Environmental Monitoring Network located on-site adjacent to its vineyards (Figure 1). This station, which has been in operation since 2002, provides outstanding local real-time and climate information and has data that covers most of the period of production, which began in 2000 (Three Sisters Vineyards, 2013).

Data from this station can be used to examine the local climate conditions and its suitability for wine production over the period 2003-2012. There are several major climatic factors that affect grape production, including winter minimum temperatures and spring frost, length of growing season, heat unit accumulation, and precipitation during key phases of the grape’s development (Bordelon, 2009). To be sure, different varieties of grapes will vary in their ability to tolerate low winter temperatures, their vulnerability to spring frosts, and their heat unit requirements to ripen (Double Vineyards, 2011).

Winter minimum temperatures are a key limiting factor for many grape varieties, which lack cold hardiness. Dahlonega has a fairly moderate climate with an annual average temperature range of approximately 19°C. Typical minimum temperatures fall slightly below or near the freezing point in December, January and February but have reached values as low as of -4 oC (Figure 2). The average minimum winter temperatures near 0°C means that even the most cold-sensitive grape varieties would have sufficient cold hardiness for the Dahlonega area (Bordelon, 2009).

The length of growing season indicates the time available for grapes to ripen. Early ripening varieties require ≥ 150 days while late ripening varieties need ≥ 180 days (Bordelon, 2009). The length of the growing season is determined by the frost-free period and is calculated from the dates of the first and last frosts of the year. The first frost of the year typically occurs around 1 November but ranges from mid-October (14 October) to mid-November (15 November). The last frost day of the season typically occurs around 2 April but can vary from early March (7 March) to early May (4 May). Thus, growing season typically lasts about 211 days, extending from April through October but its length has varied between 194 and 244 days. The long
Figure 1: (a) Map of Three Sisters Vineyards. Source image for map is Google Maps (b). GAEMN observing station (2013) Source is http://www.griffin.uga.edu/aemn/station_pics/full/DAHLO.jpg
Figure 2: Mean monthly maximum, minimum and average temperatures, 2003-2012.

Table 1: Growing Season Length and Wine

<table>
<thead>
<tr>
<th>Growing Season Length (days)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;200</td>
<td>Better for longer season varieties</td>
</tr>
<tr>
<td>&gt;190</td>
<td>Not limiting</td>
</tr>
<tr>
<td>&gt;180</td>
<td>Good</td>
</tr>
<tr>
<td>&gt;170</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>&gt;160</td>
<td>Marginal - acceptable for earliest ripening varieties</td>
</tr>
<tr>
<td>&lt;160</td>
<td>Not recommended, too short to fully ripen crop</td>
</tr>
</tbody>
</table>

¹data from [http://arcserver2.iagt.org/vll/learnmore.aspx](http://arcserver2.iagt.org/vll/learnmore.aspx)
growing season in Dahlonega makes it suitable late ripening varieties (Table 1).

Grapes need a sufficient amount of heat accumulation to grow and ripen. In viticulture, this is often measured by growing degree days (GDD), which are computed by subtracting a base temperature of 10°C from the average daily temperature and then accumulating the values over the year. During a typical growing season (1 April – 31 October) the Dahlonega area receives from 1969-2360 GDDs, with an average of 2122 GDDs (Figure 3). The Winkler scale, based on accumulated GDDs, is sometimes used to classify the climate of an area and its suitability for particular grape varieties (Table 2; Amerine and Winkler, 1944). The typical GDD of 2122 would place Dahlonega in category 4, where GDDs range from 1945-2222.

Dahlonega receives on average 1486 mm of precipitation per year with a range from 904-2119 mm over the 2003-2012 period (Figure 4). The year 2007 had unusually dry conditions and received only 60% of typical rainfall. Indeed, the broader region was suffering through a particularly severe drought. Precipitation is well distributed throughout the year in Dahlonega without a distinct dry season (Figure 5). The greatest rainfall amounts, however, occur in March, August, September, and December and minimum rainfall in October. A simple water budget shows that rainfall is typically sufficient to meet climatic demands for water, with no periods of deficit (Figure 6). Much of the year has surpluses where water supplies exceed demands after filling the soil. Only during the hot summer months does demand for water (APE) exceed supply from precipitation and soil moisture withdrawals occur.

Terroir can be roughly defined as “sense of place” and is a concept that refers to the specific characteristics of landscape, soils, and climate of a particular location. Some believe that the unique characteristics of a location impart a special quality to the grapes. In terms of climate, Dahlonega provides many favorable characteristics for wine production, including mild winters, long growing seasons with sufficient heat accumulation, and plenty of rainfall for developing grapes.

Figure 3: Cumulative growing degree days, 2003-2012. Heavy black line is the mean cumulative GDD and gray lines represent cumulative GDDs for individual years.
Figure 4: Annual total precipitation by year

Figure 5: Average monthly precipitation, 2003-2012.
Figure 6: Soil water balance. APE is adjusted potential evapotranspiration, PRE is precipitation, and AE is actual evapotranspiration. Computations were completed by assuming 150 mm per m of field capacity using average monthly inputs of temperature and precipitation.

Table 2: Winkler Scale

<table>
<thead>
<tr>
<th>GDD (°C)</th>
<th>Region</th>
<th>Sample Region¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1389</td>
<td>I</td>
<td>Rhine, Germany</td>
</tr>
<tr>
<td>1389-1667</td>
<td>II</td>
<td>Bordeaux, France</td>
</tr>
<tr>
<td>1667-1944</td>
<td>III</td>
<td>Napa, California</td>
</tr>
<tr>
<td>1945-2222</td>
<td>IV</td>
<td>Southern Spain</td>
</tr>
<tr>
<td>&gt;2222</td>
<td>V</td>
<td>North Africa</td>
</tr>
</tbody>
</table>

¹ from http://www.answers.com/topic/climate-regions-of-california-1
REFERENCES CITED


NOTES
FLOW PATHWAYS, BASEFLOW SEPARATION, AND RUNOFF PREDICTION

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INTRODUCTION

Understanding the relationship between rainfall and storm runoff is important for watershed management. Erosion that results in gully formation, for example, can be very destructive. Also, changing surface conditions may result in excessive runoff, or reduce the amount of soil moisture available to plants. This paper will review some recent research concerning the identification of flow paths in an undisturbed watershed, how those flow paths may be apportioned using a digital filter to identify storm flow, and summarize how a new technology can be employed to estimate runoff from an ungauged watershed. The field data and interpretation is from the Panola Mountain Research Watershed. This watershed is in the Piedmont Province, thus hydrologically similar to the terrain in the vicinity of the Three Sisters Winery. The approach described has also been successfully tested at the Coweeta Hydrologic Laboratory in the Blue Ridge Mountains of North Carolina. As described at the end of the paper, it could not be formally applied at the Three Sisters Winery because high-resolution topographic data is not yet available.

FLOW PATHS

Panola Mountain Research Watershed was established by the USGS in the mid 1980’s for acid rain research. It is approximately 25 km southeast of Atlanta, has a drainage area of 41 ha, and is forested with mixed hardwoods and conifers. The USGS has collected high temporal resolution runoff data measured at a flume, rainfall data from near the flume, and geochemical data from a large number of shallow to deep wells, lysimeters and zero tension lysimeters scattered across the watershed. Most of the samplers were used for only a short time, but their aggregate samples represent a reasonable range of geochemical values that can be found on the watershed. Figure 1 illustrates the watershed.

The conventional method to determine the relative contribution of several water sources is with end member mixing. Distinct sources of runoff are identified, such as soil water, event water, and groundwater. A chemical constituent in the stream flow is measured over the course of a storm or storms, and the values compared to the end member values. Because the relative contributions of the end members vary over the course of a storm, the method provides only a rough estimate of the quantities associated with the contributing areas. Evans and Davies (1998) introduced a different approach to identify the relative abundance
of three contributing sources. They plotted discharge versus chemical concentration over the course of a storm, which produced a hysteresis loop. Using the shape and direction of the loop, they asserted the relative quantities of the source areas.

Cary (2011) presented a new method to quantify flow paths called dynamic end member mixing. He used chloride and silica concentrations to match a synthetically derived hysteresis loop to the measured loop. Figure 2 shows a hysteresis loop with the associated synthetic loop for a storm. Figure 3 shows the relative contributions from four source areas derived from fitting a hysteresis loop.

Analysis of 16 large storms showed that for this watershed only a small portion of runoff can be attributed to what can be geochemically identified as true groundwater, that is, saprolite water or granitic fracture flow. Instead, a large portion of the stream flow cannot be differentiated from groundwater plus deep and/or shallow hill slope water.

**BASEFLOW SEPARATION**

Mason-Deese (2013) used Cary’s hydrograph disaggregation to compare several common digital filters. These filters are used to separate storm flow from base flow, which is essential when estimating runoff for ungauged watersheds. Lyne and Hollick (1979) first introduced a recursive digital filter to identify baseflow:

\[
b_k = \alpha b_{k-1} + \frac{(1 + \alpha)}{2} (y_k + y_{k-1})
\]

\[
b_k \leq y_k
\]
where $b_k$ is the filtered baseflow, $k$ is the time step, $y$ is the observed stream flow, and $\alpha$ is the filter parameter. Chapman (1999) proposed a modification to the Lyne-Hollick algorithm that uses the recession curve for periods after the end of storm flow, and defines the filter parameter, $\alpha$, as the recession constant:

$$
\frac{1}{2 - \alpha} b_k - 1 + \frac{1 - \alpha}{2 - \alpha} y_k \quad b_k \leq y_k
$$

Eckhardt (2005) argues that the one parameter filter is a simplified version of a more generalized two parameter filter, and

![Figure 2](image1.png)

Figure 2. Hysteresis loop for a Panola storm. The squares are numbered sequentially as sampled; the blue line is the derived loop.

![Figure 3](image2.png)

Figure 3. Runoff contributions derived from a hysteresis loop.
introduces the second parameter as $BFI_{\text{max}}$, the maximum base flow index. His filter is:

$$b_k = \frac{(1 - BFI_{\text{max}})ab_{k-1} + (1 - a)BFI_{\text{max}}y_k}{1 - aBFI_{\text{max}}},$$

$$b_k \leq y_k$$

The baseflow Index is defined as the long term ratio of baseflow to total stream flow. The $BFI_{\text{max}}$ is defined by Eckhardt as the maximum value the algorithm can model, which has no physical meaning, thus cannot be measured. He suggests that predefined values based upon the underlying geology and flow regime can be used: 0.8 for perennial streams on porous aquifers, 0.5 for ephemeral streams on porous aquifers, and 0.25 for perennial streams on hard rock aquifers.

These filters were fit to the geochemically derived Panola sub-hydrographs. In all cases the digital filters over-estimate groundwater flow, and most closely resemble groundwater plus the deeper hillslope water, or groundwater plus the two hillslope waters. Figure 4 shows the fit for one of the large storms. For these storms the filters could not adequately mimic the rapid early rise of the sub-hydrograph. These storms had a hysteresis loop that was counter-clockwise. Figure 5 shows the filters fit for a smaller clockwise storm, where the filters adequately mimic the sub-hydrograph shape. The hysteresis loop direction and sub-hydrograph shapes indicate that source area contributions have a different dynamic for the large storms. The recession parameter, $\alpha$, was fit over a relatively narrow range. The best fit of the $BFI_{\text{max}}$ did not usually agree with Eckhardt’s suggested values, but more closely agree with a regional estimate of BFI from the USGS. $BFI_{\text{max}}$ proved to be the more sensitive parameter and varied between clockwise and counter clockwise storms, even though in general the Eckhardt filter provided a better overall fit. These results suggest that the more easily parameterized Lyne and Hollick and Chapman filters would be adequate for estimating baseflow in a watershed where geochemical techniques cannot be used, but that they must be considered to be over-estimating true groundwater flow into the stream.

**Runoff Determination**

In most locations where runoff estimates are required there are no stream flow records available. Estimating this runoff has been done by a variety of methods, with many based on the unit hydrograph, which is the hydrograph that occurs for a unit value of rainfall excess over a specified period of time. A number of algorithms have been developed to estimate the unit hydrograph, including Corps of Engineers and Soil Conservation Service methodologies. A variant of the unit hydrograph is the instantaneous unit hydrograph introduced by Clark (1945). It mimics the runoff expected from a unit application of rainfall excess applied instantaneously. The storm hydrograph can be derived from this procedure by convolution:

$$Q(t) = A \int_0^t i(t)u(t - \tau)d\tau$$

where $i(t)$ is the rainfall excess, that is, the portion of rainfall that becomes runoff; $u(t)$ is the unit response function; $A$ is the watershed area; and $Q(t)$ is the direct or storm runoff (not the total runoff). Clark proposed a gamma distribution for the unit response function because it had the appropriate shape.
Recent research has proposed that the unit response function can be derived from the geomorphological characteristics of the watershed. One approach is to derive the instantaneous unit hydrograph from the convolution of response functions derived from the average length of the Strahler Order of a runoff network. Thus a gamma distribution derived from the average length of all first order stream segments would be convoluted with the gamma distribution derived from the average length of all second order streams segments, etc, until all stream segment orders have been accounted for (Cudennec et al., 2004; Fleurant et al., 2006). Both studies relied on an independent estimate of rainfall excess applied to the entire watershed and a map-based derivation of the network. But normal topographic maps do not contain the vertical scale that permits interpolating ephemeral channels beyond the obvious gully.

We propose the use of high resolution LiDAR, a light-based system to measure distance much like radar, to obtain detailed topography. Using this topography, a network is obtained using the procedures of Tarboton et al. (1992) with the latest version of the software (Tarboton, 2012). Figure 6 illustrates some of the networks that can be derived for Panola.

We have also modified the IUH assumptions. Instead of computing independently rainfall excess from rainfall and applying it to the entire watershed, we propose that runoff be computed from rainfall for an area adjacent to the stream network. This is functionally equivalent to assuming that the ratio of rainfall excess to rainfall is equivalent to the area of the watershed adjacent to the network. In other words, the watershed contributes runoff only adjacent to the network and the rest of the watershed contributes only to the non-storm baseflow. Initial results are encouraging that the area adjacent to the network channels can be estimated, and that the extent of the network contributing during a storm can be identified (Figure 7).
Figure 5. Digital filters fit to groundwater plus deep hillslope water for a clockwise storm.

Figure 6. Drainage networks for Panola. Differences relate to assumptions concerning network derivation.
THREE SISTERS WINERY

Existing LiDAR unfortunately ends adjacent to the Three Sisters Winery and a detailed network cannot be constructed for it. Figure 8 however, shows a network for the area adjacent to the site. Even without formally calculating runoff, this approach is useful for several reasons. First, it identifies the areas in the watershed that actively contribute runoff during a storm. Modification of land that does not normally contribute could significantly increase stream flow, resulting in increased flooding. Changing land use in contributing areas, however, would be expected to have minimal stream flow increases. The network areas identify where stream flow will occur,
thus areas of maximum risk of erosion. Areas with uniform slopes, under undisturbed conditions, do not usually produce significant runoff. Thus the procedure used here may show them as areas without network segments, although small elevation changes could result in a series of parallel channels down the slope. If the vegetation is disturbed or removed, these slopes are likely to start to develop incipient ephemeral channels that will ultimately develop into true ephemeral channels.

The channel network has implications for water quality as well. Chemicals introduced in the vicinity of the ephemeral channels will quickly find their way to the outlet of the watershed. Chemicals used in the areas where the channels are not found, however, will be transported slowly in the soil down slope, and only be introduced to the stream after a considerable time.

Three Sister's Vineyards

Figure 8. Network derived from LiDAR adjacent to Three Sisters Winery.
REFERENCES CITED


Mason-Deese W. 2013. Modeling stormflow in ungauged basins: Using digital filters, LiDAR, and the geomorphological instantaneous unit hydrograph In *Geology*. The University of Georgia: Athens, GA.


INTRODUCTION

Soils are a complex biological, physical, mineralogical, and chemical system that have developed in response to their environment, both past and present. Thus, properties of a soil at any point in the landscape can be considered the result of interactions among five factors considered by most scientists to control soil formation (Jenny, 1941). Four of these factors, climate, topography, vegetation, and parent material, are active and describe the physical environment to which the soil has been exposed. The fifth, time, allows the other four factors to express themselves on the soil we observe today.

For the most part, variation in the four environmental factors and, to a lesser extent, time is reflected in the concept of Major Land Resource Areas (MLRA's) (USDA-NRCS, 2006). These divisions reflect broad differences in geology, topography, climate, and vegetation across the south region and the United States. In many cases, MLRA boundaries are similar to those that delineate physiographic provinces (Georgialnfo, 2013) and or ecoregions (Georgia DNR, 2001) and the three landscape divisions often are named similarly, e.g. Blue Ridge (Fig. 1).

The northeastern part of Georgia is part of MLRA 130B, Southern Blue Ridge, which extends to the northeast into Virginia (Fig. 1A; USDA-NRCS, 2006). This belt of southwest-northeast trending mountains is strongly dissected, considerable local relief, and is characterized by steep mountain slopes with narrow valleys (Schoeneberger, 1996).

Elevations generally range from about 300 to 1,200 m, and local relief may be up to 1,000 m although relief is normally much less (Schoeneberger, 1996; USDA-NRCS, 2006). Forests were almost universal throughout the MLRA prior to European settlement except for a few areas of rounded, grassy summits called “balds” (Thornbury, 1965; Daniels et al., 1999). The area, however, has been characterized as being on of the richest centers of biodiversity in the eastern U.S. (Georgia DNR, 2001).

Mountains in this MLRA are often described as subdued as compared with those in the western United States (Thornbury, 1965). Peaks are generally rounded, and a relatively thick mantle of saprolite commonly occurs over harder rocks forming the core of the mountains (Daniels et al., 1999). Bare cliffs and peaks are rare. Upland soils are developed from either residual or colluvial parent materials, and soils on floodplains and stream terraces are developed in alluvium from streams in the narrow valleys.

Precambrian-Paleozoic metamorphic and igneous rocks underlie the majority of the Southern Blue Ridge. The degree of metamorphism varies, and this variation is generally reflected in properties of the
Figure 1A. Extent of Major Land Resource Areas 130B.

Figure 1B. Note similarity of boundaries of MLRA in Georgia with those of physiographic Blue Ridge province (GeorgiaInfo, 2013).
Figure 1C. Note similarity of boundaries of MLRA in Georgia with those of Blue Ridge Ecoregion (Georgia DNR, 2001).
soils. The following discussions of soil properties and distribution are primarily related to soils associated with rocks with a high grade of metamorphism. Many of the concepts, however, are applicable to soils on rocks with a lower grade of metamorphism. Weathering of the rocks has resulted in various thicknesses of saprolite occurring over most of the residual landscapes (Graham et al., 1990; Daniels et al., 1999).

Although many of the upland soils have been described as being developed from residual parent materials, few are truly developed in residuum. Soil creep is common on steep slopes, and upper soil horizons have developed in colluvial materials that overlie residual horizons at variable depths (Daniels et al. 1999). Soils developed entirely in colluvium are common on lower hill slope segments, narrow valleys, coves, and other concave positions (Stolt et al., 1993).

The soil parent materials over the region are dominantly acid including granite gneiss, mica schist, mica gneiss, and associated rock types, and soils in the region reflect the mineralogy of these rocks. They are dominantly Ultisols and acid Inceptisols, commonly deep, and well drained. Chemical properties are relatively uniform with low pH and base saturation. Kaolinite commonly is the major clay mineral in these soils and most have varying amounts of hydroxy-interlayered vermiculite (Graham and Buol, 1990). Intense leaching due to moderate to high hydraulic conductivity and free drainage (well or excessively-well drained) have resulted in the soils often being strongly desilicated, and gibbsite contents are often high even in moderately developed soils (Calvert et al., 1980; Norfleet and Smith, 1989).

Although soil parent materials in the region are dominantly felsic, there are isolated areas of intermediate and mafic rocks, and soils developed from these more basic parent materials have properties that may be considerably different than soils developed from acid rocks. Because of their minor aerial extent, however, soils associated with the basic rocks were not recognized in any of the soil surveys of the region. Based on characteristics of soils developed from basic parent materials in the Piedmont to the south, soils in the Blue Ridge developed from these parent materials would be expected to have relatively high pH and base saturation and commonly, moderate to high amounts of 2:1 clays with higher cation exchange capacity and shrink-swell potential. The Ca:Mg ratio of soils developed from the more basic rocks may be much lower than that found in soils in the more acid rocks in the area.

The properties of a soil are most often attributed to the combined effects of five environmental state factors; climate, parent material, topography, biology, and time (Jenny, 1941). Thus, by inference, a change in any one of these five factors will result in changes in properties of the soil. Recognition of change in one or more of the factors across the landscape is the basis for recognition of different types of soils (soil series) and for mapping the distribution of soils across the landscape (Hudson, 1992).

In the Southern Blue Ridge, topography is generally the factor to which soil differences are most often attributed. Components of topography commonly considered are elevation, slope aspect, and landscape position. These landscape properties are readily observable and commonly are associated with differences in microclimate, type of parent material, and soil age.

As soils develop in Blue Ridge landscapes, weathering of mica, feldspars, and other primary minerals releases Fe, which reprecipitates as Fe oxides and oxyhydroxides, and forms clay, i.e. mica and
Table 1. Partial list of series recognized in Blue Ridge Mountains and differentiating criteria

<table>
<thead>
<tr>
<th>Series</th>
<th>Soil Depth cm</th>
<th>Particle Size Class</th>
<th>Mineralogy Class</th>
<th>B Horizon Color</th>
<th>A Horizon: Depth Distribution of Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porters</td>
<td>100-150</td>
<td>Fine-loamy</td>
<td>Isotic</td>
<td>Brown</td>
<td>Thick dark color; uniform</td>
</tr>
<tr>
<td>Plott</td>
<td>&gt;150</td>
<td>Fine-loamy</td>
<td>Isotic</td>
<td>Brown</td>
<td>Thick dark color; uniform</td>
</tr>
<tr>
<td>Cashiers</td>
<td>&gt;150</td>
<td>Fine-loamy</td>
<td>Micaceous</td>
<td>Brown</td>
<td>Thick dark color; uniform</td>
</tr>
</tbody>
</table>

**Residuum: High Elevation (>~1,200 m); North and east facing slopes**

<table>
<thead>
<tr>
<th>Series</th>
<th>Soil Depth cm</th>
<th>Particle Size Class</th>
<th>Mineralogy Class</th>
<th>B Horizon Color</th>
<th>A Horizon: Depth Distribution of Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashe</td>
<td>50-100</td>
<td>Coarse-loamy</td>
<td>Mixed</td>
<td>Brown</td>
<td>Thin or light color; uniform</td>
</tr>
<tr>
<td>Chestnut</td>
<td>100-150</td>
<td>Coarse-loamy</td>
<td>Mixed</td>
<td>Brown</td>
<td>Thin or light color; uniform</td>
</tr>
<tr>
<td>Edneyville</td>
<td>&gt;150</td>
<td>Coarse-loamy</td>
<td>Mixed</td>
<td>Brown</td>
<td>Thin or light color; uniform</td>
</tr>
<tr>
<td>Chandler</td>
<td>&gt;150</td>
<td>Coarse-loamy</td>
<td>Mixed</td>
<td>Brown</td>
<td>Thin or light color; uniform</td>
</tr>
</tbody>
</table>

**Residuum: High Elevation (>~1,200 m); South and west facing slopes**

<table>
<thead>
<tr>
<th>Series</th>
<th>Soil Depth cm</th>
<th>Particle Size Class</th>
<th>Mineralogy Class</th>
<th>B Horizon Color</th>
<th>A Horizon: Depth Distribution of Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tallapoosa</td>
<td>&lt;50</td>
<td>Fine-loamy</td>
<td>Mixed</td>
<td>Red</td>
<td>Thin or light color; B horizon clay increase</td>
</tr>
<tr>
<td>Cowee</td>
<td>50-100</td>
<td>Fine-loamy</td>
<td>Parasequic</td>
<td>Red</td>
<td>Thin or light color; B horizon clay increase</td>
</tr>
<tr>
<td>Hayesville</td>
<td>&gt;150</td>
<td>Fine</td>
<td>Kaolinitic</td>
<td>Red</td>
<td>Thin or light color; B horizon clay increase</td>
</tr>
<tr>
<td>Fannin</td>
<td>&gt;150</td>
<td>Fine-loamy</td>
<td>Micaceous</td>
<td>Red</td>
<td>Thin or light color; B horizon clay increase</td>
</tr>
<tr>
<td>Evard</td>
<td>&gt;150</td>
<td>Fine-loamy</td>
<td>Parasequic</td>
<td>Red</td>
<td>Thin or light color; B horizon clay increase</td>
</tr>
</tbody>
</table>

**Residuum: Low Elevation**

<table>
<thead>
<tr>
<th>Series</th>
<th>Soil Depth cm</th>
<th>Particle Size Class</th>
<th>Mineralogy Class</th>
<th>B Horizon Color</th>
<th>A Horizon: Depth Distribution of Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tusquitee</td>
<td>&gt;150</td>
<td>Fine-loamy</td>
<td>Isotic</td>
<td>Brown</td>
<td>Thick dark color; uniform</td>
</tr>
<tr>
<td>Tuskasegee</td>
<td>&gt;150</td>
<td>Fine-loamy</td>
<td>Isotic</td>
<td>Brown</td>
<td>Thick dark color (thicker than Tusquitee); Uniform</td>
</tr>
<tr>
<td>Callasaja</td>
<td>&gt;150</td>
<td>Loamy-skeletal</td>
<td>Isotic</td>
<td>Brown</td>
<td>Thick dark color; uniform</td>
</tr>
</tbody>
</table>

**Colluvium: High Elevation (>~1,000 m)**

<table>
<thead>
<tr>
<th>Series</th>
<th>Soil Depth cm</th>
<th>Particle Size Class</th>
<th>Mineralogy Class</th>
<th>B Horizon Color</th>
<th>A Horizon: Depth Distribution of Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Braddock</td>
<td>&gt;150</td>
<td>Fine</td>
<td>Mixed</td>
<td>Red</td>
<td>Thin or light color; B horizon clay increase</td>
</tr>
<tr>
<td>Saunook</td>
<td>&gt;150</td>
<td>Fine-loamy</td>
<td>Mixed</td>
<td>Brown</td>
<td>Thin or light color; B horizon clay increase</td>
</tr>
<tr>
<td>Brevard</td>
<td>&gt;150</td>
<td>Fine-loamy</td>
<td>Parasequic</td>
<td>Red</td>
<td>Thin or light color; B horizon clay increase</td>
</tr>
</tbody>
</table>

**Colluvium: Low Elevation**

---

1. Depth to rock, either soft (Cr horizon) or hard (R horizon).
2. Based on weighted average sand and clay content of the upper 50 to 75 cm of the B horizon; coarse-loamy - >15% sand, <18% clay; fine-loamy - >15% sand, 18-35% clay; fine - >35% clay; loamy skeletal - <35% clay, > 35% coarse fragments.
3. Based on mineral contents of upper 50 to 75 cm of B horizon; clay fraction evaluated if fine particle size class; otherwise placement is based on fine sand and coarse silt fractions; mixed – no dominant mineral; kaolinitic (fine particle size class) - >50% kaolinite, <10% smectite; micaceous - >45% mica and stable pseudomorphs of mica in 0.02-0.25 mm fraction; parasequic – (% Fe₂O₃ + % gibbsite) >10; isotic – pH in NaF >8.4, 1500 kPa water content / % clay >0.6.
K-feldspar are weathered to kaolinite and gibbsite. Additionally, clay in near surface horizons disperses with wetting by rainfall and is translocated to subjacent B horizons by water moving vertically through the soil. The net result of these processes is reddening of subsoils and an increase in amount of clay in B horizons as compared to A and E horizons. Thus, weak to moderately developed soils on younger surfaces are browner and have uniform clay content with depth as contrasted to more developed soils on more stable surfaces that have red subsoils and an increase in clay between A and E horizons and subjacent Bt horizons (Table 1).

Generally, back-slopes at high elevation are steeper than those in foothills at the base of the higher mountains and have higher rates of erosion and associated loss of surface soil. The continual loss of surficial material reduces the age of the landscape surface, and soils are less developed than soils on more gentle slopes at lower elevation. Soils in the Blue Ridge at elevations greater than about 1,200 m are generally Inceptisols, have brown to yellowish brown subsoils, and do not have an increase in clay between A and subjacent B horizons (Table 1). Soil depth to hard rock is often <1.5 m and is commonly <1.0 m although very deep soils are common (Fig. 2).

Generally, mean annual precipitation is greater at high as compared to low elevation, and precipitation may be reduced in valleys that lie in the rain shadow of high mountains. Soil differences related to these conditions have not been recognized, however, probably because precipitation in the region and associated degree of soil development are great enough to mask soil property differences related to orographic and rain shadow effects.

More observable than orographic effects on precipitation are differences in soils related to slope aspect. At intermediate and high elevations, cooler temperatures on north and east facing slopes results in less evapotranspiration and higher soil water contents than those observed on south and west facing slopes. As a result of these aspect differences, soils on slopes with north and east aspect have higher organic matter in surface horizons, and these horizons are thicker and darker that those in soils on slopes with south and west aspects (Daniels et al., 1999) (Fig. 3). Thus, at intermediate elevation, soils on slopes with north aspect will have thick dark surface horizons and brown B horizons with similar clay content to overlying A and E horizons while those on south facing slopes will have an increase in clay and the Bt horizon will commonly be red (Table 1). At high elevation (>~1,200 m), soils on both north and south aspects will have brown B horizons and uniform clay content with depth. Surface horizons on north and east slopes, however, will be thicker and have higher organic matter than those in soils on south and west slopes.

Similar effects can be observed in coves and other concave positions that are shadowed by higher surrounding mountains. Increased soil moisture due to reduced evapotranspiration results in thick dark A horizons with relatively high organic matter and greater plant productivity than in other landscape positions. In contrast, convex nose slope positions generally have the thinnest and driest soils and a plant community adapted to droughty conditions. With the exception of isolated “balds” at high elevations, the Blue Ridge was forested prior to European settlement (Daniels et al., 1999).

Differences in forest type and other biological factors have affected soil development and properties but these differences are closely associated with
Figure 2. Blue Ridge soil profiles. A and B – high elevation, A - Edneytown, B – Plott; C and D low elevation, C- Fannin, D – Hayesville.
Figure 3. Soil relationships in intermediate to high mountains. Plott soils occur on north and east facing slopes and have a thick dark surface horizon. Tuckasegee and Cullasaja soils have developed in colluvium. (published in Soil Survey of Haywood County Area, North Carolina; October 1997; block diagram available at ftp://ftp-fc.sc.egov.usda.gov/NSSC/job_aids/graphics/diagrams/NC-2012-02-07-17.pdf).

Figure 4. Soil relationships in low to intermediate mountains. Hayesville, Evard, and Cowee soils have developed in residuum. Braddock soils have developed in colluvium. Statler soils are Ultisols developed on old stream terraces. (published in Soil Survey of Clay County, North Carolina; 1998); block diagram available at ftp://ftp-fc.sc.egov.usda.gov/NSSC/job_aids/graphics/diagrams/NC-2012-02-07-05.pdf.
differences in landscape position and parent material composition. Landscape age has also affected soil development and properties. These differences, similar to vegetation difference, are also associated with landscape characteristics including elevation, slope steepness, and landscape position, i.e. soils at high elevations and on steep slopes are less developed than those lower in the landscape and/or on more stable positions.

Soils developed from residual parent materials (or those with limited creep of upper horizons), either saprolite or indurated rock, have recognizable differences in properties from soils developed in colluvium, and soils in the region are differentiated based on their parent material. In general, soils developed from colluvium are very deep (>150 cm to rock) and often have higher contents of gibbsite than associated residual soils (Norfleet and Smith, 1989; Graham and Buol, 1990). Otherwise, residual and colluvial soils may be morphologically similar and have similar chemical and physical properties. Residual soils, however, mostly occur on convex or linear slopes as compared to colluvial soils, which typically occur in concave landscapes such as coves and footslopes. The difference in landscape position aids differentiation of residual from colluvial soils and have an appreciable effect on the hydrology and water relations of soils occurring in the different positions. This difference is reflected in species and productivity of vegetation found on soils associated with the two types of parent material.

Mineralogical differences among parent materials may result in differences in soil mineral suites and associated soil chemical and physical properties. The most easily observable soil mineralogical difference in soils in the Blue Ridge is the presence and abundance of sand and silt sized mica flakes (and pseudomorphs after mica). Soils with abundant mica in the B horizon are placed in a micaceous mineralogy class and are differentiated from similar soils with lower amounts of mica in the subsoil (Table 1). Large amounts of mica in soils are assumed to reduce soil stability, and landslides are more common in soils in the micaceous mineralogy class. Common series in the Blue Ridge with micaceous mineralogy include Fannin, Chandler, and Cashiers (Table 1).

Other mineralogical differences used as a basis for separation of soils cannot be evaluated in the field. Thus, other properties associated with the mineralogical differences including elevation, aspect, A and B horizon color, and surface horizon thickness, are used to differentiate soils with differences in B horizon mineralogy, both clay mineralogy and sand and silt mineralogy. Among the unique mineralogy classes recognized in the classification of soils in the Blue Ridge is parasequic, which recognizes soils with high amounts of goethite, hematite, and gibbsite in the clay fraction. This mineralogy class is specifically defined as having % Fe$_2$O$_3$ + % gibbsite >10. In the Blue Ridge Mountains, series in the parasequic mineralogy class include Brevard, Evard, Bradson, and Cowee.

Soils at high elevations, especially those on cooler north and east facing slopes, commonly are acid and have relatively high contents of organic matter. The soluble fraction of the organic matter is available to chelate Fe and Al in the soil solution and functional groups of these compounds and other short-range order (amorphous) components will result in high pH measured in NaF and incomplete dispersion for particle size analysis. This combination of characteristics is recognized by classification of the Porters, Plott, Tusquitee, and Tuskasagee series in the isotic mineralogy class (Table 1).
The other major properties used to differentiate among soils in the Blue Ridge is depth of soil to soft (>3 on Mohs scale) or hard rock and coarse fragment content in the upper part of the B horizon. Soil depth depends on slope steepness and the balance between soil development and soil loss rates and bedrock hardness and weatherability. For any particular elevation class (low, intermediate, and high mountains) and characteristic soil morphology, different soils will be recognized based to depth to rock (>150, 100-150, 50-100, and <50 cm). Soils with >35% coarse fragments are differentiated from those with <35%.

Associated with streams are soils developed in alluvial materials. Properties vary depending on soil and rock properties in the watershed, stream transport capacity, and position in the floodplain. Soils in floodplains, like those in uplands, are generally acid with low base saturation. Texture and soil drainage vary depending on floodplain position and characteristics. Soils on floodplains are weakly to moderately developed and are classified as Entisols and Inceptisols. Larger streams may have older and higher terraces and soils on these terraces have a clay increase and red color in the subsoil and are Ultisols (Fig. 4).

Soils in the foothills and low to intermediate elevation mountains (Fig. 4), such as those in Lumpkin County, comprise a major part of the Blue Ridge in Georgia. Hayesville and Braddock soils, which are typical of soils in the foothills, comprise more that 22% of the total area of the Blue Ridge in Georgia. Hayesville and Braddock, developed from residual and colluvial parent materials, respectively, are morphologically very similar with sandy loam surface horizons and red clayey Bt horizons.

SOILS, ROCKS, AND WINE – A QUESTION OF TERROIR

The traditional definition of “terroir” is not entirely clear, but can best be stated as “the possession of a wine of a sense of place”. A better statement may be that terroir is a set of characteristics, such as climate, landscape, and types of soil, that create the unique wine of an area (Schneider, 2013). These components affect vineyard planning, grape selection, and vine growth, but the concept that the type of soil or rock directly influences wine flavor and quality is mostly unproven. That said, wines produced on schist in New Zealand and France have been reported to have a pepper or gunflint aroma (Berry, 1990).

The concept of the type of soil affecting wine quality, however, has led to research to identify the particular soil properties and their magnitude that most strongly influence wine quality, especially nutrient and microelement contents and amounts and, in some cases, specific mineralogy. It is also led to the practice of identifying specific soil series on wine labels and publicizing the presence of “wonder soils” at specific vineyards. It is unlikely that any particular nutrient or element affects wine quality although stress induced by deficiency of a particular nutrient, especially micronutrients, or characteristic nutrient ratios may influence wine quality (Goode, 2003).

Instead of directly lending flavors to the wine, the primary role of soils in wine production is supporting vine growth and grape production by supplying water and nutrients. Soil characteristics can influence selection of rootstocks as different stocks are better adapted to specific chemical conditions such as low pH. Soils also influence vine vigor. Nutrient rich soils may lead to too much vegetative growth, which may affect fruit quality. Conversely, soils with water and/or nutrient limitations may
result in too little vegetation and low yields or degraded fruit quality (Schneider, 2013).

Vine stress is a good thing, however. The ideal environment for wine grape production is one in which the vines experience moderate water stress. For that reason, many vineyards in the western U.S. and other regions are irrigated to better control the amount and timing of soil moisture. In the humid east, well drained soils that induce water stress are most suitable, especially those with gravelly subsoils on hillslopes (Schneider, 2013). The sloping lands help to drain excess water during heavy rains, and subsoil gravel reduces water and nutrient availability and commonly induces stress during the growing season. In is important, however, to have adequate thickness of relatively stone-free topsoil for vine establishment.

As an aid to the viticulture and winemaking industries, the USDA-National Resources Conservation Service (NRCS) has recently developed rules to interpret soil suitability for wine-grape production based on soil distribution and properties from the soil survey (Soil Survey Staff, 2013). The interpretation has been customized for four groups of wine grapes, Vinifera, French-American hybrids, American, and Muscadine, because each group has different growing season requirements and optimal soil properties for vine growth, especially pH.

These ratings are based on potential production with consideration of soil and landscape properties that generally contribute to wine quality. The concept of terroir is not considered in these suitability ratings. It should be noted that this rating scheme was developed to assess soils anywhere in the U.S. Local knowledge of conditions and soils for optimum production and quality can be used to modify the rating scheme.

Among the properties considered for these interpretations are frost-free days and growing-degree days, slope (3-5% is optimal), hazard for flooding or ponding, depth to a seasonal water table, depth to root restrictive horizon, average pH from 0-150 cm, and pH in the deepest horizon. Also considered in the interpretation, although with lower weighting (less influence), are soil available water holding capacity to 150 cm (or root restrictive horizon), bulk density, minimum saturated hydraulic conductivity in the profile, weighted average organic mater content in the upper 30 cm, and hill slope position. Examples of soil suitability for wine-grape production are shown in Figure 5. Any area of the country can be evaluated through the web soil survey (Soil Survey Staff, 2013).

Weighting of the values for these properties results in a rating for wine grape suitability that ranges from 0 to 1 with 1 being the highest rating possible for a “perfect” soils with all properties considered being optimal. For soils in Lumpkin County, the ratings for different map units ranged from 0.00 to 0.43 (Table 2 and Fig. 5). The highest rating for the county, 0.43, is relatively low, but soils with this rating are fairly good for wine production when compared to soils nationwide.

The highest rated map units in Lumpkin County are dominated by soils that are very deep to rock and have red clayey subsoils. Optimal slopes for the county are moderately steep, 6-10%. Slopes higher or lower than this range and considered to be less well suited for wine grape production and have lower ratings. The least suitable map units in the area are those that occur in floodplains of small streams or are shallow (<50 cm to hard rock). For Dawson, Lumpkin, and White Counties, about 5% of the area has soils with a rating in the highest category, 0.30-0.43. In contrast, about 25%
Table 2. Rating of map units for production of Cabernet grapes.

<table>
<thead>
<tr>
<th>Map Unit Symbol</th>
<th>Map Unit Name</th>
<th>Proportionate Extent in Dawson, Lumpkin, and White Counties</th>
</tr>
</thead>
<tbody>
<tr>
<td>FaC</td>
<td>Fannin fine sandy loam, 6-10% slopes</td>
<td>1.0</td>
</tr>
<tr>
<td>HIC</td>
<td>Hayesville sandy loam, 6-10% slopes</td>
<td>2.4</td>
</tr>
<tr>
<td>HSC</td>
<td>Hiwassee loam, 2-10% slopes</td>
<td>0.6</td>
</tr>
<tr>
<td>RbD3</td>
<td>Rabun clay loam, 10-15% slopes, severely eroded</td>
<td>0.8</td>
</tr>
<tr>
<td>FaE</td>
<td>Fannin fine sandy loam, 10-25% slopes</td>
<td>5.9</td>
</tr>
<tr>
<td>HIB</td>
<td>Hayesville sandy loam, 2-6% slopes</td>
<td>0.3</td>
</tr>
<tr>
<td>HSD</td>
<td>Hiwassee loam, 10-25% slopes</td>
<td>0.7</td>
</tr>
<tr>
<td>HIE</td>
<td>Hayesville sandy loam, 10-25% slopes</td>
<td>18.1</td>
</tr>
<tr>
<td>Sta</td>
<td>Starr fine sandy loam</td>
<td>0.2</td>
</tr>
<tr>
<td>ToC</td>
<td>Toccoa soils</td>
<td>2.7</td>
</tr>
<tr>
<td>HKC3</td>
<td>Hayesville and Rabun clay loams, 6-10% slopes, severely eroded</td>
<td>0.7</td>
</tr>
<tr>
<td>TdG</td>
<td>Tallapoosa soils, 25-70% slopes</td>
<td>20.6</td>
</tr>
</tbody>
</table>

Table 2. Rating of map units for production of Cabernet grapes.

of the three county area has soils that fall into the least suitable category, <0.06.

**SUMMARY**

Soils are complex biological, physical, mineralogical, and chemical systems that have developed in response to their environment, both past and present. In the Blue Ridge Mountains in Georgia, soils reflect the mineralogical composition of the underlying rocks and are commonly acid with low base saturation. Topography, including elevation, landscape position, and aspect; parent material type; and soil depth are the properties most often used to differentiate among the soils in Blue Ridge landscapes. In many cases, topographic characteristics are used as proxy indicators of differences in vegetative productivity, soil hydrology, and mineral weathering pathway that have resulted in differences in soil development and properties. For foothills and low mountain landscapes, the soils are fairly well suited for wine grape production based on theoretical optimal conditions. The most suitable soils in these landscapes are those that are very deep to rock, acid, have red clayey subsoils, and are found on 6 to 10% slopes.
REFERENCES CITED


INTRODUCTION

Georgia gold specimens occur as nuggets or gold masses in placer and saprolite deposits and as gold veins in quartz in lode deposits with an occasional gold crystal. Gold is reported from almost all Georgia counties underlain by igneous or metamorphic rock. Park (1953) reports nearly 500 gold mines and prospects within the state. Because the occurrence and origin of Gold in Georgia has been described in previous publications (German, 1985 and 1993, Jones, 1909, and Yeates and others 1896), the purpose of this section is to describe the character of and call attention to significant gold that has been preserved in public institutions and private collections. This also serves to track collections of scientifically or historically important Georgia gold specimens.

The discovery of gold in the southeastern United States in the 1820s set off this country’s first gold rush. Although gold mining took place from Pennsylvania to Alabama, the most active mining centers were Charlotte, North Carolina, and Dahlonega, Georgia. Because so much gold was produced in these areas, U.S. Mints were established in Charlotte and Dahlonega. While in operation (1838-1861) the Dahlonega Mint produced 1,381,784 coins with a total face value of $6,190,118 (Cook, 1978). Williams (1993) provides a detailed account of the gold rush in Georgia. Despite this storied past, few gold specimens representative of Georgia’s mining heritage exist today.

Unlike today, neither a commercial demand for specimens nor a preservation mindset existed between 1828 and 1933, the period when gold was continuously mined in Georgia. Halting mining operations to collect specimens hinders productivity and removing them reduces mine revenue. As the purpose of gold mining is the economic recovery and refining of that element, it is understandable that few examples of Georgia gold specimens survive today. Nonetheless, several notable specimens survive, most in public museums and a few in private collections.

The only deliberate effort to preserve gold as gold specimens was by the Georgia Geological Survey (GGS), and the Georgia Capitol Museum. The GGS had its origins in the 1800s. A brief, early incarnation of the GGS existed between 1836 and 1840, with John R. Cotting as the first state geologist. A second geological survey was created in 1874 and lasted only seven years. In 1889 the state legislature once again established the office of state geologist directing him to “to collect, analyze and classify specimens of minerals, plants and soils” (Cave, 1922). The next GGS began operations in 1890 with offices located in the Georgia Capitol building. During visits to mines, state geologists collected samples for ore evaluation and as representations of the quality and character of the mineral resources of the state. In 1890, the halls of
the fourth floor of the Capitol building were designated as a museum to house the collections of the GGS. The Georgia State Museum of Science and Industry was established in 1955 under the Secretary of State’s office. This was because the GGS moved out of the Capitol building and into the Agriculture building in March of 1956. Much of the GGS collection remained as part of the Georgia Capitol Museum, which then broadened its collecting scope: collecting from worldwide mineral localities. The GGS began a small, informal museum that included a few gold specimens.

Although significant gold made its way into the Georgia Capitol Museum, records of which particular specimens were added to the collection, when, and their ultimate disposition is not always clear. For instance, when the GGS moved away from the capitol building in 1956, which specimens remained in the Capitol Building or moved to the Agriculture Building? Did the GGS acquire new specimens after the move? Some of these made their way to the Dahlonega Gold Museum in 1978 and Tellus Science Museum in 2009.

**Academy of Natural Sciences of Philadelphia**

Established in 1812, some consider the Academy of Natural Sciences of Philadelphia (ANSP) to be the cradle of mineralogy in America (Nolan, 1909, Wilson, 1994). Despite enormous outcry from the citizens of Philadelphia and the mineral collecting community, approximately 19,000 minerals from the ANSP collections were sold to a consortium of three mineral dealers in 2006. These minerals were first offered to museums and a few museums were able to purchase specimens appropriate to their collecting scope. In 2007 Tellus Science Museum acquired all available ANSP specimens from Kentucky, Tennessee, West Virginia, Mississippi, Alabama, Florida, South Carolina, and, of course, Georgia; totaling 138 specimens. After the fall of 2007, the remainder of the former ANSP collection not sold to museums was offered for sale to the general public.

Within the Georgia collection were two gold specimens from Battle Branch Mine, Lumpkin County. The gold is associated with galena in tiny cavities within a quartz matrix about 20 cm thick. The better of these two is now displayed at Tellus Science Museum.

**Georgia Capitol Museum (Currently on Exhibit), Atlanta Georgia**

Following a complete renovation of the Georgia Capitol Museum around 1990, most of the geology collection was placed in storage. Two cases of rocks, minerals, and fossils remained on exhibit to demonstrate the diversity of mineral resources throughout the state. Within one of these cases are two gold samples: one sulfide gold ore and a specimen of crystalline gold in quartz. A third case has a sampling of all the natural resources of the state and includes two more gold specimens. One of these is a gold nugget that probably weighs 3 to 4 ounces (no data is given) and a coarse gold in quartz (about 3 cm x 3 cm). No information is given on the location where these specimens were recovered.

**Dahlonega Gold Museum, Dahlonega, Georgia**

The Dahlonega Gold Museum on the square in Dahlonega is a Georgia Historic Site devoted to preserving and educating the public on the gold mining history of the
region. Some of that history occurred not only near this former Lumpkin County courthouse building, but actually in the building. Exhibits within the museum cover gold’s discovery, mining life, assaying ores, and minting coins. The Museum is housed in the building that was from 1836 to 1965 the courthouse for Lumpkin County. It was given to the Georgia Department of Parks and Historic sites and converted to the Dahlonega Gold Museum, which opened in 1967.

In 1978 some of the gold specimens in the displays in the GGS offices were put on indefinite loan to the Dahlonega Gold Museum (Lori Hamby, 2013, personal communication). These specimens, as well as others loaned or donated by Dr. R.D. Hogue and samples of every denomination of coin minted in Dahlonega, are currently displayed in the Museum. One of the major exhibits of Georgia gold, this combined collection provides a sampling of many important types of gold from mines in the Dahlonega District.

A few gold ore specimens are displayed in the Dahlonega Gold Museum. These include a rare octahedral crystal approximately 4 mm in diameter, examples of loose wire gold, and quartz with wire gold and small crystals. No locations are given on the coarse lode gold minerals.

Also on display is a mass of gold in quartz reportedly from the Loud mine in White County. The specimen is sawn in half and exhibited with the flat, sawn side down. The specimen is identical in character to a sawn half specimen transferred to Tellus from the Georgia Capitol Collection and reported from the Calhoun mine in Lumpkin County. Furthermore, it bears no resemblance to lode or placer gold specimens documented as from the Loud mine.

Several noteworthy examples of placers gold are represented in the collection. These include a half ounce nugget from the Yahoolla River, a pair of small (0.28 oz. and 0.173 oz.) nuggets from the Chestatee River, nuggets from the Franklin-Creighton mine and Dukes Creek, and a 3.65 ounce nugget from the Josephine mine near Auraria. The largest nugget on exhibit in Dahlonega is from the Dukes Creek placers in White County.

One of the largest gold nuggets in existence from Georgia is a 112 pennyweight (about 6 ounce) nugget found on Dukes Creek in May 1936 by W. C. Hudson (Figure 1). This location, the Hudson Gold Mine (a.k.a. Dixie Gravel Co.), is in the Nacoochee District in White County. Mr. Hudson was photographed at the mine a few days later holding the nugget (Figure 2). The Dukes Creek nugget was on exhibit in the former GGS building in the mid-1970s when Dr. Robert Cook was preparing a manuscript on mineral locations of Georgia. Cook let the current state geologist, Sam Pickering, know that he needed a photo of gold for the book. Pickering offered the Dukes Creek nugget as a subject. The only place with adequate light (Cook only had daylight balanced color film in his camera) was the roof of the Agriculture Building that housed the GGS. The resulting photo was used as the background of GGS Bulletin 92, the Minerals of Georgia (Figure 3; Cook, 1978). The Dukes Creek nugget was transferred to the Dahlonega Gold Museum in 1978 where it is on display today.

**TELLUS SCIENCE MUSEUM, CARTERSVILLE, GEORGIA**

Tellus Science Museum in Cartersville, Georgia, houses and displays the largest collection of Georgia minerals. A significant portion of the gold exhibited at
Tellus is from the Geology Collection of the Georgia Capitol Museum. In addition to the Philadelphia collection discussed above, Tellus has also purchased a few Georgia gold specimens, notably the largest surviving gold in matrix specimen.

At some point (not later than 1990), the Capitol museum restructured its exhibits to include only a few specimens that were good examples of mineral resources. All other specimens, nearly 4,000, were carefully cataloged, packed, and stored in the state warehouse in Atlanta. All specimens of the Geology Collection of the Georgia Capitol Museum not displayed at the Capitol were transferred to Tellus Science Museum in 2009, including 42 gold specimens. Tellus Science Museum has thoroughly documented all former Capitol Museum collection items. They have been photographed and all specimen data electronically recorded. Some of the collection is now on display in the museum; the remainder is housed under archival conditions.

Around 2004, a man using electronic prospecting equipment discovered gold around the former Sixes gold mine in Cherokee County, Georgia. Hundreds of small pieces of coarse gold were recovered along with what is the largest gold in matrix specimen from Georgia (Figure 4). This single specimen is 38 cm long with coarse gold associated with amphibole and quartz. This specimen and most of the gold
Many large nuggets have been recovered from placer deposits at the Loud mine in White County, Georgia. Two collections of nuggets from the Loud mine were acquired by the Georgia Capitol Museum in 1898 and some of these were transferred to Tellus Science Museum. Most are now on exhibit (Figure 5).

Rarely seen today, gold crystals were apparently abundant during active lode mining. Nineteenth century literature refers to these as “jewel gold” (Robert Cook, 2012, personal communication). One such crystal was discovered in the Geology Collection of the Georgia Capitol Museum. The crystal is a deeply hoppered crude octahedral crystal 2.5 cm tall on quartz (Figure 6 and Guidebook Cover).

The site of the first lode gold deposit in Lumpkin County, the Calhoun mine also produced significant coarse gold in quartz. These high-grade gold ores were also referred to as “Bonanza Gold”. Two specimens of Bonanza gold were in the Georgia Capitol museum collection transferred to Tellus in 2009 (Figure 7). Both were sawn in half, but the two pieces were from different specimens. The second half of one specimen was later found in the collection of the former GGS.
Figure 4 The largest existing gold in matrix specimen from Georgia. A 38 cm long specimen of gold on amphibole in quartz found near the Sixes mine in Cherokee County, Georgia. This specimen is on exhibit at Tellus Science Museum, Cartersville, Georgia. Photo by Jeff Scovil.

Figure 5 Three gold nuggets from the Loud mine in White County Georgia from the former Geology Collection of the Georgia Capitol Museum and now exhibited at Tellus Science Museum. Left to right, these weigh 6 gm, 23 gm, and 24 gm. The nugget in the center is 3.5 cm tall. Photo by Jeff Scovil
Figure 6 A rare gold crystal from the Loud mine in White County. This is part of the former Geology Collection of the Georgia Capitol Museum and now exhibited at Tellus Science Museum. Overall specimen dimensions are 3 cm high by 2.5 cm wide. Photo by Jeff Scovil.
Figure 7 “Bonanza gold”, a high-grade gold ore from the Calhoun mine in Lumpkin County, Georgia from the former Geology Collection of the Georgia Capitol Museum and now exhibited at Tellus Science Museum. This specimen is 8.4 cm wide by 6.5 cm tall and weighs 13.6 ounces. Tellus Science Museum photo.

Figure 8 The Chestatee Gold Nugget found in an undisclosed location in Lumpkin County. This nugget weighs 23.68 troy ounces (1 pound 10 ounces) and is currently in a private anonymous collection. Photo provided by Al Adams.
PRIVATE COLLECTIONS

The largest known gold nugget found in Georgia was found in the late 1990s by an anonymous landowner near Dahlonega, Georgia. The nugget weighs 23 ounces (Figure 8). The nugget was purchased by Al Adams of Gold Rush Galleries, who christened this amazing specimen the “Chestatee Nugget”. Mr. Adams obtained a notarized statement from the owner regarding the circumstances of the finding of the nugget. The Chestatee Nugget, along with a collection from Dr. Walter B. Jones, was later sold to a gold collector in the south who wishes to remain anonymous (Al Adams, 2013, personal communication).

CONCLUSIONS

Georgia boasts a nearly 200-year history of gold mining, beginning with the 1820’s to discoveries made in the last 15 years. Some gold specimens survived the stamp mill, furnace, or mint to provide a physical record of their nature. While written descriptions exist for many of these, the actual specimens provide a visual link to Georgia’s mining heritage. The largest public collections on display today are at the Dahlonega Gold Museum in Dahlonega or Tellus Science Museum in Cartersville.
REFERENCES CITED


48TH ANNUAL FIELDTRIP ROAD LOG

Paul A. Schroeder

Department of Geology
University of Georgia
Athens, GA 30602-2501

INTRODUCTION

This trip consists of stops in the Dahlonega, GA region. A brief listing of the stops is presented below with detail maps and written direction on the following pages. Excursions on both days will begin and end at the University of North Georgia Parking lot 30. Participants are encouraged to park in UNG lot 30 and travel on the coach buses provided. If you choose to travel in a personal vehicle, then it is your responsibility to follow in a timely fashion. Lunches are included in the registration fee. Water and soft drinks will be available from a traveling support vehicle.

SEQUENCE OF STOPS

Day 1 - 1. University of North Georgia parking lot 30
Day 1 - 2. Wolf Mountain Winery
Day 1 - 3. Geology Stop 1
Day 1 - 4. Geology Stop 2
Day 1 - 5. Three Sisters Vineyards and Winery (Lunch)
Day 1 - 6. Cavender Creek Vineyards and Winery
Day 1 - 7. University of North Georgia parking lot 30

Day 2 - 1. University of North Georgia parking lot 30
Day 2 - 2. Consolidated Gold Mine
Day 2 - 3. Montaluce Winery and Estates (Lunch)
Day 2 - 4. University of North Georgia parking lot 30

The first map on the following 2 map pages shows locations of the respective day-stops. A second map is added for historical interest, which is a section of the 1892 topographic map acquired from the U.S.G.S Historical topographic collections. It covers approximately the same area as show in the first map. (http://geonames.usgs.gov/pls/topomaps/). All subsequent maps provide a road log for each stop with attribution going to Goggle Maps (https://maps.google.com).
SAFTEY

The 2013 Georgia Geological Society field trip stops are located in a variety of places. Four of the stops will be at local vineyard and wineries, which should be accessible to all. The first stop at Wolf Mountain Winery will have limited parking and access. The large coach buses can’t reach the upper lot where we will be meeting at an overlook/vista. Those needing assistance getting to the vista can be transported by support vans travelling with the group. The Geology Stops 1 and 2 (on Day 1) are off roadways and extra caution is advised. All others stops will involve easy walking over moderate terrain.

TASTINGS AND PRODUCT PURCHASE GUIDELINES

The Georgia Geological Society does necessarily not promote or endorse the wineries that we are visiting, however we are most grateful for the access provided by owners and management. Each winery will offer an opportunity to taste and/or purchase their products. The terms and conditions for these opportunities will vary amongst each winery. **Tastings and product purchases are not included in your registration fee.** If you choose to partake in tasting and/or purchasing, then please come prepared to show proof of legal age and bring extra funds. The prices are set by each winery and will vary. If you plan on consuming wine during the excursion it is important that you make arrangements for a designated driver. A reminder of the Georgia’s open container law goes as follows: The law defines "open alcoholic beverage container" as any bottle, can, or other receptacle that contains any amount of alcoholic beverage and: (1) is open or has a broken seal; or (2) the contents of which are partially removed.

HAVE A SAFE, EDUCATIONAL, AND ENJOYABLE 2013 GEORGIA GEOLOGICAL SOCIETY FIELD TRIP!
Directions to Wolf Mountain Vineyards
180 Wolf Mountain Trail, Dahlonega, GA 30533
8.7 mi – about 14 mins
Departure location is UNG Lot 30

1. Head east toward Sunset Dr
go 0.1 mi
total 0.1 mi

2. Turn left onto Sunset Dr
go 154 ft
total 0.1 mi

3. Take the 1st left onto W Main St
About 2 mins
go 0.3 mi
total 0.4 mi

4. Continue onto Public Square
go 200 ft
total 0.5 mi

5. Continue onto E Main St
About 2 mins
go 0.6 mi
total 1.1 mi

6. Turn left onto GA-50 N/GA-9 N/US-19 N/Morrison Moore Pkwy E
Continue to follow GA-50 N/GA-9 N/US-19 N
About 6 mins
go 3.9 mi
total 5.0 mi

7. Turn left onto Ridley Rd
About 2 mins
go 0.5 mi
total 5.5 mi

8. Take the 3rd left onto Wolf Mountain Trail
About 14 mins
go 413 ft
total 5.6 mi

9. Slight right to stay on Wolf Mountain Trail
Destination will be on the right
go 0.1 mi
total 5.7 mi

Wolf Mountain Vineyards
180 Wolf Mountain Trail, Dahlonega, GA 30533

UNG Lot 30

©2013 Google
Directions to Georgia 400 & Georgia 60, Dahlonega, GA 30533

10.4 mi – about 17 mins
Saturday Geology Stop 1

Wolf Mountain Vineyards
180 Wolf Mountain Trail, Dahlonega, GA 30533

1. Head southeast on Wolf Mountain Trail toward Ridley Rd
   go 0.2 mi
   total 0.2 mi

2. Turn right onto Ridley Rd
   About 1 min
   go 0.5 mi
   total 0.7 mi

3. Turn right onto GA-60 S/GA-9 S/US-19 S
   Continue to follow GA-9 S
   About 7 mins
   go 4.6 mi
   total 5.4 mi

4. Turn left onto Co Rd 249/GA-60 S/US-19 S/S Chestatee
   About 8 mins
   go 5.0 mi
   total 10.4 mi

Georgia 400 & Georgia 60, Dahlonega, GA 30533
Directions to Crown Mountain Dr & Alicia Ln, Dahlonega, GA 30533
4.6 mi – about 7 mins

Georgia 400 & Georgia 60, Dahlonega, GA 30533

go 4.4 mi
About 5 mins
   total 4.4 mi

2. Turn left onto Crown Mountain Dr
   go 0.3 mi
About 2 mins
   total 4.6 mi

Crown Mountain Dr & Alicia Ln, Dahlonega, GA 30533
Directions to Three Sisters Vineyards & Winery
439 Vineyard Way, Dahlonega, GA 30533
11.4 mi – about 21 mins

1. Head north on Alicia Ln toward Morrison Moore Pkwy W
go 0.3 mi
total 0.3 mi

2. Turn right onto GA-9 N/Morrison Moore Pkwy W
   About 6 mins
go 3.0 mi
total 3.3 mi

3. Turn right onto Cavender Creek Rd
   About 6 mins
go 3.9 mi
total 7.2 mi

4. Turn left onto Town Creek Church Rd
   About 4 mins
go 2.8 mi
total 10.0 mi

5. Turn left onto Shoffelt Rd
   About 3 mins
go 1.1 mi
total 11.0 mi

6. Turn right onto Vineyard Way
   Destination will be on the left
   About 2 mins
go 0.4 mi
total 11.4 mi

Three Sisters Vineyards & Winery
439 Vineyard Way, Dahlonega, GA 30533
Directions to Cavender Creek Vineyards LLC
3610 Cavender Creek Rd, Dahlonega, GA 30533
4.8 mi – about 10 mins

1. Head southwest on Vineyard Way toward Shoffeit Rd
   About 2 mins
   go 0.4 mi
   total 0.4 mi

2. Turn left onto Shoffeit Rd
   About 3 mins
   go 1.1 mi
   total 1.5 mi

3. Turn right onto Town Creek Church Rd
   About 4 mins
   go 2.8 mi
   total 4.2 mi

4. Turn right onto Cavender Creek Rd
   Destination will be on the left
   About 1 min
   go 0.6 mi
   total 4.8 mi

Cavender Creek Vineyards LLC
3610 Cavender Creek Rd, Dahlonega, GA 30533
Directions to Unknown road
6.5 mi – about 12 mins
Return to University of North Georgia Lot 30

Cavender Creek Vineyards LLC
3610 Cavender Creek Rd, Dahlonega, GA 30533

1. Head southwest on Cavender Creek Rd toward Homer Edge Cir
   About 5 mins
   go 3.3 mi
   total 3.3 mi

2. Turn left onto GA-60 S/GA-9 S/US-19 S/Morrison Moore Pkwy E
   About 3 mins
   go 2.1 mi
   total 5.4 mi

3. Turn right onto E Main St
   About 2 mins
   go 0.6 mi
   total 6.1 mi

4. Continue onto Public Square N
   go 236 ft
   total 6.1 mi

5. Continue onto W Main St
   About 1 min
   go 0.3 mi
   total 6.4 mi

6. Turn right onto Sunset Dr
   go 154 ft
   total 6.4 mi

7. Turn right
   go 187 ft
   total 6.5 mi

8. Turn left
   go 328 ft
   total 6.5 mi

UNG Lot 30
Directions to Consolidated Gold Mines
185 Consolidated Gold Mine Rd, Dahlonega, GA 30533
1.4 mi — about 7 mins
Day 2 departure from UNG Lot 30

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Consolidated Gold Mines
185 Consolidated Gold Mine Rd, Dahlonega, GA 30533
Directions to Montaluce Winery & Estates
946 Via Montaluce, Dahlonega, GA 30533
6.9 mi – about 16 mins

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<td>2.</td>
<td>Turn left to stay on Consolidated Gold Mine Rd</td>
<td>go 354 ft</td>
<td>total 0.3 mi</td>
</tr>
<tr>
<td>3.</td>
<td>Continue onto E Main St</td>
<td>go 0.5 mi</td>
<td>total 0.8 mi</td>
</tr>
<tr>
<td></td>
<td>About 2 mins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Turn right onto GA-60 BUS N/N Grove St</td>
<td>go 1.5 mi</td>
<td>total 2.3 mi</td>
</tr>
<tr>
<td></td>
<td>About 3 mins</td>
<td></td>
<td></td>
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<tr>
<td>5.</td>
<td>Turn left onto Oak Grove Rd</td>
<td>go 4.0 mi</td>
<td>total 6.3 mi</td>
</tr>
<tr>
<td></td>
<td>About 8 mins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Turn right onto Hightower Church Rd</td>
<td>go 0.5 mi</td>
<td>total 6.9 mi</td>
</tr>
<tr>
<td></td>
<td>About 1 min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Take the 1st left</td>
<td>go 85 ft</td>
<td>total 6.9 mi</td>
</tr>
<tr>
<td>8.</td>
<td>At the traffic circle, continue straight</td>
<td>go 280 ft</td>
<td>total 6.9 mi</td>
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<td></td>
<td>Destination will be on the left</td>
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