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Folds, floods, and fine wine: Geologic influences on the terroir of the Columbia Basin

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ABSTRACT

The geomorphology, soils, and climate of Columbia Basin vineyards are the result of a complex and dynamic geologic history that includes the Earth's youngest flood basalts, an active fold belt, and repeated cataclysmic flooding. Miocene basalt of the Columbia River Basalt Group forms the bedrock for most vineyards. The basalt has been folded by north-south compression, creating the Yakima fold belt, a series of relatively tight anticlines separated by broad synclines. Topography related to these structures has strongly influenced the boundaries of many of the Columbia Basin's American Viticultural Areas (AVAs). Water gaps in the anticlinal ridges of the Yakima fold belt restrict cold air drainage from the broad synclinal basins where many vineyards are located, enhancing the development of temperature inversions and locally increasing diurnal temperature variations. Vineyards planted on the southern limbs of Yakima fold belt anticlines benefit from enhanced solar radiation and cold air drainage. Most Columbia Basin vineyards are planted in soils formed in eolian sediment that is primarily derived from the deposits of Pleistocene glacial outburst floods. The mineralogy of the eolian sediment differs substantially from the underlying basalt. Vineyard soil chemistry is thus more complex in areas where eolian sediment is comparatively thin and basalt regolith lies within the rooting zone.

The components of physical terroir that broadly characterize the Columbia Basin, such as those described above, vary substantially both between and within its AVAs. The vineyards visited on this field trip are representative of both their AVAs and the variability of terroir within the Columbia Basin.

INTRODUCTION

This field trip focuses on the variations in vineyard geology and climate that have produced a broad range of physical terroirs within the Columbia Basin, the region of eastern Washington and northeastern Oregon that lies east of the Cascade Range and north and west of the Blue Mountains and is generally below 600 m in elevation (Fig. 1). The French word *terroir* is commonly used to refer to the sum of all environmental factors that affect the production of a wine and account for its distinctive characteristics. The term is also invoked to describe the sensory qualities of a wine that relate it to specific place, an attribute wine writer Matt Kramer has described as a wine's "somewhere-ness."

It is tempting, especially for earth scientists, to overemphasize the physical components of terroir such as geomorphology, bedrock, soils, and climate (e.g., Wilson, 1998; Fanet, 2004). However, the cultural environment of a vineyard and winery also heavily influences the unique combinations of flavors, aromas,

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colors, and textures that define a wine's somewhere-ness. In Europe, both viticulture and winemaking have evolved over hundreds of years in response to the unique physical terroir of each region. Viticulturalists have determined the varieties, known as cultivars, which are best suited to their region (e.g., Pinot Noir in Burgundy) and how best to farm them. Winemakers have developed techniques designed to highlight the qualities of their region's cultivars. Thus, the physical terroir and the cultural terroir work in harmony to produce wines of a unique character. Over time, various regions have become associated with distinctive styles of wine.

Recognizing that wines derive much of their value from their unique terroirs, the French government in 1935 created a system that legally defined viticultural regions. Each wine-producing region, known as an appellation, has rigid guidelines that legally define or restrict the cultivars and the viticultural and winemaking techniques that may be utilized. Other European countries have followed suit, establishing their own guidelines for legally recognized wine producing areas. In 1978, the U.S. Bureau of Alcohol, Tobacco, and Firearms (now the Alcohol and Tobacco Tax and Trade Bureau, or TTB) established a system whereby U.S. grape and wine producers could petition to have their region formally recognized as an American Viticultural Area (AVA). The TTB regulations legally define the geographic boundaries of AVAs, but no restrictions are placed on the variety of grape or how it is grown. To be approved, a petition for a new AVA must contain "evidence that the geographical features of the area produce growing conditions which distinguish the proposed area from surrounding areas" (Section 4.25a(e)(2), Title 27, Code of Federal Regulations). If the name of an AVA appears on a wine bottle, TTB regulations require that eighty-five percent of the grapes used to make the wine must come from within the boundaries of the AVA, but place no other restrictions on winemaking techniques.

Due to the substantial variations in climate and soils, it is unreasonable to expect that all wines produced from grapes grown within the boundaries of a particular AVA will possess a shared set of sensory characteristics that define a somewhereness or "taste of place." The defining physical characteristics of an AVA are therefore best viewed as a broad theme that unites a unique collection of terroirs. True terroir can only be expressed at the scale of individual vineyards.

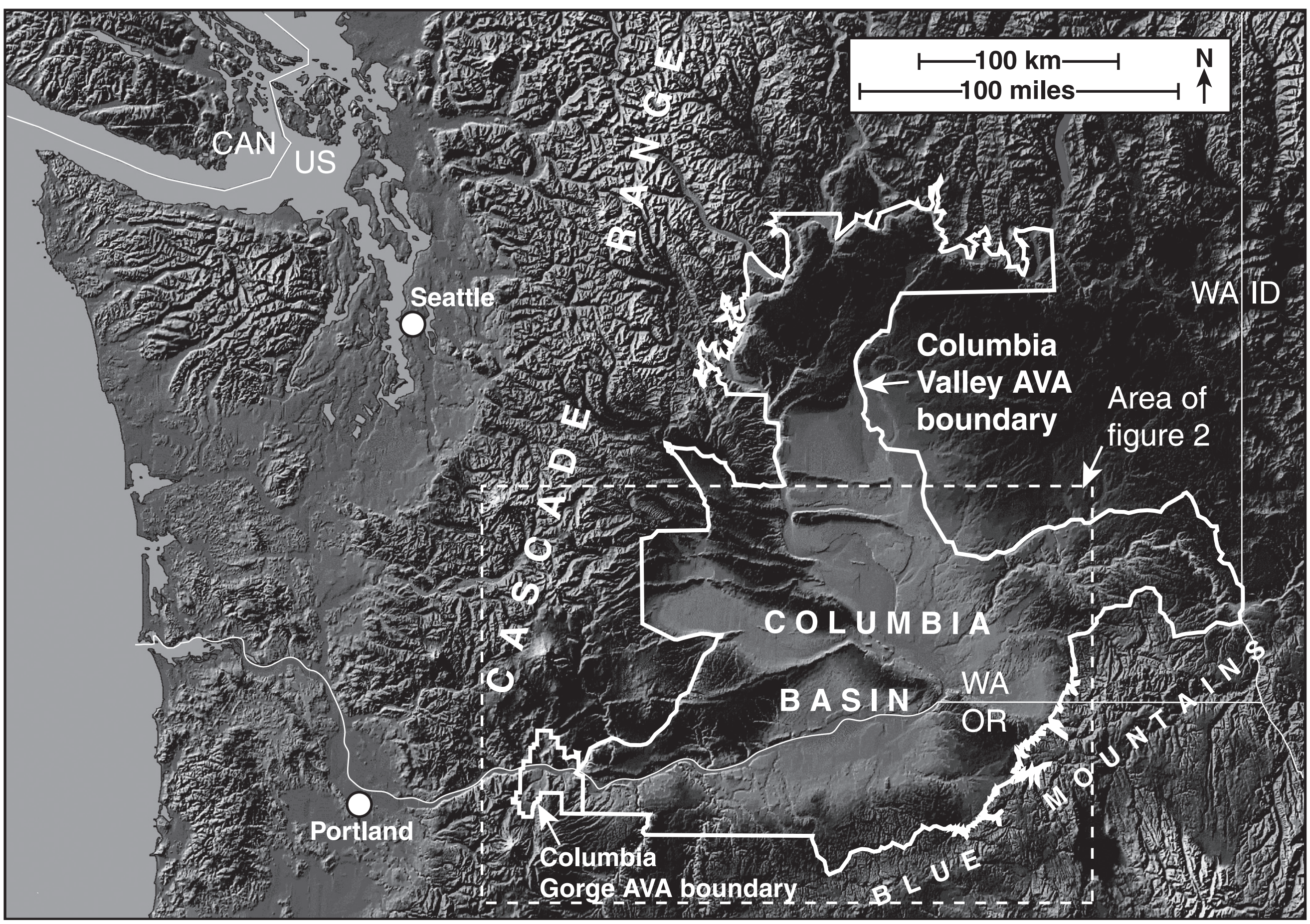

Figure 1. Shaded relief map showing locations of the Columbia Basin and Columbia Valley American Viticultural Area (AVA). ID—Idaho; OR—Oregon; WA—Washington.

Although wine grapes have been cultivated in the Columbia Basin since the 1800s, there were still fewer than 10 commercial wineries in the northwestern United States in 1970 (Gregutt, 2007). In the 1980s, the number of wineries increased dramatically, and many new vineyards were planted, primarily in the Yakima Valley, an established agricultural area with a relatively plentiful supply of irrigation water. In 1983, a petition by Yakima Valley vineyard owners and winemakers was approved, and the Yakima Valley became the first AVA in the Columbia Basin (Fig. 2). The next year, the petition for the Columbia Valley AVA, was approved. Its authors designated the boundaries to encompass most of the region within the Columbia Basin with viticultural potential, principally low elevation regions with an arid to semi-arid climate (Fig. 1). Since 1984, seven more AVAs have been designated in the Columbia Basin. Six of these—the Walla Walla Valley, Red Mountain, Horse Heaven Hills, Rattlesnake Hills, Wahluke Slope, and Snipes Mountain—lie within the confines of the Columbia Valley AVA (Fig. 2). The Columbia Gorge AVA, approved in 2004, abuts the western boundary of the Columbia Valley AVA along the Columbia River (Figs. 1 and 2).

Geologic Setting

During the Miocene, between 17 and 6 Ma, ~174,000 km^3 of continental tholeiitic basalt erupted from fissures in southeastern Washington, northeastern Washington and western Idaho (Tolan et al., 1989). At least 300 individual flows eventually covered more than 164,000 km^3 of Washington, Oregon, and Idaho, a region known as the Columbia plateau (Fig. 3). The thickness of the basalt exceeds 4 km in the central part of the plateau (Reidel et al., 1989). The course of the ancestral Columbia River followed the northern and western margin of the basalt, which rerouted rivers draining eastward from the crest of the Cascade Range. Fluvial and lacustrine sediments overlying and interbedded with the Columbia River Basalt of the western Columbia plateau are known as the Ellensburg Formation. The Ellensburg Formation consists of both laterally extensive Cascade-derived

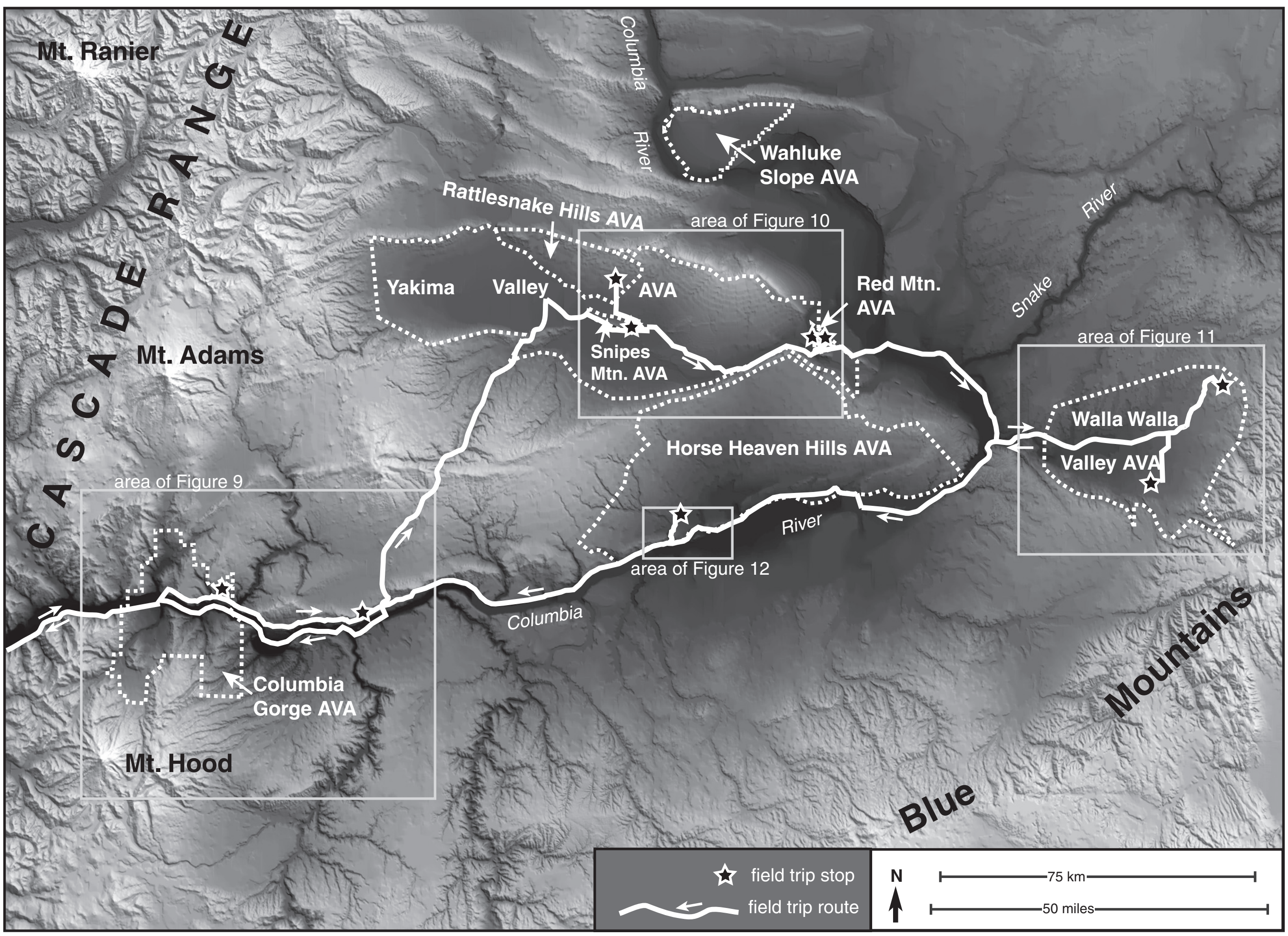

Figure 2. Shaded relief map of the Columbia Basin showing the field trip route, locations of the Columbia Gorge American Viticultural Area (AVA), and locations of the seven sub-AVAs of the Columbia Valley AVA.

volcaniclastic debris-flow deposits and polymict conglomerate deposited within the channels of the ancestral Columbia River (Smith, 1988). The Columbia River Basalt Group and Ellensburg Formation form the bedrock in all of the vineyards visited on this field trip as well as in the vast majority of the Columbia Valley AVA (Fig. 3).

As the basalt flows were emplaced, they were folded by north-south compression induced by partial coupling between the North American and Pacific plates (Reidel et al., 1984, 1989, Zoback and Zoback, 1980). In the southwestern part of the Columbia Basin, the compression created the Yakima fold belt, a series of generally east-trending anticlines separated by broad synclines (Fig. 4). The present landscape of the Yakima fold belt reflects the youthfulness of its tectonism; anticlines form ridges and synclines form valleys. The asymmetric anticlines of the Yakima fold belt are generally north vergent and have thrust faults associated with their steeper limbs. The broad synclines of the Yakima fold belt are largely a consequence of the adjacent anticlines and were not formed by active downwarping of the basalt (Reidel et al., 1994).

As the anticlinal ridges of the Yakima fold belt began to grow, erosion by the ancestral Columbia and Yakima Rivers was initially able to keep pace, creating the water gaps still utilized by these rivers (Fig. 5A). However, the combination of the rising anticlinal ridges, volcanism, and isostatic subsidence of the thick pile of basalt centered in the Pasco Basin eventually steered the rivers to the east along synclinal axes (Fecht et al., 1987) (Fig. 5B). The ancestral Columbia and Yakima Rivers were ultimately captured by the ancestral Salmon-Clearwater River, which had carved Wallula Gap, a water gap through the Horse Heaven Hills anticline (Fig. 5C). Downstream from Wallula Gap, the present-day Columbia River coincides with the course of the ancestral Salmon-Clearwater River, which was itself guided by a series of synclinal structures along the southern margin of the Yakima fold belt. By the late Pliocene, the present-day drainage pattern of the southern and western parts of the Columbia plateau, characterized by broad synclinal basins connected by relatively narrow water gaps, had been established (Fig. 5D)(Fecht et al., 1987).

At elevations below 330 m, Miocene and Pliocene rocks and sediments of the Columbia Basin are commonly overlain by sediments deposited by catastrophic glacial outburst floods. There is evidence of at least four cycles of catastrophic flooding that may have commenced as early as 2.6 Ma (Bjornstad et al., 2001; Spencer and Jaffee, 2002). Sediments deposited by the

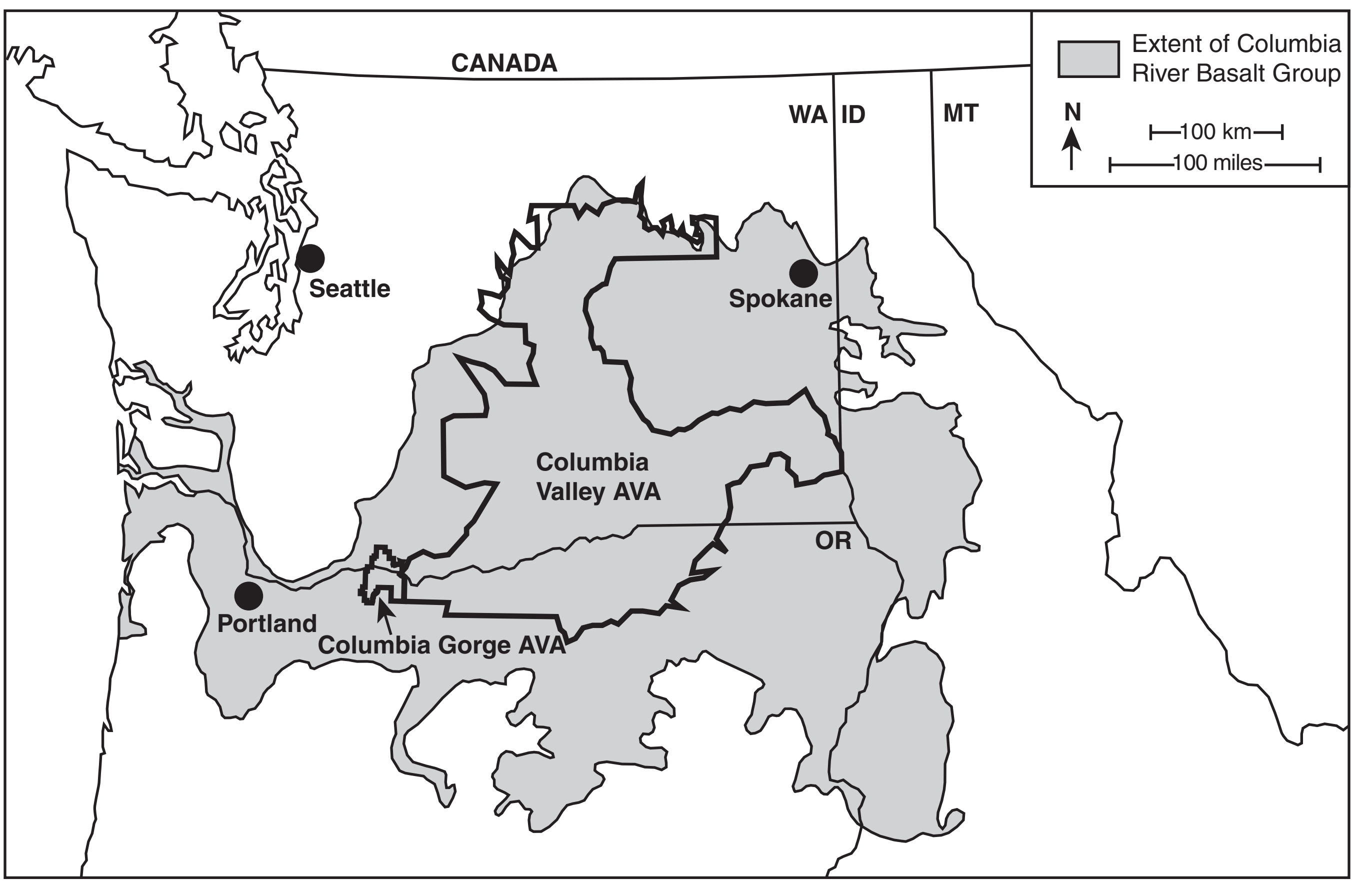

Figure 3. Map showing the Columbia Valley American Viticultural Area (AVA), the Columbia Gorge AVA, and extent of the Columbia River Basalt Group, based on Tolan et al. (1989). ID—Idaho; MT—Montana; OR—Oregon; WA—Washington.

earlier floods have been largely removed by erosion, but deposits from the most recent cycle, known as the Missoula floods, are still laterally extensive and lie within the rooting zone of many Columbia Basin vineyards.

The Missoula flood cycle occurred between 18,000 and 12,000 radiocarbon years ago as the result of the repeated release of up to 2500 km^3 of water derived primarily from glacial Lake Missoula, a 7800 km^2 lake in western Montana formed when the Purcell Trench lobe of the Cordilleran ice sheet blocked the Clark Fork River (Fig. 6) (Bretz et al., 1956; Baker, 1973, Baker and Bunker, 1985; Waitt, 1980, 1994, Bjornstad, 2006). Each time the glacial ice dam catastrophically failed, the floods, with a discharge that sometimes exceeded 10 times the combined flow of all modern rivers, swept across the eastern and central Columbia Plateau. The floods scoured away the eolian sediment derived from previous flood cycles, and carved deep channels, known as coulees, into the underlying basalt. The flood-eroded landscape of coulees interspersed with erosional remnants of basalt, known as scabs, is referred to as the Channeled Scabland (Bretz, 1923).

The various routes of the floodwaters converged at Wallula Gap, the only outlet for the Pasco Basin (Fig. 6). As the floodwaters stalled at the constriction, the area upstream of Wallula Gap was inundated to an elevation of at least 365 m. Sediment with graded bedding was deposited in many parts of the back-flooded areas as the floodwaters slowed. Slackwater sediment derived from each successive Missoula flood eventually accumulated to form a rhythmic sequence of graded beds known as the Touchet beds. By the end of the Missoula flood cycle, up to 40 m of Touchet beds had accumulated in parts the Pasco Basin and in the valleys of the Walla Walla and Yakima Rivers (Waitt, 1980, Carson and Pogue 1996). Slackwater sediments were also deposited downstream from Wallula Gap in the Umatilla Basin, as the Missoula floods slowed and spread out. Below the Umatilla Basin, erosion by the floods created channeled scabland topography on the floor of the Columbia River gorge and stripped loess and colluvium from its walls, accentuating the stepped topography created by differential erosion of the stacked lava flows of the Columbia River Basalt. Side canyons in the Columbia Gorge created

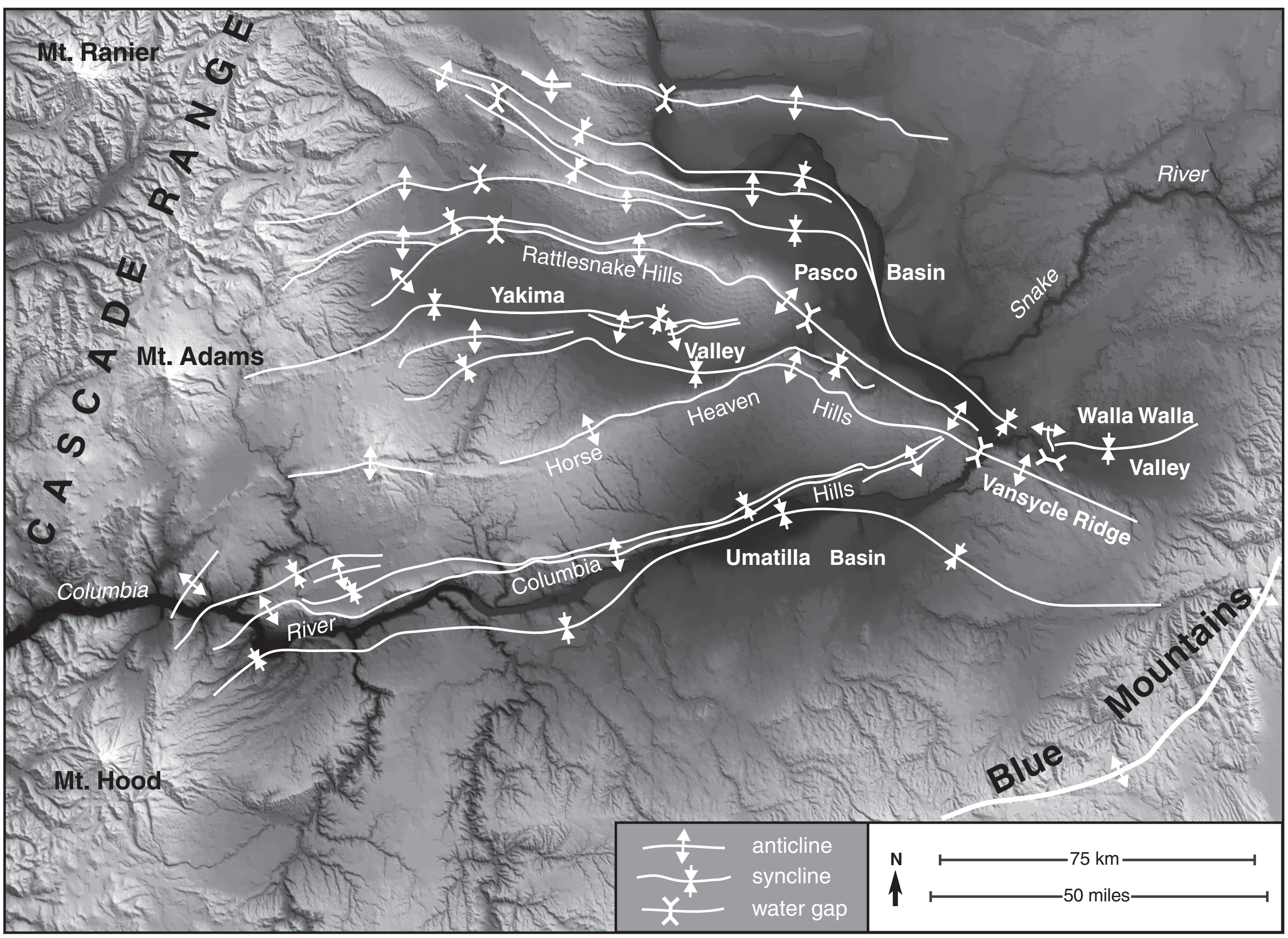

Figure 4. Shaded relief map showing location of the axial traces of major folds of the Yakima fold belt and Blue Mountains anticline, based on Tolan and Reidel (1989) and Newcomb (1970).

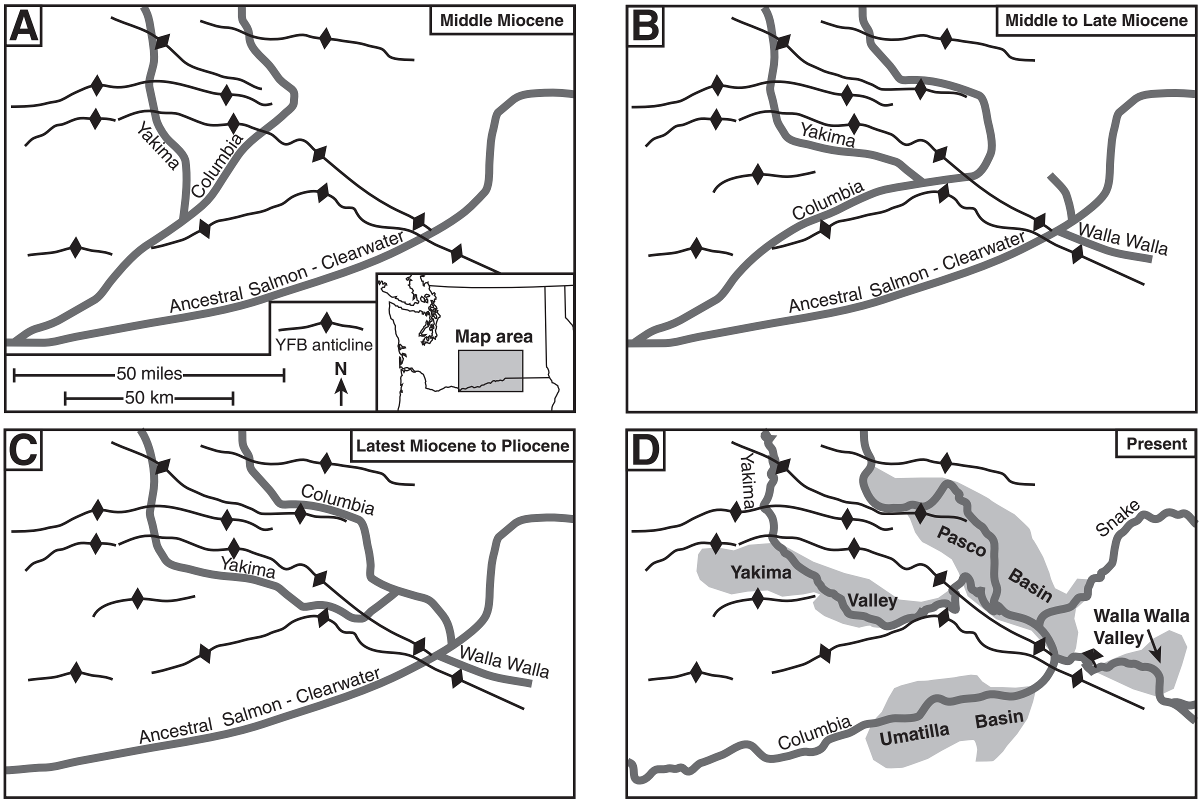

Figure 5. Model of Neogene evolution of major rivers in the Columbia Basin, based on Fecht et al. (1987). YFB—Yakima fold belt.

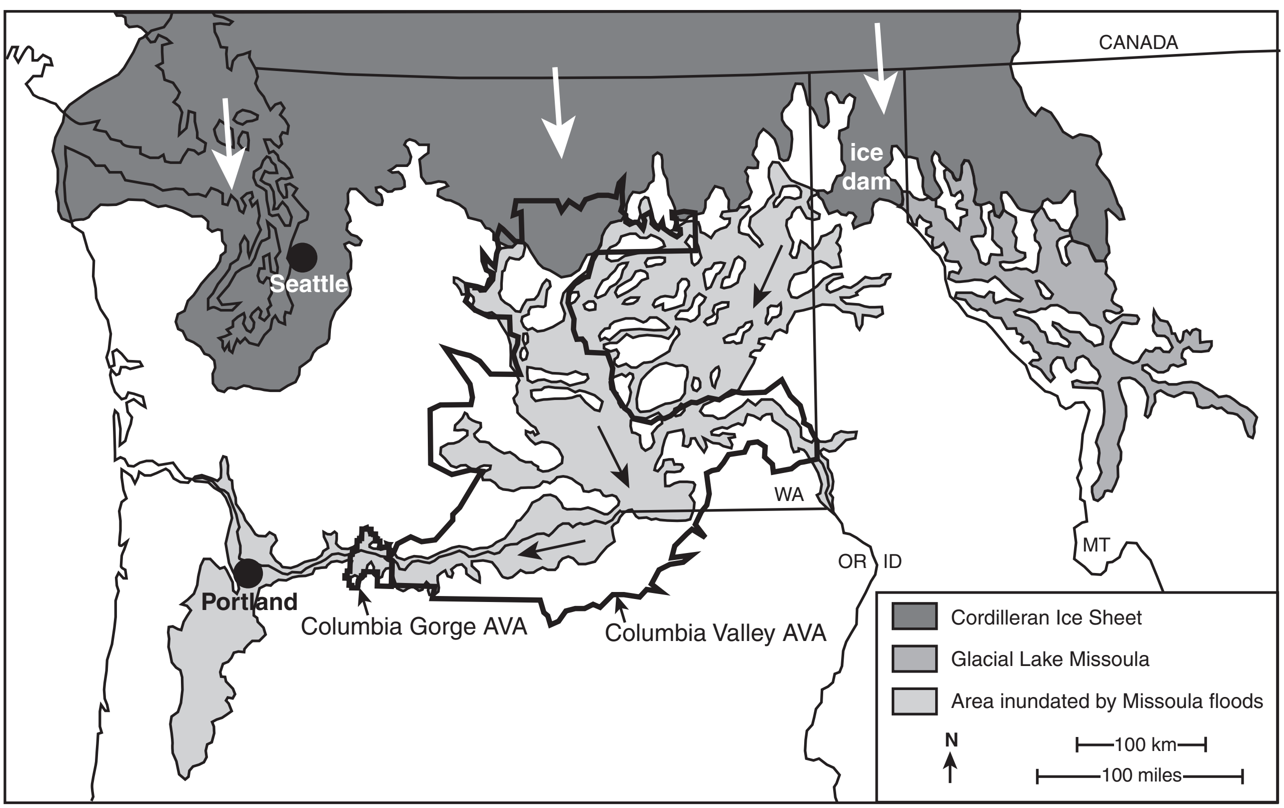

Figure 6. Map showing location of Cordilleran ice sheet at maximum advance, Glacial Lake Missoula, and areas inundated by the Missoula floods. AVA—American Viticultural Area.

eddies in the Missoula floods in which enormous gravel bars were deposited. The maximum elevation of the Missoula floods can be estimated by the highest occurrence of erratics that mark the final resting place of icebergs derived from the glacial dam.

Climate

The Columbia Basin is sheltered to the north and east by the Rocky Mountains, which limit the invasion of the polar and arctic air masses from northern Canada. The Cascade Range to the west largely blocks the Pacific air masses that moderate the climate of coastal areas of the Pacific Northwest. As a result, the basin has a much drier and more continental climate than coastal areas, but its winters are generally milder than regions at similar latitudes farther inland.

Annual precipitation patterns are related to a semi-permanent offshore center of high pressure that deflects precipitation-producing low-pressure systems to the north during the summer. Summer rainfall is rare in the Columbia Basin, and temperatures frequently exceed 35 °C from July through mid August. The off-shore high-pressure area drifts southward during the fall, steering low-pressure systems into the Northwest and initiating an interval of cloudy and wet weather that often persists into late spring. Almost all precipitation in the Columbia Basin occurs between late fall and early spring (Ruffner, 1980).

The climate of the viticultural areas of the Columbia Basin is strongly influenced by the orographic barrier of the Cascade Range to the west, which deprives the invading maritime air masses of much of their moisture. The mountains force the air aloft, where it cools to its dew point temperature, initiating cloud formation and precipitation that provides the western slopes of the Cascades with some of the highest annual precipitation in the United States. The moisture-depleted air is adiabatically warmed as it descends the east side of the mountains, further lowering its relative humidity and inhibiting precipitation. The precipitation gradient on the eastern slopes documents this rain shadow effect. In some areas along the east slope of the Cascades, average annual precipitation drops by as much as 200 cm over a horizontal distance of 40 km (Fig. 7). Annual precipitation in the principal viticultural areas of the Columbia Basin averages less than 25 cm making irrigation a necessity (Fig. 7). Dry land viticulture is only possible where annual precipitation exceeds 50 cm in the eastern part of the Walla Walla Valley AVA and western part of the Columbia Gorge AVA.

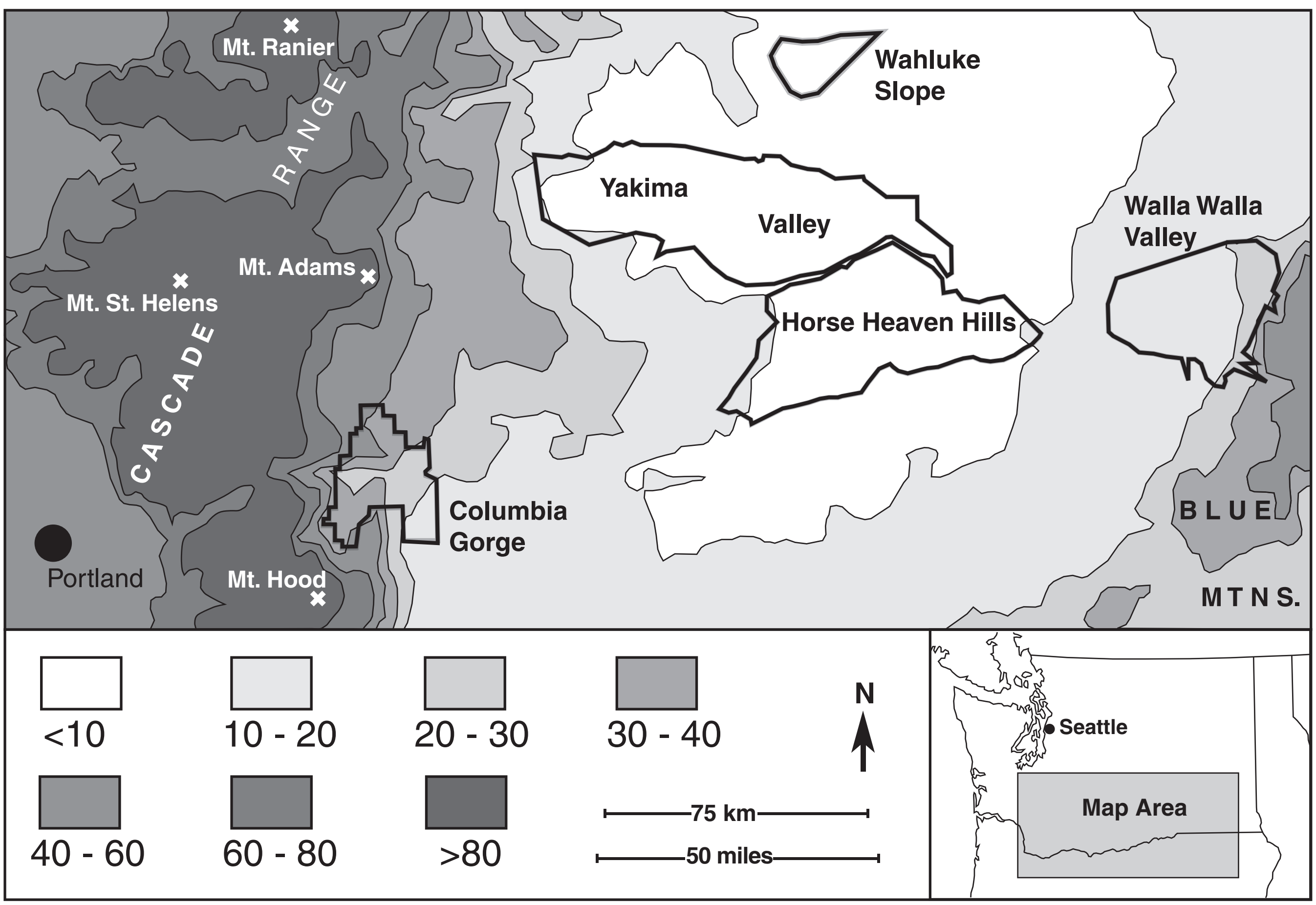

Figure 7. Map showing annual average precipitation, in inches, in the Columbia Basin and surrounding areas, derived from Daly (2000).

The mesoscale climate of the Columbia Basin is strongly influenced by its many water gaps, which impede air movement. On clear nights, air cooled by rapid radiational heat loss pools behind these constrictions, creating temperature inversions. Vineyards on or near basin floors therefore have larger diurnal and seasonal temperature variations and a greater risk of damage from frost and freeze events. The primary temperature-dependent variables used to evaluate vineyard sites, such as growing degree-days, average temperature, and number of frost-free days, locally show substantial variation over relatively short distances, due to the affects of elevation, local topography, slope angle, and aspect. Due to these variations, it is possible in many AVAs to find sites suitable for both cool climate cultivars such as Reisling and Chardonnay and warm climate cultivars such as Grenache and Mourvedre.

Soils

Loess of varying thickness, largely derived from the deflation of Pleistocene catastrophic flood deposits, forms the parent material of the silt-loam soils typical of most Columbia Basin vineyards (McDonald and Busacca, 1988). In vineyards with elevations below the maximum height of the Missoula floodwaters, loess up to 2 m thick typically overlies Columbia River Basalt, Ellensburg Formation, or flood-derived gravels and slackwater sediments (Touchet beds). These eolian soils typically have a higher percentage of sand in areas downwind and proximal to the larger slackwater basins. Downwind of the Pasco Basin, in the Palouse region, elevations above the maximum flood height commonly feature soils developed in >3-m-thick intervals of loess derived from multiple Pleistocene flood cycles (McDonald and Busacca, 1992). Throughout the Columbia Basin, eolian sediments are generally thinner and soils more poorly developed on moderately to steeply sloping south- to west-facing (windward) hillsides.

Most vineyards in the Columbia basin are planted in arid to semi-arid regions dominated by Aridisols (Boling et al., 1998). These soils typically have a pronounced zone of calcium carbonate deposition that locally forms hardpans that are impenetrable by the roots of grapevines. Irrigation is required to sustain viticulture in these soils as they dry out completely during the summer. Some vineyards are planted in soils classified as Entisols, which were formed in recent eolian deposits and show little to no profile development. Loess-derived soils in regions receiving more than 23 cm (9 in) of precipitation and where perennial grasses are the dominant natural vegetation are generally classified as Mollisols. In regions where the thickness of the loess-based Mollisols exceeds 2 m and rainfall exceeds 50 cm (20 in), dry land viticulture is possible.

Geologic Influences on Terroir

Geology primarily influences wine quality through its effects on vineyard topography, climate, and the textural, hydrologic, and thermal properties of vineyard soils (Seguin, 1986; Gladstones, 1992; Huggett, 2005; Van Leeuwen and Seguin, 2006; Maltman, 2008). Despite the popular notion (e.g., Kramer, 2008) that some wines express a “goût de terroir,” a literal “taste of place,” research has yet to reveal any direct links between the geochemistry of a vineyard’s soil and bedrock and the complex flavor and aroma compounds of its wines (Goode, 2005). It should be apparent that it is not possible to taste Kimmeridgian limestone in a Chablis, or Devonian slate in a Reisling from the Moselle Valley, especially since these rocks, like most, are flavorless. It is possible, however, that variations in mineral-derived nutrients could indirectly affect wine quality through an ability to catalyze, inhibit, or alter the synthesis of organic compounds within the grapevine or during the winemaking process.

The most important geological influences on the terroir of the Columbia Basin are the Cascade Range, the folds of the Yakima fold belt, and the Missoula floods. The rain shadow produced by Miocene uplift of the Cascade Range (Takeuchi and Larson, 2005) provides a sunny, arid climate that enhances photosynthesis and flavor development in grapes and allows precise control of vine water uptake through irrigation. Although the notion of a direct contribution to Columbia Basin terroir by the products of Cascade Range volcanoes may be romantic and appealing, tephra is only a minor component of the soils of most vineyards (Baker et al., 1991) and typically has little effect on soil chemistry, texture, or hydrology. Columbia Valley terroir is most significantly affected by Cascade Range volcanism in the Columbia Gorge AVA and in the western part of the Yakima Valley AVA. The soils in some Columbia Gorge vineyards are developed in basaltic alluvium and ash derived from Quaternary Cascade Range volcanoes (Gregutt, 2007). In the western Yakima Valley, vineyard soils at some sites are developed in Cascade-derived dacitic volcaniclastics of the Miocene Ellensburg Formation (Busacca and Meinert, 2003).

The boundaries of the seven smaller AVAs that lie within the Columbia Valley AVA are largely based on topography that is a consequence of Yakima fold belt structures. Four are largely situated on dip slopes on the south-facing limbs of Yakima fold belt anticlines (Rattlesnake Hills, Red Mountain, Wahluke Slope, Horse Heaven Hills), two are in synclinal valleys (Walla Walla Valley, Yakima Valley), and one encompasses both sides of an anticlinal ridge (Snipes Mountain)(Fig. 2). Although the boundaries of the Columbia Gorge AVA are not influenced by Yakima fold belt structures, the axes of several Yakima fold belt folds cut obliquely through the heart of the AVA and locally exert a strong control on vineyard site topography.

Topographic variables such as slope and aspect influence viticulture primarily through their affects on solar radiation and cold air drainage. For example, the gently inclined (5°–10°) south-facing dip slopes of Yakima fold belt anticlines receive 3%–5% more solar energy per unit area than the relatively flat floors of the synclinal basins. Due to clear skies and low humidity, air temperatures typically decline rapidly after sunset in the Columbia Basin. The cold nocturnal air drains from the sloping flanks of the Yakima fold belt anticlines into adjacent synclinal basins. Consequently, AVAs situated on the south limb of

Yakima fold belt anticlines are better protected from frost and freeze damage and contain many of the warmest vineyards in the Columbia Basin (Gregutt, 2007). For the same reasons, many of the coldest vineyards are located on the flat floors of synclinal basins at relatively low elevations. These vineyards are routinely inundated by cold air that drains into the basins and pools behind water gaps. This effect is quite pronounced in the Walla Walla Valley AVA, where average ripening season (1 August–31 October) temperatures, growing degree-days, and frost-free days generally increase with elevation (Pogue and Dering, 2008). In 2008, the effects of nocturnal cold-air pooling were recorded by temperature data loggers installed on the south-facing slopes of Snipes Mountain, an anticlinal ridge in the center of the Yakima Valley. Ripening season growing degree-days (10 °C) increased with elevation at a rate of 175/100 m and the average ripening season temperature increased at a rate of 2.5 °C/100 m (Fig. 8).

The Missoula floods, through their impacts on soils and landforms, are perhaps the greatest single geological influence on Columbia Basin terroir. The vast majority of Columbia Basin vineyards are planted in soils derived directly or indirectly from flood-deposited silt and sand. These well-drained soils facilitate irrigation and encourage the vines to root deeply. The mineralogy of the flood-derived soils, which are dominated by quartz, feldspars, hornblende, and micas (Baker et al., 1991), indicates little, if any, contribution from weathering of the Columbia River Basalt, the predominant bedrock. Vineyard soil chemistry is therefore more complex in areas where flood-derived soils are thin, since the vines are exposed to a new suite of minerals once the roots encounter basalt or basalt-derived regolith.

Many Columbia Valley vineyards are planted on landforms produced by both erosional and constructional processes related to the Missoula floods. Vineyards on the floors of the Walla Walla Valley and Yakima Valley are commonly situated on terraces of Missoula flood slackwater deposits (Touchet beds) (Carson and Pogue, 1996; Meinert and Busacca, 2000). In the Wahluke Slope AVA, most vineyards are planted on the surface of the Priest Rapids bar, a gigantic Missoula floods sand and gravel bar. Eolian sand and silt mantle the flood-eroded surfaces of gently dipping basalt flows in the Columbia Gorge (Allen et al., 1986) producing excellent vineyard sites.

ROAD LOG

Day 1 Summary

The route on Day 1 (Figs. 9 and 10) follows the Columbia River east from Portland, with two stops in the Columbia River Gorge. After crossing the Horse Heaven Hills at Satus Pass and descending into the Yakima Valley, we will make four stops at vineyards with terroirs representative of the Snipes Mountain, Rattlesnake Hills, and Red Mountain AVAs. After dinner on Red Mountain, the route to our hotel in Walla Walla takes us across the Pasco Basin and up the valley of the Walla Walla River.

Stop 1. Syncline Wine Cellars, Columbia Gorge AVA

Driving instructions: From Portland, travel east on Interstate 84 to Hood River. Take Exit 64 (White Salmon/Government Camp). Turn left (north) and cross the Columbia River toll bridge. At the intersection with State Route 14, turn right (east). After 6 miles, turn left (north) onto Old Highway 8. After 3.5 miles, turn left (north) onto Balch Road. After 0.2 mile, turn left (west) into Syncline Wine Cellars.

Syncline Wine Cellars and the estate vineyard, known as Steep Creek Ranch, are located within the 725 km^2 Columbia Gorge AVA (Fig. 9), established in 2004. According to the petitioners, the boundaries of the AVA were designed primarily to enclose the region near the Columbia River dominated by silt-loam soils that lies between the 76 cm (30 in) and 46 cm (18 in) isohyets (annual precipitation contours) and below an elevation of 610 m (2000 ft) (Federal Register, v. 68, no. 124, p. 38,251–38,255). The petitioners included Missoula flood–carved basalt benches and the famous Columbia Gorge winds, which moderate the area's climate, as geographic features distinctive to the proposed AVA.

Syncline Wine Cellars is owned and operated by James and Poppie Mantone. The Mantones named their winery for the Mosier Syncline, a Yakima fold belt structure whose N70E-trending

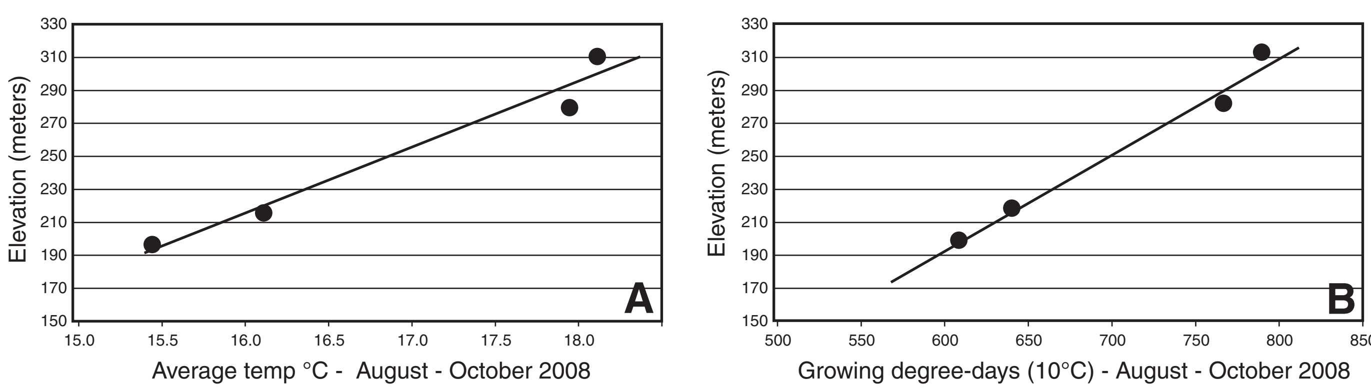

Figure 8. Graphs of (A) average temperature versus elevation and (B) growing degree-days versus elevation for four sites on the southwest slope of Snipes Mountain.

axial trace passes ~200 m south of their property (Fig. 9) (Korosec, 1987). Syncline wines were first produced in 1999 from Pinot Noir harvested from Celilo vineyard, which lies 20 km west of the winery on the slopes of Mount Underwood, a Quaternary shield volcano. Syncline now specializes in Rhone varietals (e.g., Grenache, Syrah, Mourvedre, Viognier) that are sourced from vineyards throughout the Columbia Basin. Wines from the biodynamically farmed estate vineyard were first produced in 2007. The vineyard consists of 0.4 ha of Rhone varietals planted in Balake very gravelly loam. The soils are developed in a mixture of Missoula flood gravels, basalt alluvium, and loess deposited on the Pomona Member of the Miocene Saddle Mountains Basalt (Korosec, 1987). The vineyard lies at an elevation of 145 m, well below the maximum height attained by the Missoula floods in this area (Waitt, 1994; Benito and O'Connor, 2003). A second vineyard, Steep Creek Ranch block 2, will soon be planted in the thin loess that mantles the southeast facing dip slopes that lie above and west of block 1.

Stop 2. Maryhill Winery, Columbia Valley AVA

Driving instructions from Syncline Wine Cellars: Return to Old Highway 8, turn left (east) and drive 3 miles to the intersection with Washington Highway 14. Turn left (east) on 14 and drive 22.3 miles to the entrance to Maryhill Winery.

Craig and Victoria Leuthold established Maryhill Winery in 2000 and released 4,500 cases in their first year of production. By 2008, Maryhill had grown to become the fifteenth largest winery in Washington, with a total production of 80,000 cases of 27 wines made from 18 cultivars. Approximately 40% of the grapes used for Maryhill wines are from the estate vineyards. The remainder is sourced primarily from vineyards in the Yakima Valley, Horse Heaven Hills, and Wahluke Slope AVAs. For an excellent summary of the long history of viticulture at Maryhill, refer to Irvine (1997).

Although the vineyards surrounding Maryhill winery lie within the gorge of the Columbia River, they are outside the boundaries of the Columbia Gorge AVA. They are, however,

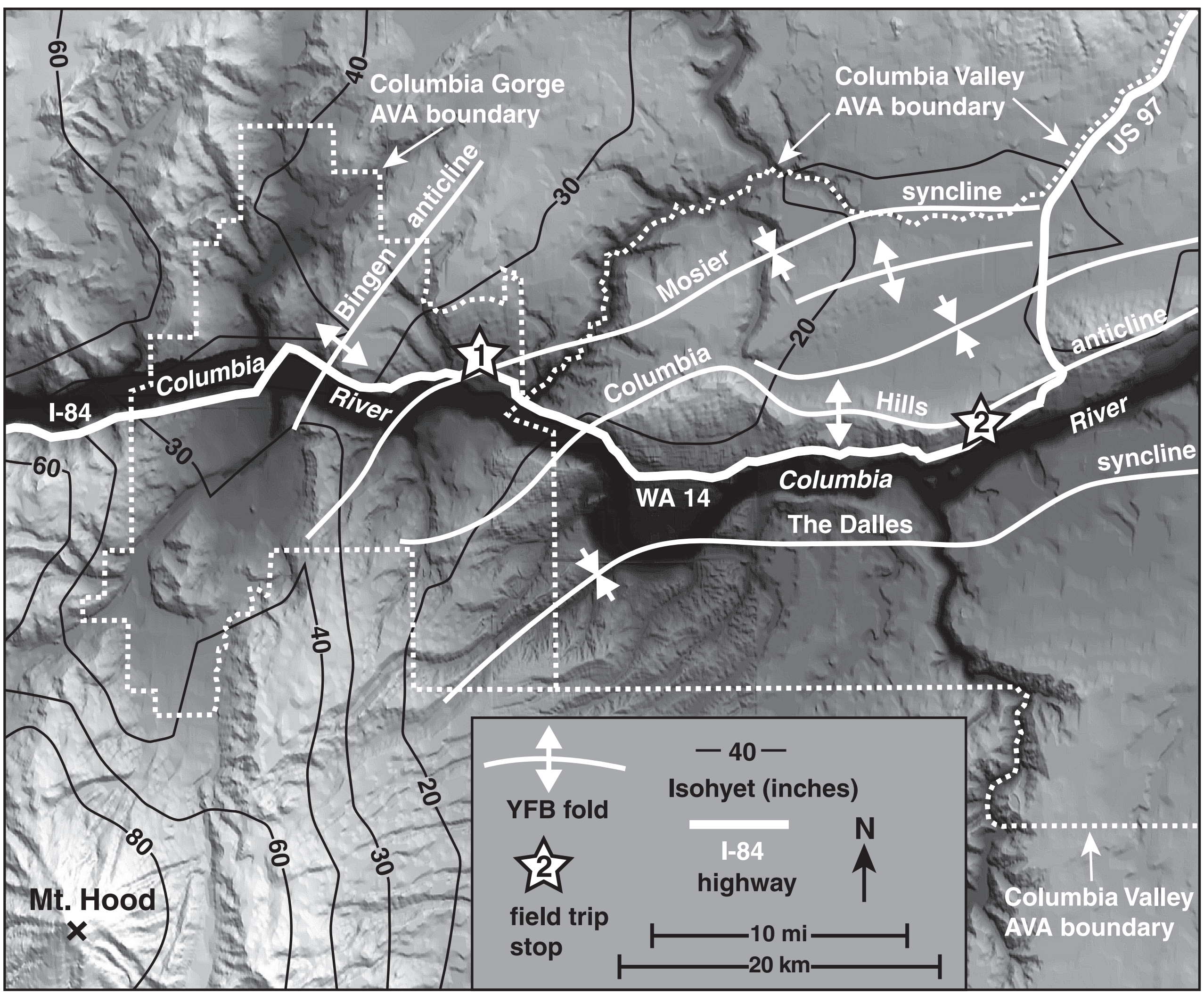

Figure 9. Shaded relief map showing Day 1 field trip Stops 1 and 2. Fold locations from Tolan and Reidel (1989). YFB—Yakima fold belt.

within the boundaries of the 46,620 km^2 Columbia Valley AVA, by far the largest in the Columbia Basin (Figs. 1 and 9). According to the Department of Treasury Decision that established the AVA (ATF-190, 49 FR 44895), it is characterized as a "large, treeless basin…broken by long sloping basaltic uplifts extending generally in an east-west direction." The decision also noted that elevations within the Columbia Valley AVA were generally below 2000 feet and annual precipitation less than 15 inches. Based on these criteria, the Maryhill vineyards display archetypal Columbia Valley macro-terroir.

The Gunkel family owns and manages the Maryhill vineyards, where they cultivate 19 varieties of wine grapes, on 34.5 ha divided between two terraces. The lower terrace, at an elevation of 60–91 m, consists of silt loam and fine sand soils overlying the Frenchman Springs member of the Wanapum Basalt. On the upper terrace, at elevations that range from 207 to 244 m, silt loam soils mantle the Roza member of the Wanapum Basalt (Bela, 1982). The loess-based soil that mantles the basalt bedrock is highly variable in thickness and texture and includes significant percentages of basalt alluvium and colluvium as well as Missoula flood gravels and ice-rafted erratics (Dan Gunkel, 2009, personal commun.).

In this area, the maximum height of the Missoula floods was ~325 m or ~100 m above the elevation of the Maryhill Winery (Benito and O'Connor, 2003). The floods created the vineyard terraces by stripping colluvium and regolith from the gently dipping basalt bedrock. The south slope of the terraces mimics the gentle dip of the underlying basalt, which lies in the north limb of the Dalles-Umatilla syncline. A south-vergent thrust fault that generally coincides with the route of Washington Highway 14 separates the bedrock in the vineyards from steeply dipping and locally overturned basalt exposed north of the highway in the south limb of the Columbia Hills anticline (Fig. 9)(Bela, 1982).

Stop 3. Newhouse Vineyards, Snipes Mountain AVA

Driving instructions from Maryhill Winery: Return to Washington Highway 14 and turn right (east). After 3.2 miles, bear left (north) onto U.S. Highway 97. After traveling 59.5 miles, turn right (east) onto Washington Highway 22. After 4.7 miles, turn left (north) onto Washington Highway 223. After traveling 3.2 miles, turn right (east) onto Emerald Road. Follow Emerald Road for 8.0 miles as it winds its way along the south side of Snipes Mountain before turning left (north) onto U.S. Grape Road. Park on the side of the road after 0.3 miles.

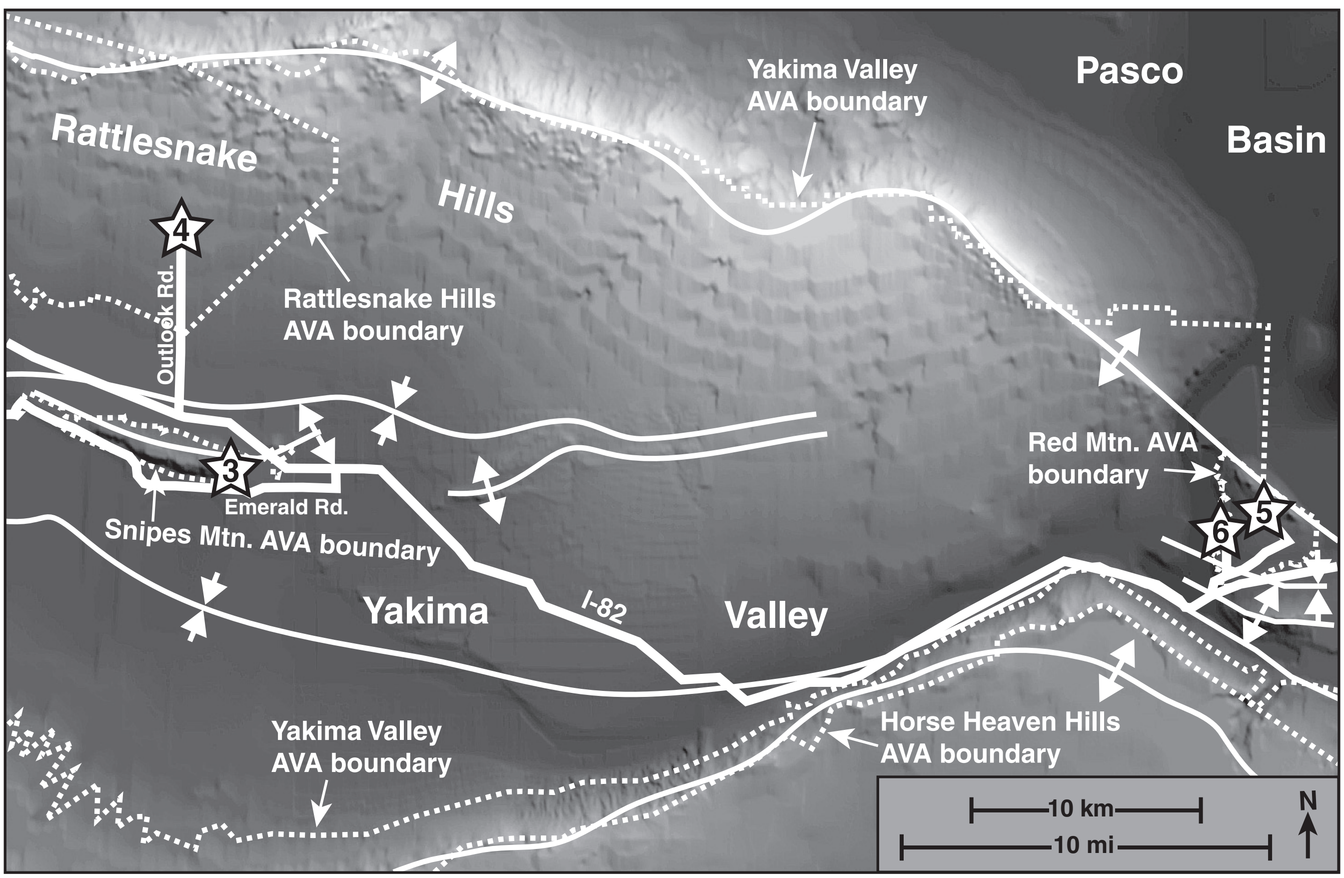

Figure 10. Shaded relief map showing Day 1 field trip Stops 3, 4, 5, and 6. Fold locations from Tolan and Reidel (1989) and Reidel and Fecht (1994). Symbols same as in Figure 9. AVA—American Viticultural Area.

Established in February of 2009, Snipes Mountain is Washington's newest AVA, and second smallest, at 16.8 km^2, after Red Mountain. It lies entirely within the boundaries of both the Yakima Valley and Columbia Valley AVAs (Figs. 2 and 10). According to the petitioners, the distinguishing features of the Snipes Mountain AVA include steep and elevated topography, outcrops of Ellensburg Formation, and well-drained rocky soils (Federal Register, v. 73, no. 82, p. 22,884–22,887). The boundaries of the AVA are largely based on topographic contours that encircle Snipes Mountain, the geomorphic expression of a relatively minor N70°W-trending south-verging Yakima fold belt anticline. Bedrock exposures consist of Miocene Saddle Mountains Basalt and the Ellensburg Formation, represented here by channel deposits of the ancestral Columbia River known as the Snipes Mountain conglomerate (Campbell, 1977, Smith, 1988). Clast lithologies in the Snipes Mountain conglomerate are dominated by Cascades-derived dacitic porphyry, and quartzite derived from outside the Columbia Basin.

On the steeper south side of Snipes Mountain, vineyards are largely confined to the lower slopes where they are planted in loess mixed with alluvium and colluvium derived from mass wasting of the steeper terrain above. In contrast, the vineyards on the north side reach almost to the crest of the mountain and are planted in more uniform loess-based soils that are typically deeper and contain fewer rock fragments. Relative to the steeper south side, the gently sloped north side of Snipes Mountain retains more of its original cover of Missoula flood slackwater deposits, or Touchet beds, which blanket the floor of the surrounding Yakima Valley. Over 50% of the soils in the Snipes Mountain AVA, mostly on north-facing slopes, belong to the Warden series, which is developed in loess over Missoula flood sediments. The most voluminous of the Missoula floods inundated all but the top 15 m of Snipes Mountain.

W.B. Bridgeman, a pioneer of the wine industry in the state of Washington, first recognized the viticultural advantages of Snipes Mountain's elevated topography and south aspect. Bridgeman planted wine grapes on Snipes Mountain in 1917 and founded Upland Winery in 1934 (Irvine, 1997). The Newhouse family purchased the Bridgeman vineyards and defunct Upland Winery in 1972 and eventually expanded their Snipes Mountain vineyard properties to include ~243 ha. Presently, at least 30 varieties of wine grapes are grown on 270 ha within the Snipes Mountain AVA. The vineyards supply grapes to more than 25 wineries. The Newhouse family recently revived the Upland Winery brand and they continue to cultivate the original Bridgeman vineyards, which include some of the oldest grapevines in Washington.

Stop 4. DuBrul Vineyard, Rattlesnake Hills AVA

Driving instructions from Snipes Mountain: Return to Emerald Road, turn left (east) and travel 1.0 mile to Midvale Road. Turn left (north) on Midvale Road and travel 0.2 mile and turn left (west) onto the westbound on-ramp for I-82. After traveling 3.0 miles on I-82, take exit 63. Turn right (north) on Sunnyside Road and travel 0.2 mile to Yakima Valley Road. Turn left (west) on Yakima Valley Road and travel 0.8 mile to S. Outlook Road. Turn right (north) on S. Outlook and travel 5.2 miles to the entrance to DuBrul vineyard.

The terroir of the DuBrul vineyard is typical of the Rattlesnake Hills AVA, in which it lies (Figs. 2 and 10). The Rattlesnake Hills AVA lies mostly within the confines of the Yakima Valley AVA and entirely within the Columbia Valley AVA. According to the petition to the TTB, the topography of the Rattlesnake Hills AVA is characterized by "dissected canyons, terraces, and ridges" that trend south from main ridgeline formed by the Rattlesnake Hills anticline (Federal Register, v. 70, no. 104, p. 31,398). The boundaries were defined to limit the AVA to elevations above 850 feet, to avoid "damaging spring and fall frosts, heavy winterkill conditions, alkali soils, and high water tables" (Federal Register, v. 70, no. 104, p. 31,397). The AVA petition also notes that soils below 1100 feet are typically developed in loess overlying Missoula flood sediments, while soils above 1100 feet are typically developed in loess overlying Ellensburg Formation.

The DuBrul vineyard consists of 18 ha of Cabernet Sauvignon, Cabernet Franc, Merlot, Syrah, Reisling, and Chardonnay planted in 1992 by Hugh and Kathy Shiels. Wines produced from grapes grown in DuBrul vineyard consistently receive high scores from wine critics. The Shiels assign much of the credit to DuBrul's well-drained soils, relatively high elevation (340–404 m), and sloping topography that enhances cold air drainage.

The silt loam soils of DuBrul vineyard are developed in loess of varying thickness deposited on Miocene Ellensburg Formation and alluvium of Pleistocene to Holocene age (Schuster, 1994) In the northeastern part of the vineyard, loess overlies caliche-cemented gravels in dissected Pleistocene alluvial fans. This part of the vineyard has the thinnest soils and ripping was required to extend rooting depth in some areas. The well-rounded quartzite clasts in the gravels were derived from the Snipes Mountain Conglomerate, which crops out extensively on the southern slopes of the Rattlesnake Hills. In the central and southern parts of the vineyard, the loess-based soils are generally thicker and overlie sandstone and conglomerate of the Ellensburg Formation. The southeastern part of the vineyard is planted on the floor of a small valley in loess that overlies unconsolidated Holocene alluvium. The southern one-fourth of the vineyard lies as much as 10 m below the 365 m upper limit of the Missoula floods. Soils in this part of the vineyard were derived in part from slackwater sediments and contain ice-rafted erratics.

Stop 5. Grand Rêve Estate Vineyard, Red Mountain AVA

Driving instructions from DuBrul vineyard: Retrace the field trip route to Exit 63, I-82. Enter I-82, east bound, travel 32.9 miles, and take the Benton City exit. Turn left (north) and travel 0.1 mile to E. Kennedy Road. Turn right (east) and travel 0.2 mile to Washington Highway 224. Turn left (north) and travel 4.2 miles to Antinori Road. Turn left (north), travel 1.8 miles, and park on the side of the road just past Col Solare winery.

Red Mountain AVA, at 13.8 km^2, is Washington's smallest AVA and is nested within both the Yakima Valley and Columbia

Valley AVAs (Figs. 2 and 10). Red Mountain is the geomorphic expression of the Red Mountain anticline, a doubly plunging, northwest-trending fold of the Yakima fold belt. The boundaries of the AVA encompass the southwest limb of the Red Mountain anticline and the trough of the adjacent Benton City syncline (Reidel and Fecht, 1994)(Fig. 10). Miocene Saddle Mountains Basalt forms the bedrock throughout the AVA. Discontinuous interbeds of light-colored tuffaceous lacustrine mudstone locally separate individual lava flows. In most of the AVA, Missoula flood sediments that are highly variable in both texture and thickness overlie the basalt bedrock (Meinert and Busacca, 2002). Red Mountain was directly in the path of the Missoula floods, which inundated all but its uppermost 64 m. The floodwaters, rushing around either side of the obstruction, created a back-eddy on the mountain's southwest side (Meinert and Busacca, 2002). The eddy's slower waters allowed suspended and bed load gravels to settle, and its swirling currents trapped icebergs. Graded beds of finer grained sediment were deposited when the floods eventually pooled behind the constriction at Wallula Gap, 45 km to the southeast. As the floodwaters drained, they reworked some of the slackwater sediment and stranded the icebergs, which melted and released their cargo of erratic rocks. This complex scenario, repeated with each flood, accounts for the extreme heterogeneity of the Missoula flood sediments on Red Mountain.

The soils of Red Mountain vineyards are formed in eolian sediment that overlies Missoula flood sediments. The most common soil series are the Warden and Scooteney, which developed in loess and sandy loess. Soils of the Hezel series, developed in dune sand, are present in the central part of the AVA (Rasmussen, 1971; Meinert and Busacca, 2002). The hot arid climate at Red Mountain promotes the precipitation of calcium carbonate that encrusts and cements gravels and forms layers of variable thickness at the interface between soil horizons with differing hydraulic conductivity.

Viticulture commenced on Red Mountain with the planting of Kiona vineyard by Jim Holmes and John Williams in 1975. Over the next 20 years, Red Mountain fruit was recognized for its high quality and vineyard acreage continually increased. In 2001, the TTB approved a petition by viticulturalists for a Red Mountain AVA. The petition cites Red Mountain's characteristic warm daytime temperatures, high diurnal temperature variations, and soil associations as distinguishing characteristics (Federal register, v. 65, no. 98, p. 31,853–31,856). The AVA presently hosts over 283 ha of vineyards that regularly produce grapes for some of Washington's finest wines.

Situated at elevations between 292 m and 375 m, Grand Rêve estate is the highest and steepest vineyard on Red Mountain, as well as one of the youngest, with first harvest expected in 2010. The lower, southern half of the vineyard features gentle slopes with Warden soils developed in relatively thick loess over Missoula flood sediments. The soils of the upper northern half of the vineyard are highly variable with respect to thickness, texture, and subsoil material, which includes basalt of various textures, Missoula flood sediment, tuffaceous lacustrine mudstone, and thick caliche.

The development of this site is obviously driven by the desire to produce terroir-focused wines. Vineyard manager Ryan Johnson carefully designed each vineyard block at Grand Rêve to match the terroir. Decisions regarding cultivar, trellising design, irrigation, row orientation, and plant spacing were based on a detailed analysis of topography and soil profiles exposed in backhoe trenches.

Stop 6. Dinner at Terra Blanca Winery and Estate Vineyards, Red Mountain AVA

Driving instructions from Grand Rêve estate vineyard: Return to Washington Highway 224, turn right (west) and travel 3.8 miles to N. DeMoss Road. Turn right (north), travel 0.5 mile, and turn right (east) at the entrance to Terra Blanca.

Geologist Keith Pilgrim started Terra Blanca winery in 1997. Caliche-encrusted rocks in the soils of the surrounding estate vineyards inspired the winery's name. Currently, 32 ha of Cabernet Sauvignon, Merlot, Syrah, and Chardonnay are planted in Warden and Scootenay series soils formed in loess over Missoula flood sediments. The estate vineyards are planted on slopes above the Yakima River at elevations ranging from 152 to 209 m. A small part of the estate vineyards are technically outside the boundaries of the Red Mountain AVA, which in this area is defined by the 560 ft contour line. Due to its relatively low elevation, the Terra Blanca estate vineyard should generally experience warmer daily high temperatures and colder daily low temperatures than Grand Rêve estate vineyard. The risk of frost and freeze damage at Terra Blanca vineyards is somewhat greater than at Grand Rêve, due to its lower elevation and proximity to the Yakima River, a pathway for cold air.

Terra Blanca winery currently produces more than 30,000 cases of wine from grapes grown on the estate and in vineyards of the Yakima Valley AVA. The wine produced at Terra Blanca is aged in oak barrels that are stored in one of Washington State's most extensive wine cave systems.

After dinner at Terra Blanca, we will travel to Walla Walla, where we will spend the night at the Marcus Whitman Hotel.

Driving instructions from Terra Blanca winery to the Marcus Whitman Hotel: Return to Washington Highway 224, turn right (west) and travel 0.4 mile to E. Kennedy Road. Turn right (west) and travel 0.2 mile to N. Webber Canyon Road. Turn left (south) and travel 0.1 mile to the I-82 on-ramp (eastbound). Enter I-82, travel 5.1, and take Exit 102 onto I-182/U.S. 12 toward Kennewick/Richland. Travel 16.2 miles on U.S. Highway 12 and bear left (east) at the fork. Travel 0.2 mile and turn left (east) at the stop sign. Travel east for 28.6 miles and take the N. 2nd Avenue exit. Turn right and travel 0.3 mile south to the entrance to the Marcus Whitman Hotel.

Day 2 Summary

The stops and commentary on the morning of Day 2 will focus on the significant variations in physical terroir within the Walla Walla Valley AVA. After lunch, we will follow the

Columbia River through Wallula Gap and back to Portland, making one stop in the Horse Heaven Hills AVA.

Driving instructions from the Marcus Whitman Hotel to Spring Valley Vineyards: Turn left (north) onto 2nd Avenue and travel 0.3 mile and turn left (west) onto the on-ramp for U.S. Highway 12 (eastbound). Travel 1.4 miles on U.S. Highway 12, turn left (north) onto Lower Waitsburg Road, and then immediately right onto Middle Waitsburg Road. After traveling 9.8 miles, turn right (south) onto Corkrum Road. After traveling 1.4 miles, turn left (north) into Spring Valley Vineyards.

Stop 1. Spring Valley Vineyards, Walla Walla Valley AVA

Viticulture has a long history in the Walla Walla Valley, dating back to at least the 1870s. Several of the early Walla Walla wineries, founded by Italian immigrants, were annually producing thousands of gallons of wine before 1883, when the vines were killed by temperatures that dropped to –30 °C (Irvine, 1997). Although vineyards persisted on family farms, the modern resurgence of viticulture and winemaking did not begin until 1974, when Gary Figgins planted Riesling and Cabernet Sauvignon at the site that had hosted his family's Black Prince (Cinsault) vineyard. The success of Figgin's Leonetti Winery, founded in 1977, catalyzed the growth of the modern wine industry in the Walla Walla Valley, which now hosts over 100 wineries.

The Walla Walla Valley AVA, established in 1984, is Washington's second oldest. The boundaries enclose a region that is transitional between the forested Blue Mountains and the arid interior of the Columbia Basin (Figs. 7 and 11). The AVA therefore hosts an especially diverse range of terroirs (Meinert and Busacca, 2000; Pogue, 2009). In the lower, western part of the AVA, annual precipitation is generally less than 38 cm and soils are typically developed in less than 1 m of sandy loess over Missoula flood slackwater deposits. In contrast, annual precipitation often exceeds 50 cm near the eastern boundary of the AVA, which is defined by the 2000 ft topographic contour in the Blue Mountain foothills (Fig. 11). In the eastern part of the AVA, above the 350 m limit of the Missoula floods, soils are typically formed in 3+ m of loess over basalt bedrock. Although most Walla Walla Valley viticulture is associated with loess-based soils, a significant and growing percentage of the AVA's vineyards are planted

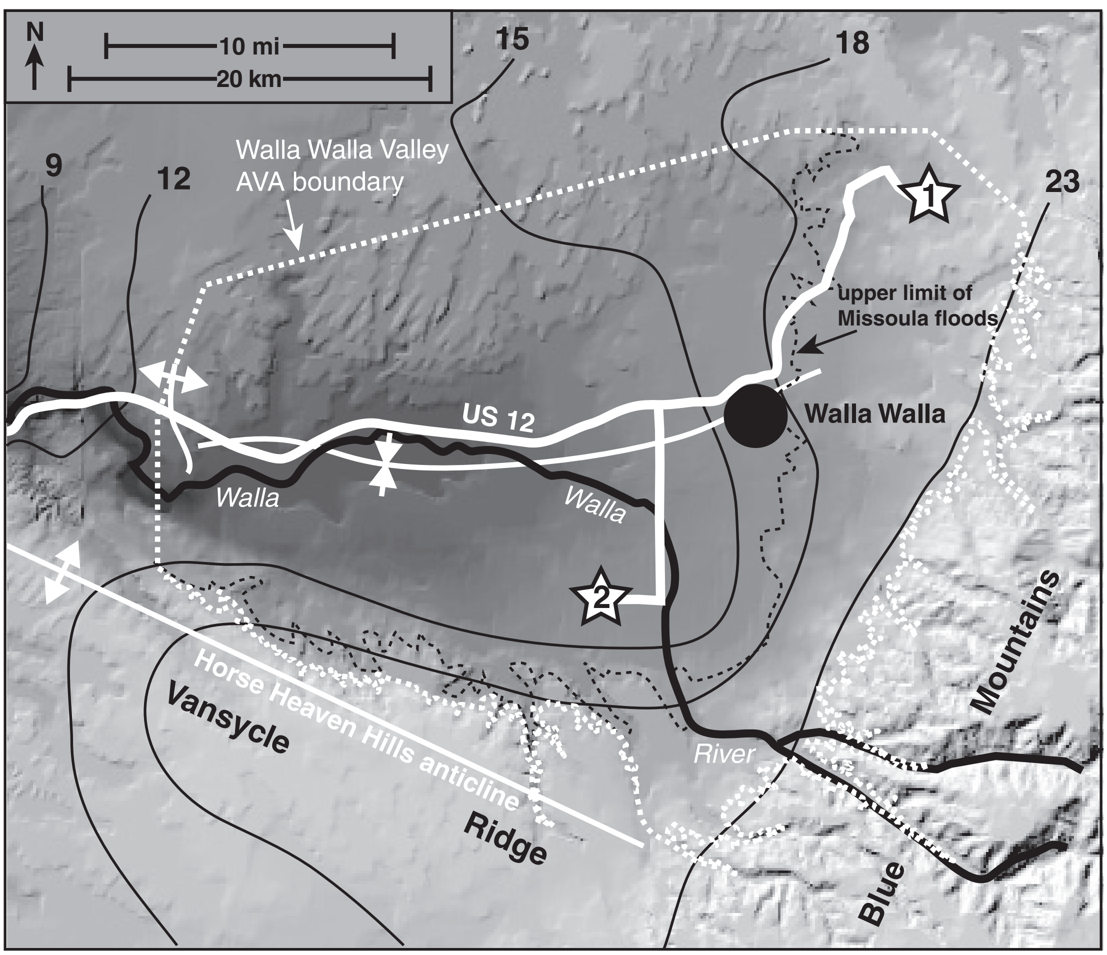

Figure 11. Shaded relief map showing Day 2 field trip Stops 1 and 2. Fold locations from Tolan and Reidel (1989). Symbols same as in Figure 9. AVA—American Viticultural Area.

in cobblestone alluvium deposited by the Walla Walla River and Mill Creek. Vineyards have recently been planted on the relatively steep slopes of the Vansycle Ridge escarpment and the canyons of the Blue Mountains. These sites feature very thin soils formed in mixed loess and basalt colluvium.

Air temperature in the Walla Walla Valley AVA is strongly influenced by geomorphology (Pogue and Dering, 2008). The water gap near the western boundary of the AVA produces the most significant effects, by inhibiting the drainage of cold nocturnal air from upstream areas of the Walla Walla Valley. During the August to October ripening season, average temperature and growing degree-days increase with elevation to 450 m due to the effects of nocturnal cold air pooling. The major stream valleys in the AVA provide channels for cold air that drains westward from the interior of the Blue Mountains. These cold air currents reduce the average ripening season temperatures by 0.5 °C to 2.0 °C at vineyards within 500 m of major streams. Adiabatic warming of down-sloping winds increases the average temperature and growing degree-days recorded at vineyards near the base of Vansycle Ridge (Pogue and Dering, 2008).

Spring Valley vineyard started as an experiment in 1993 when the Derby family planted a 0.8 ha block of merlot on their farm in the rolling wheat fields northeast of Walla Walla (Gregutt, 2007). At that time, the site was considered a viticultural frontier due to its moderate to steep slopes, relatively high elevation (396–457 m) and thick Walla Walla and Athena series silt-loam soils. With the first harvest, Walla Walla wineries quickly recognized the high quality of Spring Valley fruit, and a new terroir was born. By 1999, the Derbys were producing their own estate-bottled wines from a vineyard that had grown to 16 ha of Cabernet Sauvignon, Cabernet Franc, Syrah, Petit Verdot, and Malbec. In 2005, the Derbys entered into a partnership with Ste. Michelle Wine Estates, the largest wine producer in Washington. Since that time, 30 ha of new vineyards have been planted.

Stop 2. Cayuse Vineyards, Walla Walla Valley AVA

Driving directions from Spring Valley Vineyards: Retrace the field trip route to U.S. Highway 12. Turn right (west) on U.S. Highway 12 and travel 3.3 miles to Gose Road. Turn left (south) on Gose Road and travel 0.8 mile to Wallula Road. Travel straight across Wallula Road onto N. College Avenue. After 2.0 miles, turn right (south) onto Washington Highway 125. After traveling 1.9 miles, Washington Highway 125 becomes Oregon Highway 11. After traveling 2.7 miles on Oregon Highway 11, turn right (west) on Sunnyside Road and travel 1.8 miles to Cayuse Vineyards.

In 1996, while scouting for vineyard land in the Walla Walla Valley, Frenchman Christophe Baron noticed that the soils in orchards near Milton-Freewater, Oregon, were rich in basalt cobbles. The resemblance of these cobblestones to the famous "galets roulés" (rolled stones) of the southern Rhone Valley of France inspired Baron to purchase land and plant his first vineyard. The soils that impressed Baron, classified as Freewater very cobbly loam, are developed on an alluvial fan that formed where the Walla Walla River spills out of the foothills of the Blue Mountains and onto the relatively flat floor of the Walla Walla Valley (Pogue and Dering, 2007). Derived from a mixture of loess, Missoula flood sediment, and basalt gravels, the alluvial soils are texturally and chemically distinct from the loess-based soils in which most Columbia Basin vineyards are planted. From the very first vintage, the wines produced from the cobbly Milton-Freewater vineyards were critically acclaimed. Baron is quick to attribute the distinctiveness and quality of his wines to the unique hydrologic, thermal, and chemical properties of his vineyard's soils and his adoption of biodynamic agricultural practices.

Vineyard management practices at the Cayuse vineyards are designed to accentuate the positive effects of the rocky soils. The soils are regularly raked to concentrate the large stones on the surface where they can absorb solar energy. The sun-warmed rocks accelerate the conduction of heat to the root zone and radiate heat to the clusters, which are trellised low to the ground to take advantage of this effect. The densely planted vines in the Cayuse vineyards are forced to root deeply to compete for irrigation water, which is applied sparingly to the extremely well drained soils.

Stop 3. Champoux Vineyard, Horse Heaven Hills AVA

Driving directions from Cayuse Vineyards: Retrace field trip route to U.S. Highway 12. Turn left (west) onto U.S. Highway 12 and travel 26.7 miles to intersection of U.S. Highways 12 and 730. Enter U.S. Highway 730 by driving straight ahead. After following U.S. Highway 730 for 25.2 miles, turn right (north) onto the entrance ramp for I-82 westbound. After 1.8 miles, take exit 131. Turn left (west) on Washington Highway 14 and travel 31.5 miles to Alderdale Road. Turn right (north) and travel 5.5 miles to the entrance to Champoux Vineyard.

At 2300 km^2, the Horse Heaven Hills AVA is the second largest sub-AVA of the Columbia River Valley AVA. The AVA's southern boundary is the north shore of the Columbia River and its northern boundary coincides approximately with the axial trace of the Horse Heaven Hills anticline (Fig. 2). In general, the land surface slopes gently to the south-southeast, mimicking the dip of the underlying basalt. Near the Columbia River, the gentle topography is interrupted by the Columbia Hills, the geomorphic expression of a series of small-scale northeast-trending Yakima fold belt anticlines (Figs. 4 and 12).

Most of the Horse Heaven Hills AVA was repeatedly inundated by the Missoula floods, which deposited gravel bars near their main channel along the flanks of the Columbia Hills and graded slackwater sediments elsewhere (Fig. 6). The soils in most vineyards are developed in loess and fine sand derived from flood sediments that were deposited south and west of the AVA in the Umatilla Basin.

The climate throughout the Horse Heaven Hills AVA is characterized by sustained winds, low rainfall, and average temperatures and growing degree-day totals that are among the highest in the Columbia Basin. Vineyards are concentrated in the Columbia Hills to take advantage of irrigation water, moderately sloped, south-facing hillsides, and the temperature moderating influences of the Columbia River.

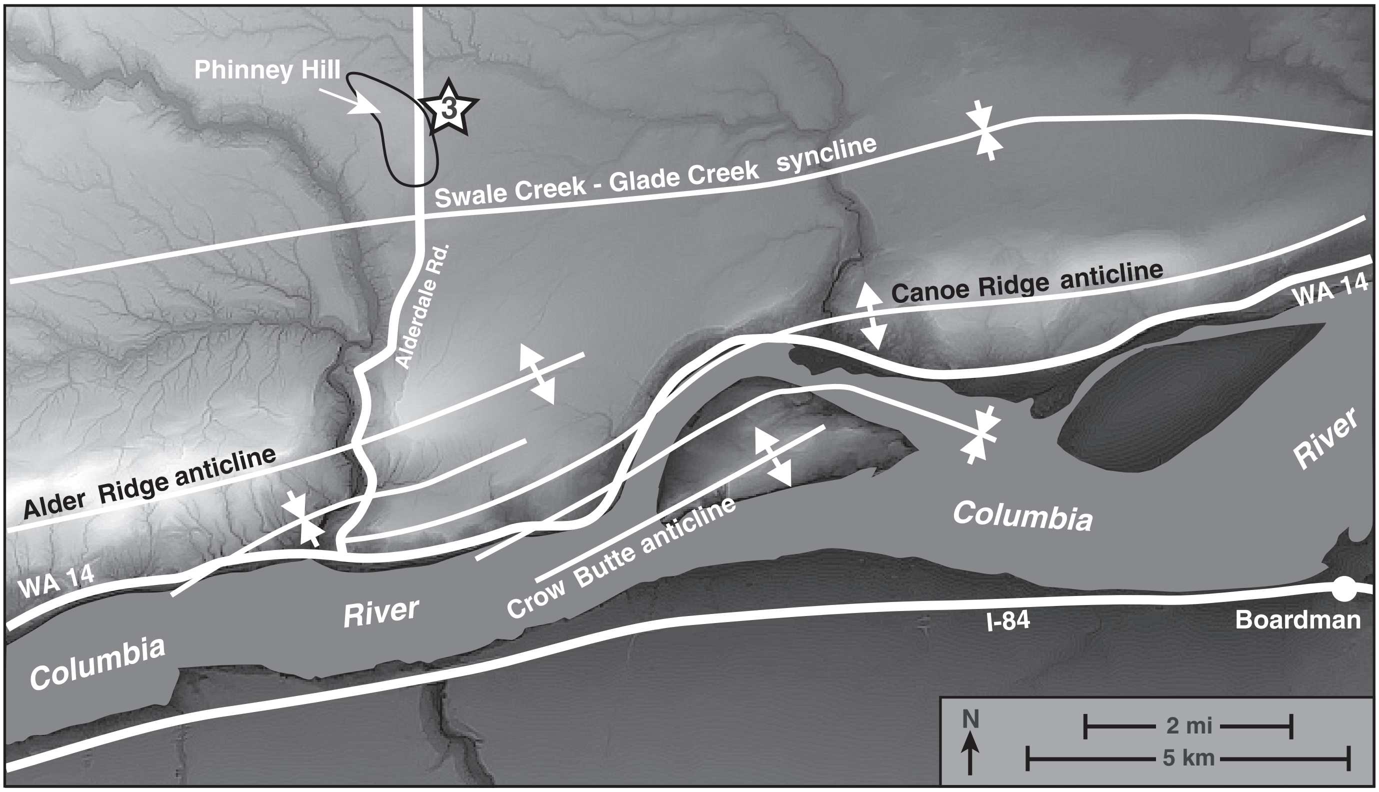

Figure 12. Shaded relief map showing Day 2 field trip Stop 3. Fold locations from Newcomb (1971). Symbols same as in Figure 9.

Planted in 1972, the original 3 ha of Cabernet Sauvignon in block 1 of Champoux vineyard are the oldest grapevines in the Horse Heaven Hills AVA. Originally known as Mercer Ranch vineyard, it was renamed for viticulturist Paul Champoux who took over its management in 1986 and became part owner in 1996 (Gregutt, 2007). Presently, Champoux vineyard includes 71 ha of Cabernet Sauvignon, Riesling, Chardonnay, Lemburger, Muscat, Merlot, Cabernet Franc, Syrah, and Petit Verdot. The vineyard is famous for its Cabernet Sauvignon, which has been used to make many of Washington's most critically acclaimed wines.

Most of Champoux vineyard is planted on relatively flat terrain in soils developed in 50–100 cm of sandy loess that overlies Touchet beds. The original 1972 block is planted on the lower slopes of Phinney Hill in sandy loess that overlies gravel and tuffaceous sediment that may correlate with parts of the Ellensburg Formation (Fig. 12)(Newcomb, 1971).

Driving directions to Portland: Retrace the field trip route to Washington Highway 14 and turn right (west). Follow Washington Highway 14 for 47.7 miles to U.S. Highway 97. Turn left on U.S. Highway 97 and travel 2.4 miles to I-84. Enter I-84 westbound and travel 102 miles to Portland.

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