GEOLOGIC CONTROLS ON VITICULTURE IN THE WALLA WALLA VALLEY, WASHINGTON

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INTRODUCTION

The critical zone is defined as the life-sustaining region on and near Earth's surface that is affected by the interaction of geologic, hydrologic, biologic, and atmospheric processes. Investigations into critical zone processes are needed to reveal how weathering transforms minerals, organic matter, solutions and gases to sustain life. Like all organisms, the health and character of grape vines and their fruit is determined by factors such as climate and the availability of water and nutrients. The main objective of this project was to evaluate how critical zone factors affect the physical environment and chemical character of grapes grown in the Walla Walla Valley of Washington state. Students had the opportunity to explore the geology, geochemistry, hydrology and microclimates of vineyards in the Walla Walla Valley that have been producing award-winning wines for over a decade (Fig. 1). In addition to these scientific studies, students had the opportunity to learn more about viticulture and to gain insight into the wine-making industry.

Figure 1: The Pepperbridge Vineyard is planted in soils derived from Holocene loess overlying Pleistocene Missoula flood deposits.

TERROIR

Viticulture is strongly affected by the climate, soils, and landscape at each vineyard site. The French have long recognized that wines from vineyards in different regions have distinctive qualities. They attribute these unique aromas, flavors, and other characteristics to the uniqueness of the site, or terroir of the vineyard. Although the term "*terroir*" has often been described as untranslatable, it can be roughly defined as the sum of all of the physical characteristics that make each vineyard site unique. *Terroir* is ultimately the basis for the French wine classification system, which defines the boundaries for regions, known as appellations, sharing a similar *terroir*. The grape growing regions of Washington, the second largest producer of wine grapes in the United States, have been similarly subdivided into a number of American Viticultural Areas (AVAs). However, most Washington State AVAs contain numerous *terroirs* due to substantial internal variations in climate, geology, and soils. Such is the case with the Walla Walla Valley AVA, which straddles the border with Oregon in the southeastern part of the state (Fig. 2).

The Walla Walla Valley AVA is located at 46° N, a latitude that lies midway between the famous French wine appellations of Burgundy and Bordeaux. The relatively high latitude provides vineyards in the Walla Walla AVA with an average of 30 minutes more daily sunshine during the growing season than vineyards in the famous Napa Valley of California. The western lower elevation (122 m minimum) part of the AVA annually receives less than 18 cm of precipitation due to the rain shadow produced by the Cascade Mountains while as much as 65 cm of precipitation falls in the higher (610 m maximum) eastern part of the AVA. Very little precipitation

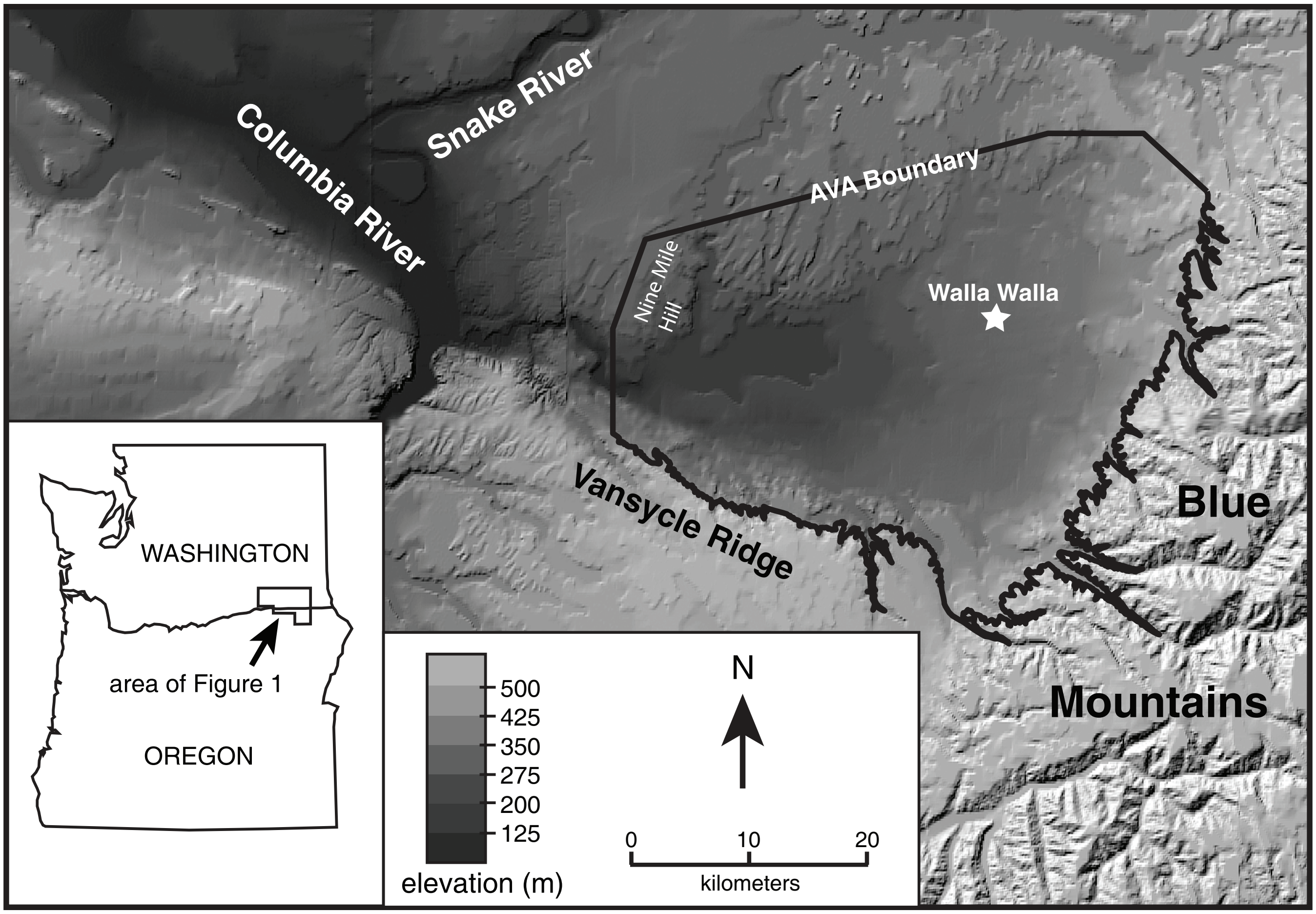

Figure 2: Shaded relief map of the Walla Walla Valley AVA.

falls during the growing season, so water uptake by the vines is precisely controlled by irrigation. The Walla Walla Valley AVA has become famous in recent years for award-winning red wines produced primarily from syrah, merlot, and cabernet sauvignon grapes. However, the broad range of microclimates in the AVA permit the cultivation of most wine grape varieties.

GEOLOGICAL SETTING

Highlights of the geological history of the Walla Walla Valley include massive flood basalt eruptions, cataclysmic glacial outburst floods, and thick deposits of windblown silt. Southeast of Walla Walla, the Blue Mountains expose the Columbia River Basalt Group which was erupted primarily between 17-15 Ma (early Miocene); (Carson and Pogue, 1996) This basalt forms the bedrock in most of eastern Washington including the entire Walla Walla River basin. A series of cataclysmic glacial outburst floods known as the Missoula floods occurred between 15,300 and 12,700 years ago (Waitt, 1985). Each outburst discharged up to 2,500 km3 of water from modern-day Montana (Atwater, 1986, Baker and Bunker, 1985, Pardee, 1910). When the floods reached the narrow outlet to the Columbia Basin known as Wallula Gap, they were temporarily impounded, flooding the valleys of the Walla Walla and Yakima Rivers. The sediments deposited by each flood accumulated in these river valleys as graded rhythmites known as the Touchet beds. The Touchet beds are the primary source for many of the soils in the Walla Walla Valley. In many parts of the valley, fluvial and aeolian processes have reworked the flood sediments. The prevailing southwest winds eroded the silt fraction from the barren sediment-covered landscape left behind by each Missoula

Major categories of soil *terroirs* in the Walla Walla Valley AVA

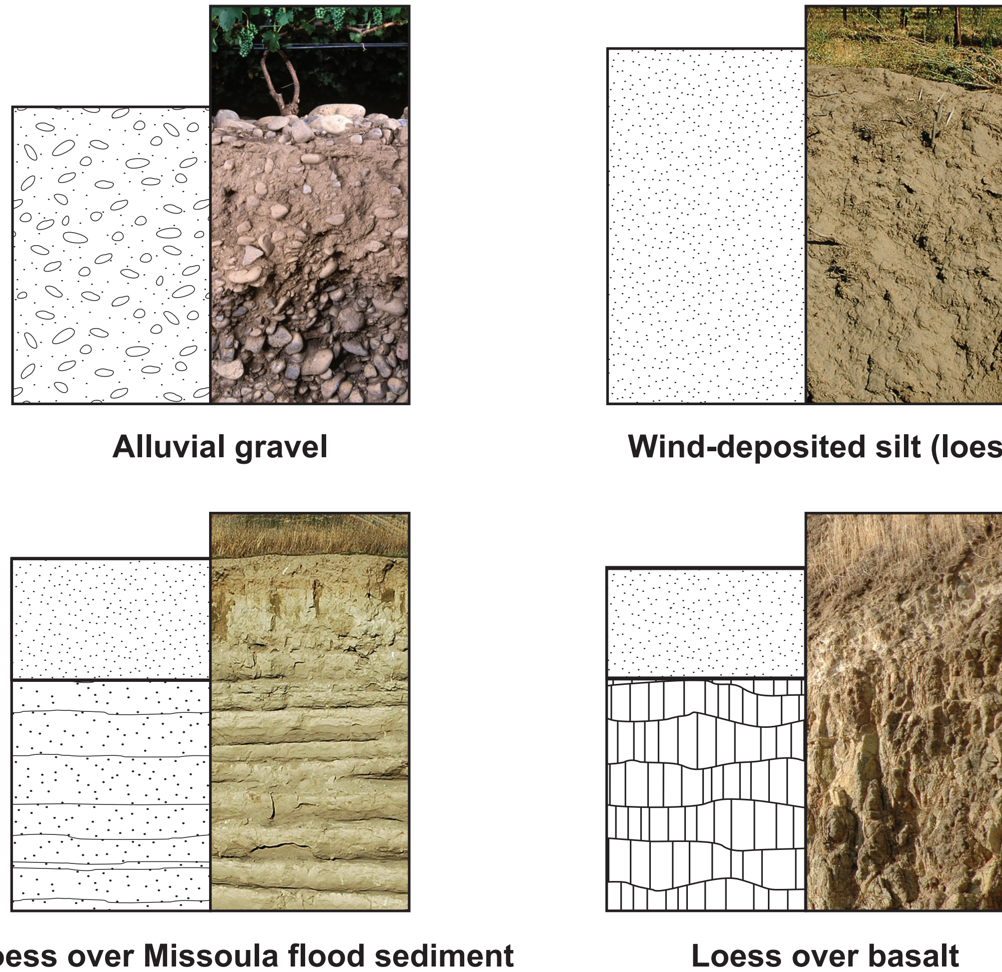

Figure 3. Photographs of the four major soil terroir categories in the Walla Walla Valley AVA.

flood. The winds transported the silt to the northeast, blanketing the landscape with thick deposits of loess.

The chemical and physical characteristics of the soils of the Walla Walla Valley AVA help the wines develop desirable flavors and chemical characteristics that distinguish them from the wines of other areas of the world. Within the Walla Walla Valley, grapes are grown on a variety of soils derived from the materials discussed above (Meinert and Busacca, 2000). Although the bedrock for most of Walla Walla is Columbia River Basalt, no soils in this region are derived directly from the weathering of the basalt bedrock. Most soils in the Walla Walla Valley AVA have been minimally influenced by the chemistry of this rock because the overlying sediments were transported to the area by catastrophic floods and wind. The soil component of the *terroir* at vineyard sites in the Walla Walla Valley AVA can be broadly divided into four categories (Fig. 3):

1) Thick loess where grape roots never reach underlying units.
2) Thin loess where grape roots penetrate underlying basalt bedrock.
3) Thin loess where grape roots penetrate underlying Missoula flood deposits.
4) Thick alluvial gravels dominated by basalt cobbles.

Weathering and pedogenesis (soil formation) following the deposition of the material listed above has produced a great deal of variation with regards to the soil chemistry, soil texture, and water drainage requiring more than a single site evaluation at each vineyard. For this project, the resolution of the data collected was a function of the five soil-forming factors (parent material, climate, biology/organics, topography, and time) as well as farming and irrigation practices. All the data collected for this project was incorporated into a GIS database in order to provide an in-depth evaluation of how these soils and their chemistries varied geographically.

METHODOLOGY

Our overall goals were to evaluate the (1) soil science and geochemistry, (2) hydrology/soil physics and (3) microclimates of the Walla Walla Valley AVA in order to provide new insight into how critical zone processes affect the environmental chemistry of vineyards and their vines and grapes. (Fig. 4). Specific problems addressed are summarized below.

Soil Science and Geochemistry

1) How do soil trace metals influence the trace metal composition of the plant, fruit, and ultimately wine?
2) Can the extractable/bioavailable elements in a soil be used to trace where a wine was grown?
3) Does soil chemistry really play a role in defining the character of a wine?
4) What is the extent that farming practices influence the chemistry and physical character of vegetation?

Hydrology/Soil Physics

1) How does the soil hydrology vary based on the soil type and overall in each winery?
2) Is it possible to provide a more effective irrigation strategy for each winery to aid in water conservation based on the soil physics data collected?
3) Despite the arid climate of the Walla Walla Valley, is dryland farming a potential viticultural practice?

Figure 4: Students collecting samples and data at vineyards near Milton-Freewater, OR.

Microclimates

1) Are the claims of many wineries regarding the importance of rocky soils to vineyard temperature variations valid? If so, how significant are these variations?
2) What is the range of temperature variations within a flat vineyard versus a hilly vineyard?

3) How important is topography with regards to the microclimates of Walla Walla Valley AVA vineyards?

OVERVIEW OF STUDENT PROJECTS

Karl Lang examined temperature fluctuations related to microclimates as a function of ground surface material. He collected temperature measurements at the level of individual grape clusters and at depths below the surface in four vineyards with different types of ground cover. By comparing the relative temperature differences between locations and the ambient air and surface temperatures, he was able to evaluate how ground cover affects the actual temperature a grape cluster experiences. Surfaces covered with cobble alluvium are able to maintain higher subsurface temperatures for a longer period of time than grass- or bare soil-covered vineyards. Additionally, his results demonstrate that ambient vineyard air temperature measurements are not a good proxy for the temperatures actually experienced by grape clusters.

Anna Weber investigated the relationships between soil electrical conductivity (EC) and a suite of chemical and physical soil properties at a future vineyard site near Milton-Freewater, OR. The use of EC surveys are currently being used as a proxy to indirectly evaluate soil properties, but its efficacy has not yet been robustly tested in the field or in the Walla Walla area. By assessing the soil chemistry and field-saturated hydraulic conductivities at ten 2 m deep soil pits at the Milton-Freewater site, she was able to quantify the relationships of the soil properties to soil EC. Anna was able to determine that soil EC can reliably predict trends in available K, available Ca, and pH across the field despite the complexity of soil systems that may affect EC measurements.

Ruth Indrick analyzed the chemistry of the rocks, soils, and grapevines in vineyards near Milton-Freewater, OR, to determine the sources of available nutrient elements for the grapevines in vineyards with varying farming practices. By comparing the total rock chemistry to the total soil chemistry, nutrient inputs, including loess and anthropogenic sources, were assessed. Comparing the concentration of elements in the plant to the concentration of elements in the soil also aided in determining the dependency of biogeochemical interactions and nutrient uptake between the grape plants and the soil in vineyards with juxtaposing farming methods.

Season Martin evaluated the biogeochemical relationship between soil chemistry and syrah plant chemistry in fourteen vineyards in the Walla Walla Valley AVA. Her work demonstrates that no apparent correlation is apparent between Ca, Zn, Sr, and Rb in grape juice and the soils; however, Fe in juice samples was identified to be positively correlated to values in the soil. Based on her analyses, she was able to determine that bulk elemental soil concentrations and plant uptake processes may not correspond to chemistries reported in juices.

Anna Mazariello sampled vineyard soils within the Walla Walla Valley AVA to evaluate and interpret elemental distributions throughout the valley. Anna was able to determine that the chemical weathering of the parent material affects a range of elements present within a soil. Based on her GIS work, Anna proposes that vine health is potentially related to chemical weathering of the soil parent material which is influenced by variations in climate and weathering rates as elevation increases.

John Nowinski assessed soil-water interactions in the Walla Walla Valley by examining variations in precipitation, soil texture, soil permeability, soil moisture, and soil chemistry. His results suggest that increased precipitation at higher elevations creates a soil moisture gradient in the valley. The rainfall distribution also appears to influence soil texture by increasing the weathering of silt to clay at higher elevations. He also found that soil chemistry reflects this process, with pH decreasing at higher elevations and available cations increasing due to the higher clay content. Soil permeability plays no clear role in any of these interactions. His findings indicate that dryland vineyards are possible at higher elevations in the Valley and could potentially produce high quality fruit because the grapevines would benefit from mild water stress and increased nutrient availability.

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