DEFINING THE TERROIR OF THE COLUMBIA GORGE WINE REGION, OREGON AND WASHINGTON, USA USING GEOGRAPHIC INFORMATION SYSTEMS (GIS)

Hilary Whitney and Scott Burns*

Department of Geology, Portland State University
**Corresponding author: Whitney. Email: hilaryannwhitney@gmail.com. Burns. E-mail: burns@pdx.edu*

Abstract
The Columbia Gorge Wine Region (CGWR) extends for about 100km along the Columbia River and includes the Columbia Gorge American Viticultural Area (AVA) and the southwest portion of the Columbia Valley AVA. As of September 2013, the region is home to 82 vineyards, 513 hectares (1268 acres), 36 wineries and 41 different varieties of *Vitus Vinifera*, with Pinot Noir being the most widely planted grape variety in both AVAs. To better understand the physical factors affecting Oregon and Washington wine, this project analyzes the climate, topography, geology and soil at vineyards in the CGWR using Geographic Information Systems and existing earth science databases.

Vineyards range in elevation from 29 to 548 meters (95 to 1799 feet). The microclimates vary within this relatively small wine region, allowing for diversity in grape varieties planted. Three Winkler climate regimes are represented within the CGWR, including Regions Ia, Ib, and II from the Winkler Index (Jones et al., 2010). The average growing season temperatures range from 13.7°C (55.7°F) to 17.7°C (63.9°F) and the average growing degree-days range from 871 for °C (1567 for °F) to 1664 for °C (2994 °F). 58% of the vineyards are characterized within an intermediate climatic regime, 29% are within a cool climatic regime, 9% are within a warm climatic regime and 4% are on the boundaries between a cool, intermediate or warm regime. The growing degrees days calculated for the CGWR are similar to those measured in the Willamette Valley, Oregon, Burgundy, France, Umpqua Valley AVA, Oregon and Bordeaux, France.

All of the soils used to grow grapes are well drained and within a xeric moisture regime. 30 soil types are represented among the vineyard sites, with the Chemawa Series (Underwood Mountain) and Walla Walla Series (eastern portions) being dominant. Majority of the soils contain a silt loam texture, with 46.5% of the total vineyard acreage planted on soils formed in loess from eastern Washington and Oregon. The Missoula Floods influence the texture and age of the soil in this region, with skeletal textures close to the Columbia River and finer textures at higher elevations. Other common geological deposits at vineyards in the CGWR include, Quaternary Basalt (19.6%), Missoula Flood deposits (9.1%), The Dalles Formation (8.0%), Columbia River Basalt Group (7.5%), Pliocene Basalt (3.0%), Quaternary Surficial deposits (3.0%), lahars (2.3%) and Quaternary Basaltic Andesite and Andesite (0.9%).

Common geological deposits, soil series, and climate conditions at vineyard sites vary spatially in the region, making this one of the most diverse wine regions in terms of growing conditions in the Pacific Northwest.

Columbia Gorge, terroir, geographic information systems (GIS).

1 INTRODUCTION

Recent terroir research conducted in the in the Pacific Northwest has been conducted using a combination of field work and existing earth science databases on soils, geology, topography and climate to define the terroir on a regional scale (Burns, 2012; Jones et al., 2004; Meinert and Busacca, 2000, 2002). Terroir conditions have been defined for the Willamette Valley (Burns, 2012), Walla Walla Valley (Meinert and Busacca, 2000; Pogue, 2012), Umpqua Valley (Jones et al., 2004), and the Red Mountain AVA in Washington (Meinert and Busacca, 2002).

The CGWR is emerging as a wine region, increasing from about 43 vineyards to 82 vineyards from 2003 to 2013. This region has gained recognition as a "World of Wine in 40 miles" by the diverse range of grape varieties planted within this relatively small region. As the CGWR continues to grow, vintners and winemakers continue to experiment with different types of grape varieties, to determine the best quality of wine for this region. Although the climate is well known by vintners to vary within the region, definitive boundaries of the climatic conditions have not yet been defined. Also, little is known about how other terroir conditions, such as the geology, soils, and topography vary at vineyard sites throughout the region. The goal of this research was to compile the dominant physical terroir conditions at each vineyard block in the CGWR into a database to provide winemakers in this region with the knowledge of major terroir conditions in order to bolster the quality of wine made from this area.

2 MATERIALS AND METHODS

During the summer of 2013, a grower survey was conducted to determine the current locations of vineyards and wineries within the CGWR. With the help of the Columbia Gorge Wine Association, growers and wine makers were interviewed to provide information specific to each vineyard, including : grape varieties grown and corresponding acreage, and irrigation and rooting techniques.

A shapefile containing the boundaries of the Columbia Gorge Wine Region first had to be drawn in order to spatially depict the growing conditions using ArcGIS. The boundaries of the Columbia Gorge AVA and Columbia Valley AVA were traced from an existing shapefile found in ArcGIS Online (Environmental Systems Research Institute; Peale, 2013). The existing shapefile contains all 2013 AVA boundaries in Washington State and was created using Federal register documents and referenced digital raster graphics (Peale, 2013). Vineyard Global Positioning System (GPS) locations collected during the growers survey were imported into ArcGIS and each vineyard block was traced on aerial photographs provided by the National Agriculture Imagery Program (NAIP) and saved into the new polygon layer (Figure 1). The acreage of each vineyard was calculated using the calculate geometry tool in the Editor toolbox and checked with acreage estimations collected during the growers survey.

Figure 1: Aerial Photographs from the National Agriculture Imagery Program (NAIP) were used to trace vineyard boundaries once GPS locations were imported into Arc Map.

Soil vector data downloaded from the Gridded Soil Survey Geographic (gSSURGO) Database for Oregon and Washington (http://datagateway.nrcs.usda.gov/) was converted to a raster format in the Albers Equal Area projection to have a cell size of ten meters using a cell assignment of maximum area. A number code was assigned to each soil type and the major soil type at each vineyard block was summarized using the Zonal Statistics as Table tool in the Spatial Analyst toolbox. The resulting table included one number for each vineyard block, representing the major soil type. The soil series names were joined to each number code, which were then joined again to vineyard boundary polygon layer. Soil series for each vineyard block were permanently added to the vineyard shapefile, to be later imported into the vineyard database in Excel. After spatially analyzing the soil data and performing the site visits, it was apparent that individual soil series dominated certain regions within the CGWR. Soil sub-regions were then drawn in GIS around areas with one or more dominant soil series. If one or more soil series was 90% contained in a specific region, then boundaries were drawn to include those series.

Geological maps used to determine the geology at each vineyard sites ranged in scale from 1:36,000 to 1:100,000 and include the most updated maps for the Hood River Valley, Oregon and Washington (Ma et al., 2009; McClaughry et al., 2012a; Washington State Department of Natural Resources Staff, 2010). Each map was imported into GIS and merged together using data management tools. Similar geological units across all three maps were consolidated into one shapefile, to form one geological map for the wine region. The consolidated shapefile was converted to a raster file, and the major geological mapping unit was calculated for each vineyard

site using the Zonal Statistics as Table tool in the Spatial Analyst toolbar. In addition, the parent material provided in the gSSURGO database for each map unit was used to determine the extent of loess at vineyard sites (Soil Survey Staff, 2012a, b).

The PRISM dataset used for this study includes monthly precipitation and maximum and minimum temperature rasters (400m resolution) from 1981-2010. Monthly precipitation rasters were summarized for annual and growing season (April-October) periods using the field calculator in the GIS toolbox. Monthly maximum and minimum temperature rasters were processed into (1) growing degree days (GDDs, °C units) from April to October using a base temperature of 10°C (50°F) and (2) average growing season temperatures (GST, C° units) from April to October using equations provided in Table 1. A new raster grid containing GDD and GST values was classified by the criteria set for each climatic regime (Table 1; Jones et al., 2010).

Table 1. Average Growing Season Temperatures (GST)s and Growing degree-days (GDD) are calculated using equations provided by Jones (2010).

Variable	Equation	Months	Class Limits		
				°C units	°F units
Average Growing Season Temperature (GST)	$\sum_{Apr\,1}^{Oct\,31} [([T_{max} - T_{min}]/2) - 10.0]$	Apr-Oct	Too Cool	< 13°C	< 55°F
			Cool	13-15°C	55-60°F
			Intermediate	15-17°C	60-63°F
			Warm	17-19°C	63-66°F
			Hot	19-21°C	66-72°F
			Very Hot	21-24°C	72-75°F
			Too Hot	> 24°C	> 75°F
Growing degree-days (GDD)	$\frac{\sum_{Apr\,1}^{Oct\,31}(T_{max} + T_{min})/2}{n}$	Apr-Oct	Too Cool	< 850	< 1500
			(Region Ia)	850-1389	1500-2000
			(Region Ib)		2000-2500
			(Region II)	1389-1667	2500-3000
			(Region III)	1667-1944	3000-3500
			(Region IV)	1944-2222	3500-4000
			(Region V)	2222-2700	4000-4900
			Too Hot	> 2700	> 4900

3 RESULTS AND DISCUSSION

As of September 2013, the region is home to 82 vineyards, 513 hectares (1268 acres), 36 wineries and 41 different varieties of *Vitus Vinifera*. Vineyards range in elevation from 29 to 548 meters (95 to 1799 feet).Vintner responses to a grower's survey suggest that 28 grape varieties account for 98% of the estimated grape variety acreage, with Pinot Noir being the most widely planted grape variety in both AVAs.
The boundaries of each climatic regime were mapped based on 1981-2010 PRISM data, the Winkler Index (Amerine and Winkler, 1944) updated by Jones et al. (2010) and climatic maturity groupings designed for Oregon (Jones et al., 2002; Jones et al., 2010). Three Winkler climate regimes are represented within the CGWR, including Regions Ia, Ib, and II from the Winkler Index (Jones et al., 2010). The diversity in regimes allows for a diversity of grape varieties to be planted within the regime. The average growing season temperatures and growing degree days, respectively, from 1981-2010 calculated for vineyards ranges from 13.7°C (55.7°F) to 17.7°C (63.9°F) and 871 for °C (1567 for °F) to 1664 for °C (2994 °F) respectively. 58% of the vineyards are characterized in an intermediate climatic regime, 29% are within a cool climatic regime, 9% are within a warm climatic regime and 4% are on the boundaries between a cool, intermediate or warm regime. 80% of the vineyards are within Regions Ia and Ib characterized by the Winkler Index, and 20% are within Region II. The growing degrees days calculated for the CGWR are similar those measured in the Willamette Valley, Oregon, Burgundy, France, Umpqua Valley AVA in Oregon and Bordeaux wine region in France.

All of the soils used to grow grapes are well-drained, within a xeric moisture regime, which is favorable for viticulture. 30 soil series are represented among the vineyard sites, with the Chemawa Series (Underwood Mountain) and Walla Walla Series (eastern portions) being the dominant soil series. Majority of the soils contain a silt loam texture. Soil Survey data for Oregon and Washington suggest that loess is extensive in the CGWR, with 46.5% of the total vineyard acreage planted on soils formed in loess. The Missoula Floods also greatly influenced the texture and age of the soil in this region, with skeletal textures close to the Columbia River and finer textures at higher elevations. Other common geological deposits at vineyards in the CGWR include,

Quaternary Basalt (19.6%), Missoula Flood deposits (9.1%), The Dalles Formation (8.0%), Columbia River Basalt Group (7.5%), Pliocene Basalt (3.0%), Quaternary Surficial deposits (3.0%), lahars (2.3%) and Quaternary Basaltic Andesite and Andesite (0.9%). Common geological deposits, soil series, and climate conditions at vineyard sites vary spatially in the region, and therefore it is suggested that future work focus on separating the region into separate climatic sub-AVA regimes to better reflect the diversity in terroir conditions.

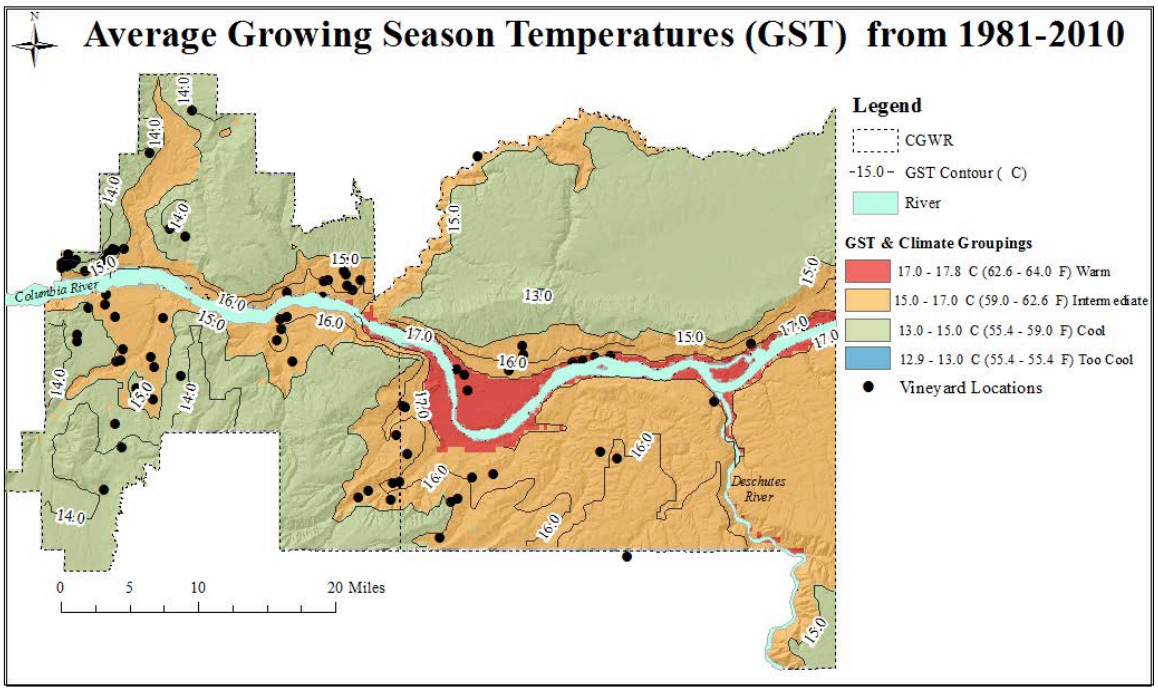

Figure 1. The average growing season temperatures in the CGWR range from 12.9 to 17.8˚C (55.2 – 64.0˚F). Vineyards are located in 3 climatic grouping based off of criteria set by Jones (2003). Most vineyards are within an intermediate climatic regime.

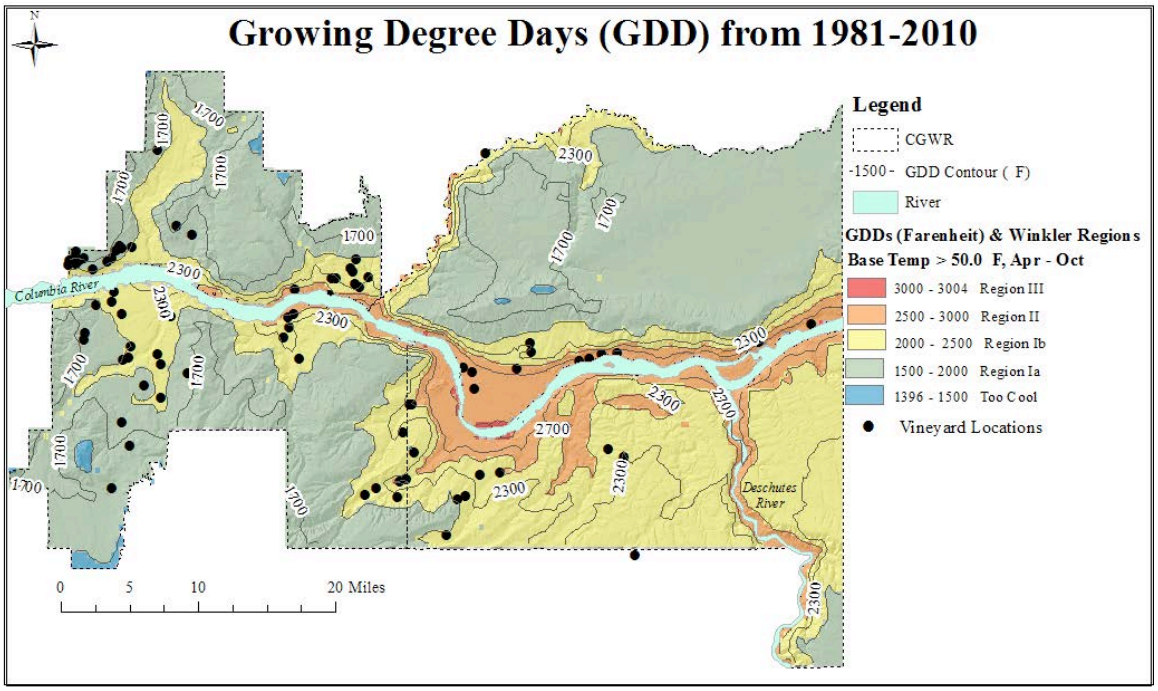

Figure 2. Growing Degree days range from 1396 to 3004 in the CGWR. Vineyards are located within 3 Winkler Region from criteria set by Winkler and Amerine and updated by Jones (2003). Most vineyards are within Region Ib.

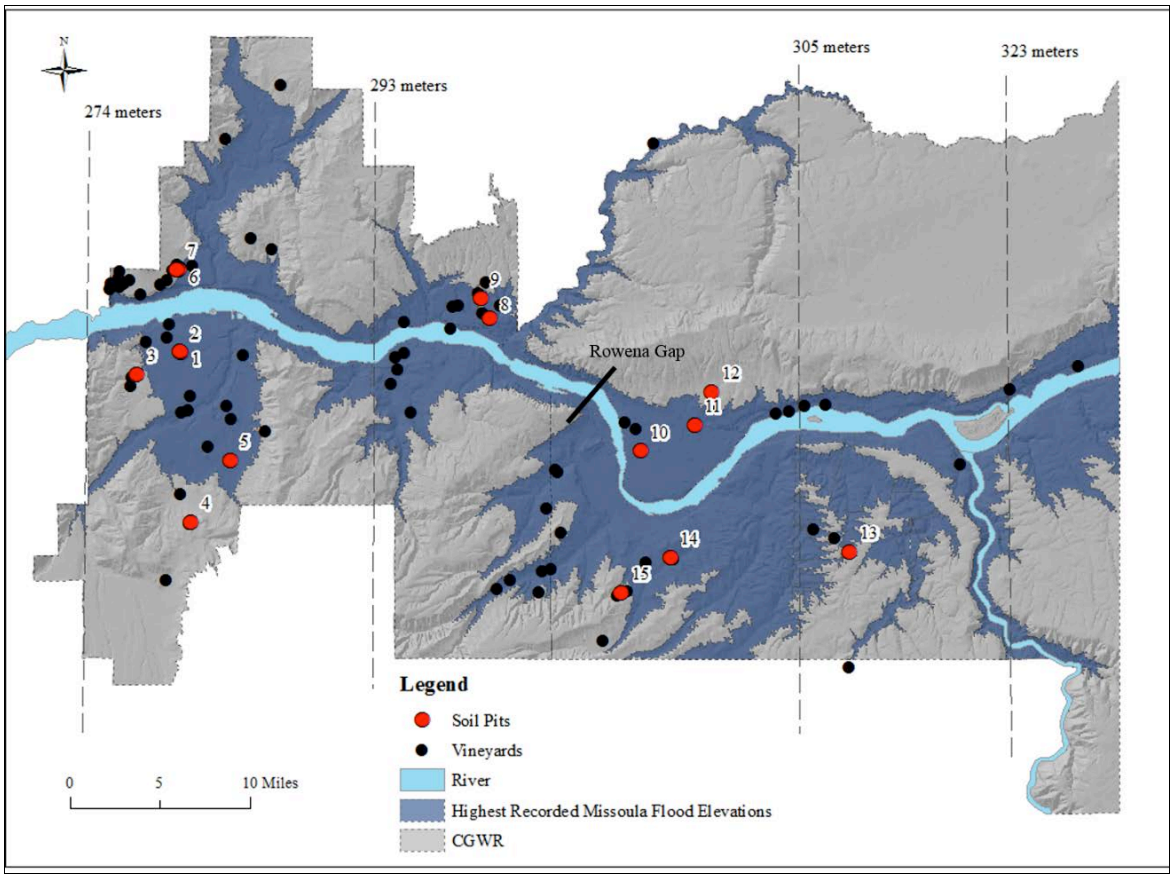

Figure 3. Extent of the Missoula Flood s in the CGWR. The extent was estimated using maximum flood elevations provided by Benito and O'Connor (2003).

4 CONCLUSION

As of 2013, there are 82 vineyards and 38 wineries in the CGWR. Participants in the soil survey showed that vineyard management decisions are dominantly based on the climatic conditions. For the most part, vitners have planted grapes varieties in regions typical for cool, intermediate and warm varieties and therefore, it can be concluded that the diversity in grape varieties is reflective of the diverse range of climatic conditions in this region (Jones, 2010). Irrigation practices also reflect the decrease in precipitation east to west, within irrigation practices taking place below 60 centimeters of rainfall. From 1981-2010, minimal rainfall has taken place during the growing season, which makes this region suitable for grape production. Pinot Noir is the dominant grape variety planted in this region. The climate in which the Pinot Noir is planted is common for this grape variety, however it is expected that the Pinot Noir planted on the western end with differ than what is planted on the eastern end. In general, warmer varieties are planted in the Columbia Valley AVA and cooler varieties are planted in the Columbia Gorge AVA. The soils in the region are all well-drained and are characterized within a xeric moisture regime. Textures and ages of the soils are influenced by the Missoula Floods. Loess is also a dominant geological factor on the vineyard soils in the eastern portion of this study. Seven sub-region are recommended in this study based on commonalities in soil series and climatic regimes. A unique combination of terroir conditions are located in each sub-group, and therefore the character of wine produced from vineyards in each of these regions. Future work of paring wine from each of these regions is needed to depict the influences of the terroir to the wine of the CGWR.

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5 LITERATURE CITED

Amerine, M. A., and Winkler, A. J., 1944, Composition and quality of musts and wines of California grapes, Volume 15, Hilgardia, p. 493-675.

Association, C. R. G. W. G., 2002, Columbia Gorge Appellation American Viticultural Area Petition, *in* Bureau of Alcohol, T., & Firearms-Regulations Division, ed.

Benito, G., and O'Connor, J. E., 2003, Number and size of last-glacial Missoula floods in the Columbia River valley between the Pasco Basin, Washington, and Portland, Oregon, Volume 115: Geological Society of America Bulletin, p. 624-638.

Burns, S., 2012, The Importance of Soil and Geology in Tasting Terroir with a Case History from the Willamette Valley, Oregon, *in* Dougherty, P. H., ed., The Geography of Wine, Springer Netherlands, p. 95-108.

Jones, G. V., Duff, A. A., Hall, A., and Myers, J. W., 2010, Spatial Analysis of Climate in Winegrape Growing Regions in the Western United States: American Journal of Enology and Viticulture, v. 61, no. 3, p. 313-326.

Jones, G. V., Hille, P., Pine, J., and Jones, H. E., 2002a, Mapping Varietal Potential for Quality Wines in Oregon using PRISM Spatial Climate Dara, American Meteorological Society, 13th Conference on Applied Climatology: Portland, Oregon.

-, 2002b, Mapping Varietal Potential for Quality Wines in Oregon using PRISM Spatial Climate Data, 13th Conference on Applied Climatology: Portland, Oregon, American Meteorological Society.

Jones, G. V., Snead, N., and Nelson, P., 2004, Geology and wine 8. Modeling viticultural landscapes: A GIS analysis of the terroir potential in the Umpqua Valley of Oregon: Geoscience Canada, v. 31, no. 4, p. 167-178.

Ma, L., Madin, I. P., Olson, K. V., and Watzig, R. J., 2009, Oregon Geologic Data Compilation: Oregon Department of Geology and Mineral Industries, scale 1:100,000.

McClaughry, J. D., Wiley, T. J., Conrey, R. M., Jones, C. B., and Kennetg E. Lite, J., 2012a, Digital Geological Map of the Hood River Valley, Hood River and Wasco Counties, Oregon: Oregon Department of Geology and Mineral Industries Open File Report O-12-03, p. 2-5.

Meinert, L. D., and Busacca, A. J., 2000, Geology and Wine 3. Terroirs of the Walla Walla Valley appellation, southeastern Washington State, USA: Geoscience Canada; Volume 27, Number 4 (2000).

-, 2002, Geology and Wine 6. Terroir of the Red Mountain Appellation, Central Washington State, U.S.A: Geoscience Canada; Volume 29, Number 4 (2002).

Peale, P., 2013, WSDA-2012 Washington State AVA's: ESRI Online database.

Pogue, K., 2012, Thoughts on becoming a terroirist, Volume 34: Walla Walla, WA, Whitman Magazine:Whitman College, p. 12-13.

Soil Survey Staff, 2010, Keys to soil taxonomy: Washington, D.C., U.S. Department of Agriculture, Natural Resources Conservation Service, p. v, 338 p.

-, 2012a, Gridded Soil Survey Geographic (gSSURGO) Database for Oregon, United States Department of Agriculture, Natural Resources Conservation Service.

-, 2012b, Gridded Soil Survey Geographic (gSSURGO) Database for Washington, United States Department of Agriculture, Natural Resources Conservation Service.

Staff., 2010, Digital Geology of Washington State at 1:100,000-scale: Washington Division of Geology and Earth Resources, scale 1:100,000.