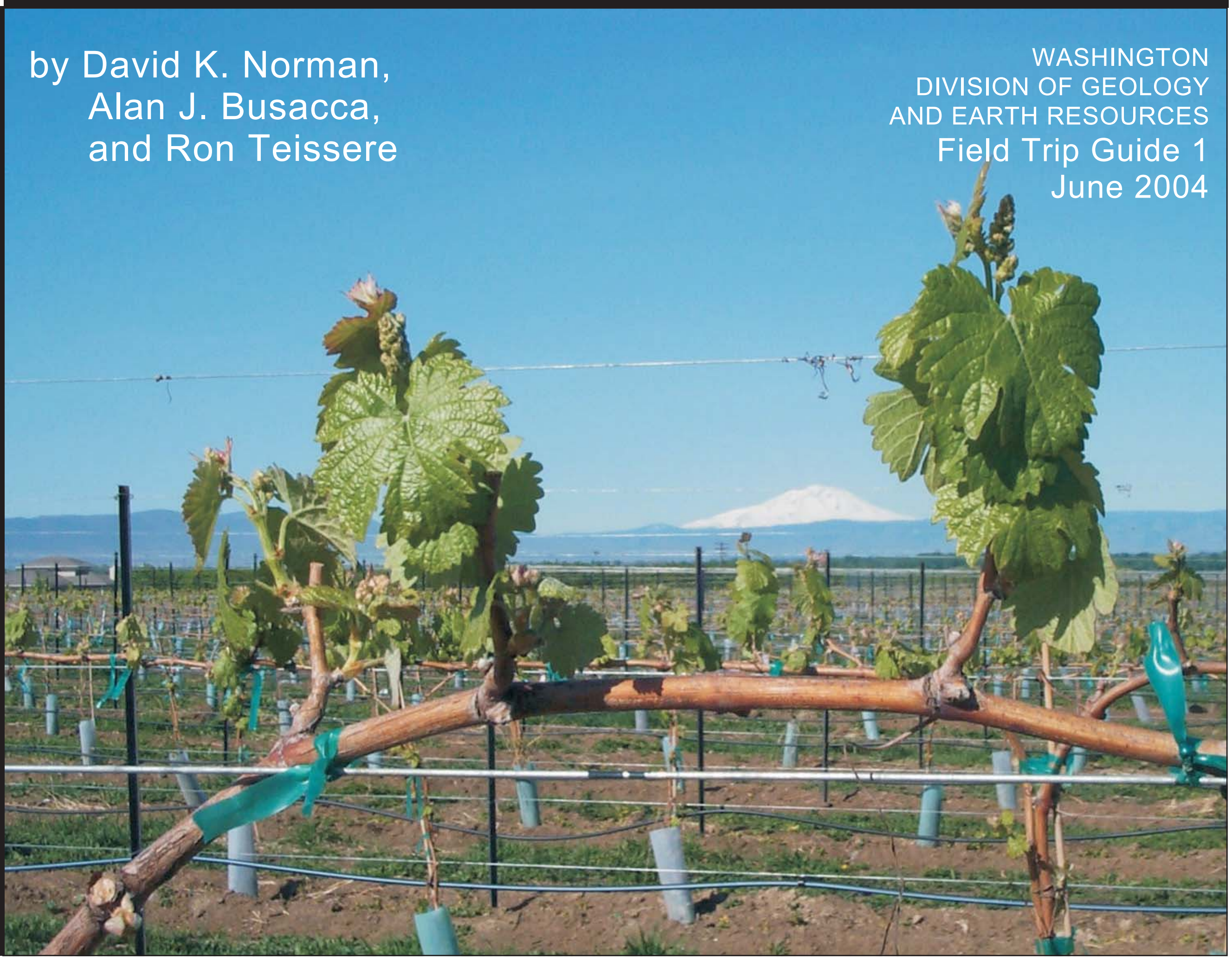
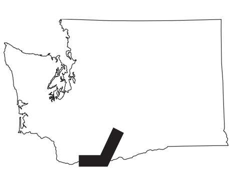
NATURAL RESOURCES

GEOLOGY OF THE YAKIMA VALLEY WINE COUNTRY— A Geologic Field Trip Guide from Stevenson to Zillah, Washington

by David K. Norman,
Alan J. Busacca,
and Ron Teissere

WASHINGTON
DIVISION OF GEOLOGY
AND EARTH RESOURCES
Field Trip Guide 1
June 2004





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Cover photo: View from Bonair Winery and vineyard near Zillah, Washington. Mount Adams, 12,276 feet (3742 m) high, is in the distance. Mount Adams is one of the largest volcanoes in the Cascade Range. It is second in eruptive volume only to Mount Shasta and far surpasses Mount Rainier. The last eruption was about 1000 years ago *(Photo by Gail Puryear, Bonair Winery, Inc.)*

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Geology of the Yakima Valley Wine Country—A Geologic Field Trip Guide from Stevenson to Zillah, Washington

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INTRODUCTION

This field trip will examine the terroir (pronounced *tehr-wahr'*) of Washington vineyards in the Rattlesnake Hills wine-growing region of the Yakima Valley and the Columbia River Gorge. Terroir involves the complex interplay of climate, soil, geology, and other physical factors that influence the character and quality of wine. These are the main factors in good viticultural practice and expert winemaking (Busacca and Meinert, 2003). The trip will begin at Skamania Lodge near Stevenson, Washington, travel east along the Oregon side of the Columbia River Gorge via Interstate Highway 84 (I-84) to Biggs, and traverse the Horse Heaven Hills to the Yakima Valley via U.S. Highway (US) 97 (Fig. 1). The trip will then return to Stevenson via US 97 and State Route (SR) 14, this time traveling along the Washington side of the Columbia River.

Washington is second only to California in wine production in the United States, and some of its vineyards and wines are among the world's best. Most Washington vineyards are east of the Cascade Range on soils formed from Quaternary sediments that overlie Miocene Columbia River Basalt Group flood basalts (Figs. 2 and 3). Eastern Washington has an optimum climate for wine grape production—approximately 6 to 8 inches (15–45 cm) of rainfall annually with a pronounced winter maximum and warm, dry summers (Busacca and Meinert, 2003).

Currently there are approximately 240 wineries in Washington and more than 300 wine grape growers. Total wine grape production in 2002 was 109,750 tons from 24,800 acres of bearing vineyards (WASS, 2002). Wine grape production will continue to increase, since there are an additional 6000 acres of wine grapes planted that were not yet bearing fruit in 2002. Most grape vines start producing commercial yields in their third year.

Of the wine produced in Washington in 2002, 43 percent was white and 57 percent was red, down from a majority (62 percent) of white wine in 1998. For example, the production of Semillon and Chenin Blanc in this four-year period decreased 35 percent, whereas the production of Cabernet Sauvignon, Merlot, and Syrah increased 200 percent. This trend toward a predominance of red wine production in Washington will likely continue because of the increased planting of red varietals and the higher prices realized from red grapes in general (Busacca and Meinert, 2003).

Only 18 percent of Washington's wine grapes are from vineyards more than 20 years old, and in these older vineyards, white grapes (73 percent) predominate over red grapes (27 percent). For example, Riesling was the most widely planted white wine grape prior to 1982 at 54 percent of its 2002 acreage. In contrast, Cabernet Sauvignon, Merlot, and Syrah were the three

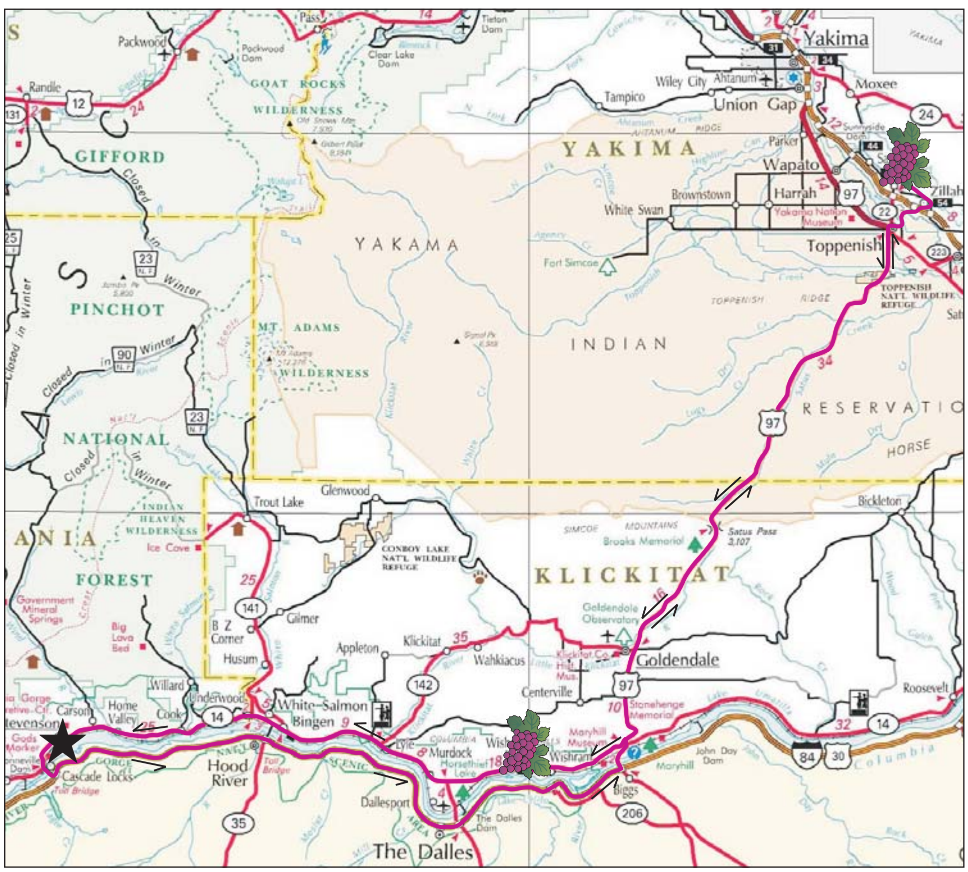


Figure 1. Route map. (Modified from WSDOT, 2002.)

most widely planted red grapes in 2002 and had only 12, 5, and 0 percent, respectively, of their current acreage planted prior to 1982 (Busacca and Meinert, 2003).

Merriam-Webster's dictionary defines 'appellation' as "a geographical name (as of a region, village, or vineyard) under which a winegrower is authorized to identify and market wine." The current Washington appellations (American Viticultural Areas or AVAs) are Columbia Valley, Puget Sound, Red Mountain, Walla Walla Valley, and Yakima Valley (Fig. 2). As with most other wine-growing regions, some Washington AVAs are nested, such that the Columbia Valley appellation, which produces more than 90 percent of the state's wine grapes, includes the Yakima Valley, Walla Walla Valley, and Red Mountain appellations.

The area available in Washington for future planting is very large. In the 10.7-million-acre Columbia Valley appellation, only about 30,000 acres are planted with wine grapes. Even the smallest appellation, Red Mountain, has room for expansion with only about 710 acres out of the 4040 acres of the AVA planted with vines. In many cases, the availability of water for irrigation is a greater limitation than the suitability of land for growing high-quality grapes (Busacca and Meinert, 2003).

The Yakima Valley appellation was established in 1983 and is Washington's first appellation. The Yakima Valley has a 190-day growing season with annual precipitation of approximately 8 inches (20 cm). Presently there are about 40 wineries in the Yakima Valley. More than one third of Washington's vineyards are in the Yakima Valley—about 10,000 acres. The Rattlesnake Hills section of the Yakima Valley appellation, where we will be visiting, has 1215 acres of vineyards and 28 individual growers (Gail Puryear, Bonair Winery, written commun., 2004). A petition to grant AVA status for a new Rattlesnake Hills AVA to define this area along the hills that bound the northern part of the Yakima Valley was submitted in early 2004.

Appellation status has been granted as of May 2004 for a new Columbia Gorge AVA (Lonnie Wright, Columbia Country Vineyards, oral commun., 2004). Like the Columbia Valley AVA, the Columbia Gorge AVA straddles the Columbia River, with part of the AVA in Oregon and part in Washington. Grape acreage is growing in the Columbia Gorge AVA, with approximately 80 acres of white grapes and 50 acres of red grapes in the Washington part in 2002 (WASS, 2002) and about 150 to 200 acres total of grapes in the Oregon part in 2004 (Lonnie Wright, Columbia Country Vineyards, oral commun., 2004). The Columbia Gorge AVA has about 16 wineries at present.

Geology

Most Washington vineyards are on the Columbia Plateau, which is bordered on the north and east by the Rocky Mountains, on the south by the Blue Mountains, and on the west by the Cascade Range (Figs. 2 and 3). The area is underlain by the Columbia River Basalt Group (CRBG), which covers more than 77,200 square miles (200,000 km^2) and has an estimated volume of more than 90,300 cubic miles (234,000 km^3) (Reidel and others, 2003). The CRBG is divided into five formations—the Saddle Mountains, Wanapum, Grande Ronde, Imnaha, and Picture Gorge Basalts. It was erupted mostly between 17 and 5.5 Ma (early Miocene) from north–south fissures roughly paralleling the present-day Washington–Idaho border and consists of a thick sequence of about 300 continental tholeiitic flood-basalt flows (Reidel and others, 2003). Most (more than 96 volume percent) of the lava flooded out in the first 2.5 million years (Reidel and others, 2003). The CRBG has individual flows each with estimated eruptive volumes of at least 700 cubic miles (3000 km^3), making them the largest documented individual lava flows on Earth (Baksi, 1989; Landon and Long, 1989; Tolan and others, 1989). On the basis of geophysical evidence, the basalts are known to reach a maximum thickness of 16,000 feet (5000 m) in the Pasco Basin. Twenty-one of these flows poured through the Columbia River Gorge, forming layers of rock up to 2000 feet (600 m) thick. This dwarfs the erupted volumes of typical Cascade volcanoes; even the explosive eruption of Mount St. Helens in 1980 yielded only about 0.2 cubic miles (1 km^3) of volcanic material (Pringle, 2002). Concurrent with the CRBG eruptions was the folding and faulting of the basalt in the western part of the Columbia Basin. The east–west trending anticlinal ridges and synclinal valley is known as the Yakima fold belt (Fig. 2)(Reidel and others, 2003). The Yakima River valley is bounded by the Horse Heaven Hills anticline to the south and Rattlesnake Hills anticline to the north.

Quaternary deposits in the Columbia River Gorge and southeastern Washington are those of the cataclysmic Missoula (or Spokane) floods (Fig. 3). The Cordilleran ice sheet advanced from Canada several times during the Pleistocene and covered parts of Washington, Idaho, and Montana. The ice formed dams that produced glacier-impounded lakes on several drainages in northern Washington, Idaho, and Montana. The largest of these blockages, on the Clark Fork River near the Idaho–Montana border, created glacial Lake Missoula (Pardee, 1910)(Fig. 3). The lake covered 3000 square miles (7800 km^2) of western

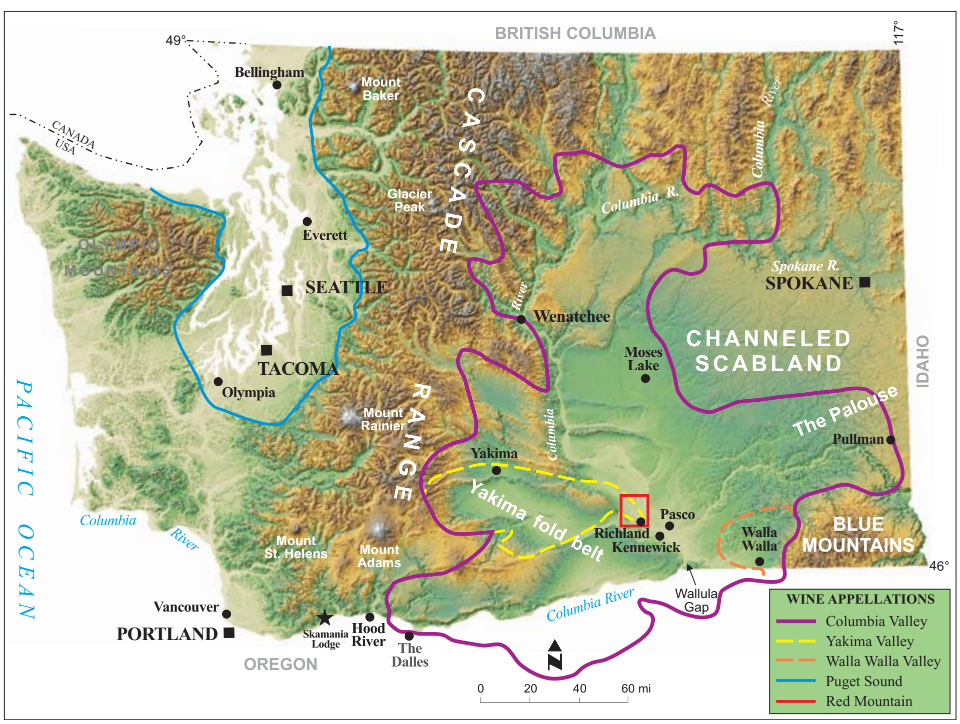


Figure 2. Location of Washington appellations (AVAs).

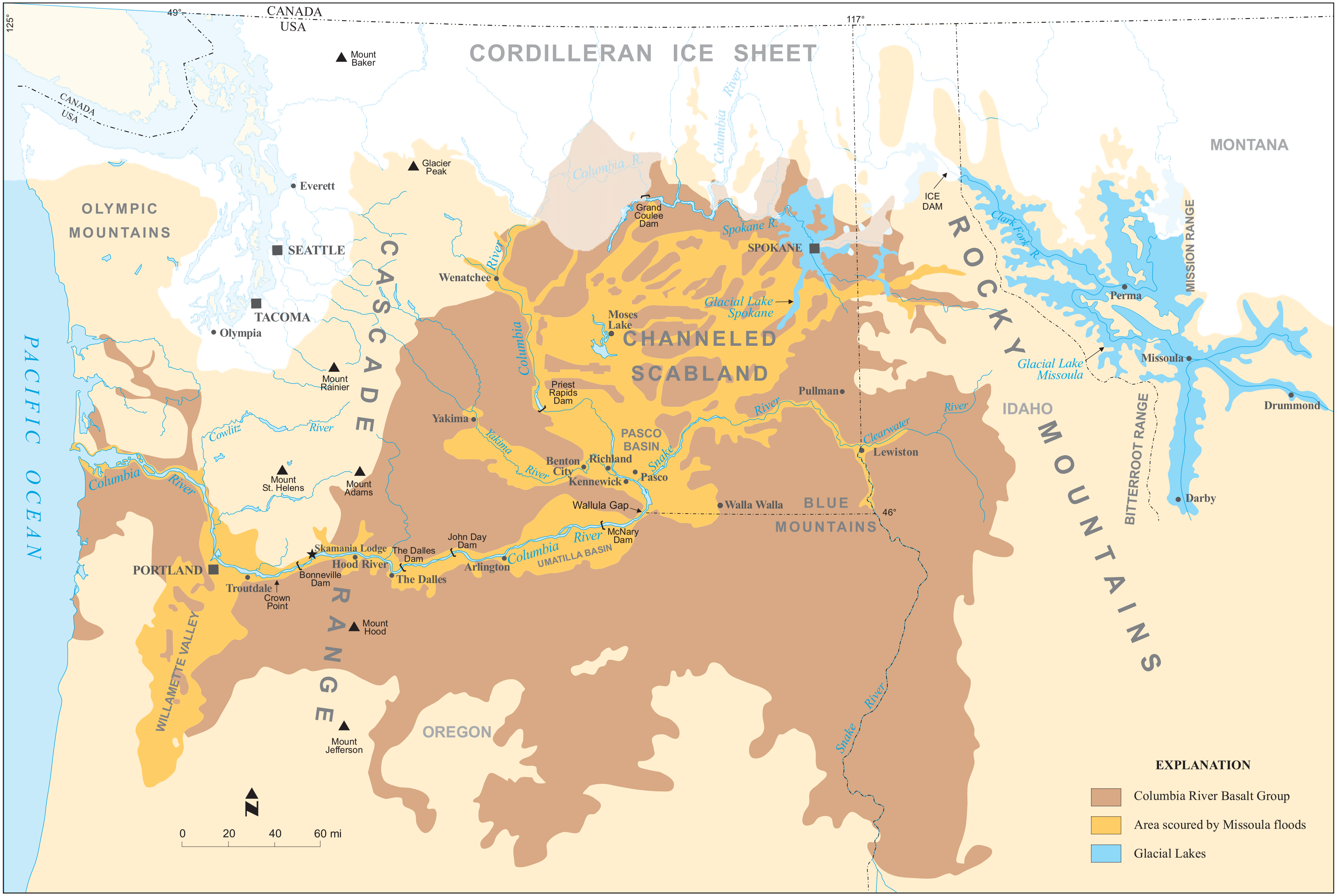


Figure 3. Columbia Plateau and surrounding area, showing the probable extent of the Cordilleran ice sheet, ice-dammed glacial lakes, Missoula floods, and Columbia River Basalt Group. The failure of the ice dam of the Clark Fork River in western Montana released a 2000-foot (600-m) wall of water that rushed across eastern Washington again and again, eroding a series of intertwining canyons called 'coulees'. This area is known as the Channeled Scabland. The various flood pathways converged in the Pasco Basin, where there was a narrow exit for the waters—Wallula Gap. The narrowness of the gap caused the floodwaters to back up and form a 1200-foot (365-m)-deep lake covering over 3500 square miles (9000 km^2). Several other temporary lakes were created by similar events near The Dalles and Portland, Oregon. (Modified from Waitt, 1985, and Weis and Newman, 1989. Extent of the Columbia River Basalt Group from Reidel and others, 1994.)

Montana and held 600 cubic miles (2500 km^3) of water (Carson and Pogue, 1996).

The ice dams failed repeatedly, releasing gigantic glacial floods that swept across northern Idaho, through the Spokane Valley, southwestward across eastern Washington, and down the Columbia River Gorge en route to the Pacific Ocean (Fig. 3)(Carson and Pogue, 1996). The Missoula floods are the largest known floods on Earth in the last two million years; the flow of water was ten times the combined flow of all the rivers of the world.

The flood crest at Wallula Gap on the Columbia River at the Washington–Oregon border was about 1200 feet (365 m), as evidenced by glacial erratics that were left stranded on the slopes of the Horse Heaven Hills and other anticlinal ridges. This constriction caused back-flooding of local river valleys and basins upstream of Wallula Gap, which resulted in deposition of relatively fine-grained slackwater sediments characterized by rhythmically graded bedding. These graded rhythmites, locally called Touchet (pronounced *Too'-shee*) beds, are indicative of multiple floods during the last glacial maximum and may record more than 40 major glacial floods (Flint, 1938; Waitt, 1980, 1985). Floodwaters were similarly constricted at places along the Columbia Gorge, such as near Arlington, Oregon, causing back-flooding of the Umatilla Basin. The water that poured down the Columbia River Gorge stripped away soil, surficial sediments, and talus up to 1000 feet (300 m) elevation as far as The Dalles, Oregon (Fig. 3). By the time it reached Crown Point, the surface of the last flood had dropped to about 600 feet (180 m) elevation (Allen, 1979). The average interval between Missoula floods was about 30 years (Waitt and others, 1994), with the last flood occurring about 13,000 years ago.

Figure 4. The Columbia River funnels between the Pliocene twin granodiorite porphyry intrusions of Shellrock Mountain, Oregon (on the left) and Wind Mountain, Washington (on the right). View to the west.

On the Columbia Plateau, the floods eroded a spectacular complex of anastomosing channels, locally called 'coulees', into southwest-dipping basalt surfaces. Huge cataracts also eroded into the basalt, forming what are now called 'dry falls' as well as 'loess islands', which are erosional remnants of an early thick loess cover on the plateau. The floods deposited immense gravel bars and ice-rafted erratic boulders at high elevations. Collectively all of these features make up the Channeled Scabland as detailed in early work by J Harlen Bretz, who was the first person to describe the gigantic Missoula floods (Bretz, 1923, 1925, 1928a,b,c, 1932).

Soils

Loess, sand dunes, and sand sheets have accumulated on the Columbia Plateau throughout much or all of the Quaternary Period (Busacca, 1989). The loess is thickest, up to 250 feet (75 m), in a 4000 square mile (10,000 km^2) area east of the Columbia Valley appellation called The Palouse (Fig. 2). Most recently, during the last stages of the Pleistocene (from ca. 20 ka to 14 ka) and continuing through the Holocene, prevailing southwesterly winds have continued to erode rhythmites and other glacial sediments from older episodes of outburst flooding and redeposited them into the present sand dunes, sand sheets, and loess (McDonald and Busacca, 1988; Sweeney and others, 2002). Soils formed from these windblown sediments are the backbone of agriculture in all of eastern Washington (Boling and others, 1998; Busacca and Meinert, 2003). In the Rattlesnake Hills area, many of the vineyards are located on thin loess deposits that have capped Miocene-age volcaniclastic sediments of the Ellensburg Formation and rhythmite deposits of the Missoula floods. Even along the Columbia Gorge, soils are formed from a veneer of eolian sand or silt over eroded basalt or basaltic colluvium, although as you travel west into the Gorge, the eolian influence declines markedly as prevailing westerly winds find less and less flood sediment to deflate into an eolian cover.

Soils in the Columbia Plateau and Columbia Gorge areas are dominantly Mollisols, Aridisols, Entisols; soils in the forested areas are dominantly Andisols (Boling and others, 1998). Mollisols are the dark, humus-rich prairie soils; Aridisols are desert soils and often have cemented hardpans of lime (calcium carbonate) because of limited leaching; and Entisols are soils with no profile features, such as are found in shifting sand dunes. Andisols are the soils weathered from volcanic tephra and from some volcanic flow rocks. Soils used for wine grapes are commonly Aridisols in which the upper horizons are loess or sheet sands and the lower horizons are formed in stratified silty to gravelly outburst flood sediments. Some have a lime-silica cemented hardpan at the interface between materials. Some wine-grape soils are formed in loess or sand to a depth of 5 feet or more. Thus there are major differences between different soils in rooting depth, texture, and resulting water-holding capacity, which are key properties for inducing controlled water stress to improve grape quality, and in nutrient status.

Pre-agricultural vegetation in southeastern Washington ranged from sagebrush-steppe in the driest areas, to steppe (perennial grass prairie), to coniferous forest at higher and wetter elevations in the Cascade, Blue, and Rocky Mountains (Daubenmire, 1988).

Climate

Climate is one of the more important components of terroir, and it is the most difficult to evaluate because it varies in both space and time. There are many climate variables, and these can be measured at three different scales. Macroclimate is on a continental to regional scale and controls the length of the growing season and other long-term trends and extremes. Mesoclimate is on a regional to vineyard scale and is affected by topography, elevation, slope, aspect, and proximity to bodies of water or other moderating influences. Microclimate ranges from the scale of a vineyard down to individual vines, grape clusters, and even smaller domains if measurement permits. Macroclimate changes on a geologic time scale (thousands to millions of years), but both mesoclimate and microclimate can vary seasonally, daily, or even hourly. Both mesoclimate and microclimate can be affected by human activities such as urban development, wind machines, irrigation, and canopy management (Busacca and Meinert, 2003).

Although many climatic variables can be measured, four of the more important are temperature, humidity, wind, and sunlight (solar radiation). These and others are collected systematically by a variety of meteorological services, but in the state of Washington we are fortunate to have the Washington State University (WSU) Public Agricultural Weather System (PAWS) that automatically and continuously collects climatic data, which are available at http://frost.prosser.wsu.edu/ (Busacca and Meinert, 2003).

The climate of the Columbia Plateau is influenced to a great extent by prevailing westerly winds and by the Cascade Range and Rocky Mountains. The Cascade Range creates a rain shadow, and as a result, the climate of the Columbia Plateau is arid to sub-humid (6–40 in. or 15–100 cm of mean annual precipitation). The amount of precipitation is closely correlated with elevation, generally increasing from west to east and southeast as elevation rises. The Rocky Mountains protect this section of Washington from the coldest of the arctic storms that sweep down through Canada (Busacca and Meinert, 2003).

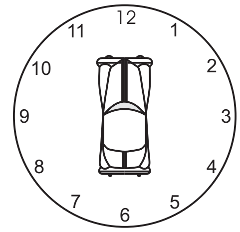
During the summer, high-pressure systems prevail, leading to dry, warm conditions and low relative humidity. Average afternoon temperatures in the summer range from 68° to more than 95°F (20°–>35°C). Most of the growing season is very dry, and some vineyards experience no measurable precipitation during the summer months. Washington gets 17.4 hours per day of sunshine during the growing season, which is 2 hours more than the Napa Valley in California. The rainy season extends from October to late May or June, as frontal storms sweep across the area. In eastern Washington, much of the precipitation from mid-December to mid-February is in the form of snow (Busacca and Meinert, 2003).

As an example of climates of Washington appellations, Red Mountain (at the east end of the Yakima Valley appellation near Benton City; see Fig. 2) is a warm vineyard site with 3409 degree-days[1] recorded in 1998 and an average of 3016 degree-days for the years of record. For comparison, the Napa Valley in California and the Barossa Valley in Australia average 3280 and 3090 degree-days respectively; Bordeaux, France, averages 2520. Red Mountain also may be the driest viticulture area in Washington, with an average annual precipitation of 5 inches (17.8 cm) and a low in 1999 of 3.3 inches (8.4 cm). Typically, in most areas of the state, the time of year with lowest precipitation coincides with that of highest temperatures, and because of the low soil water-holding capacity and general absence of water tables, this creates a moisture deficit that requires irrigation in most vineyards. Because of the high evapotranspiration rates in such conditions, drip irrigation is the dominant method of supplying supplemental water (Busacca and Meinert, 2003).

Early in the season, the growing degree-days accumulate slowly; however, as temperatures rise, they accumulate faster. Growing degree-days for grapes is commonly reported as the summation of the daily degree-days summed from April 1 to October 31.

TRAVEL LOG

Begin the trip from Skamania Lodge in Stevenson, Washington. Head west on SR 14 to the Bridge of the Gods, cross the Columbia River to the Oregon side and proceed east on I-84.



To tell you where to look, we use the 'clock face' system, in which the front of the vehicle is twelve o'clock and the back is six o'clock.

Milepost

I-84 MP47 — Herman Creek, Oregon. Government Island (and its jetty-rock quarry) consists of pyroxene trachyte (Allen, 1979).

MP48 — Active landslide area. This area has repeatedly disturbed the highway roadbed, lifting it up tens of feet. Removal of millions of yards of landslide material by highway engineers has failed to stop the movement (Allen, 1979).

MP49–MP51 — Across the river is Wind River, Washington. There is a good view at eleven o'clock of the flat top of the Wind River intracanyon lava flow, which came from a small volcano, Trout Creek Hill, 15 miles (24 km) up the valley to the northwest. The broad, flat surface west of Wind River and under the town of Carson is underlain by basalts of Trout Creek Hill, which consist of several lava flows that moved down the Wind River valley about 340 ±75 ka (Korosec, 1987) and temporarily dammed the Columbia River to a depth of at least 150 feet (45 m)(Waters, 1973).

Wind River was named New Timber by Lewis and Clark because they first saw the Oregon big leaf maple, a newly discovered species, here. Later they changed the name to Cruzzare's River after their French boatman. At the time, there were large village sites on each side of the outlet (Spranger, 1985).

The Columbia River funnels between the twin granodiorite porphyry intrusions of Shellrock (Oregon side) and Wind (Washington side) Mountains (Fig. 4). Shellrock Mountain, with its constant raveling of platy rubble at a repose angle of 42 degrees, was a major obstacle to early road building through the Gorge.

MP55 — Starvation Creek, Oregon. Historic site of Chinese 'coolie ovens' used in the building of the railroad in the 19th century. Notice the fine columnar colonnade in Grande Ronde Basalt at the base of the entablature cliff. The creek was named by occupants of a train stalled here by snow slides for four days in 1884.

The falls, cascading down 186 feet (57 m), are the easternmost of the spectacular series of falls in the Gorge. Observations of waterfalls over Columbia River basalt (M. H. Beeson, Portland State Univ., unpub. data, 1978) have shown that falls often occur

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[1] The concept of 'degree-days' (also called day-degrees, heat units, or heat summation) is based on the observation that relatively little plant growth and ripening occurs in grapes below 50°F (10°C). Standard degree-days are calculated based upon the amount of time above the 50°F (10°C) threshold. The calculation of the degree-day (DD) for a 24-hour period requires the following formula:

$$((\text{max.°F} + \text{min.°F})/2) - \text{base°F} = \text{DD}$$

where the base temperature is 50°F. For example: If on April 3 the maximum temperature is 60°F and the minimum temperature is 50°F, the DD for April 3 would be

$$((60°\text{F}+50°\text{F})/2) - 50°\text{F} = (110°\text{F}/2) - 50°\text{F} = 55°\text{F} - 50°\text{F} = 5\ \text{DD}$$

where flows are flat lying or dipping upstream. This condition allows blocks produced by vertical joints to remain stable until support is withdrawn by erosion of softer interflow material at the base of individual flows. Therefore, the rate of erosion of interflow areas probably largely controls the rate of retreat of the falls. The amphitheater-shaped valleys common to many of the falls within the Gorge are due to the freeze–thaw action of water from the splash mist that has penetrated the joints (Tolan and others, 1984).

MP56 Viento State Park, Oregon. Although ‘viento’ is Spanish for ‘windy’, and this region is the windiest in the Gorge, the name has an entirely different origin, derived from the first two letters of the names of three railroad men, Villard, Endicott, and Tolman (Allen, 1979).

MP58 Mitchell Point, Oregon. Mitchell Point, ahead, consists of Grande Ronde Basalt dipping 30 degrees to the southeast, capped by 100 feet (30 m) of Troutdale Formation quartzitic gravels, which in turn are unconformably overlain by later lavas with low initial dip (Fig. 5). Across the river at ten to eleven o’clock lies the Underwood Mountain shield volcano, whose lava flows unconformably overlie steeply east-dipping Grande Ronde Basalt a few hundred feet above the river level (Fig. 6). Underwood lavas crossed and probably dammed the river. Remnants crop out for 2 miles (3.2 km) east of Mitchell Point (Allen, 1979). Mitchell Point is one of the windiest spots in the Gorge. The old scenic highway tunnel through the point is 50 feet (15 m) above the present freeway (Allen, 1979).

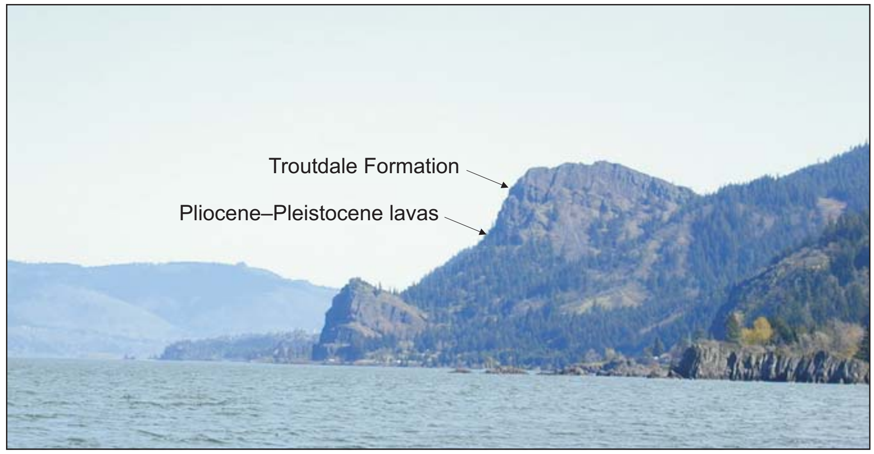

Figure 5. Mitchell Point. Miocene Columbia River Basalt Group lavas dip 30 degrees to the southeast, capped by 100 feet (30 m) of Troutdale Formation quartzitic gravels, and unconformably overlain by Pliocene to Pleistocene lavas with low initial dip. View to the east.

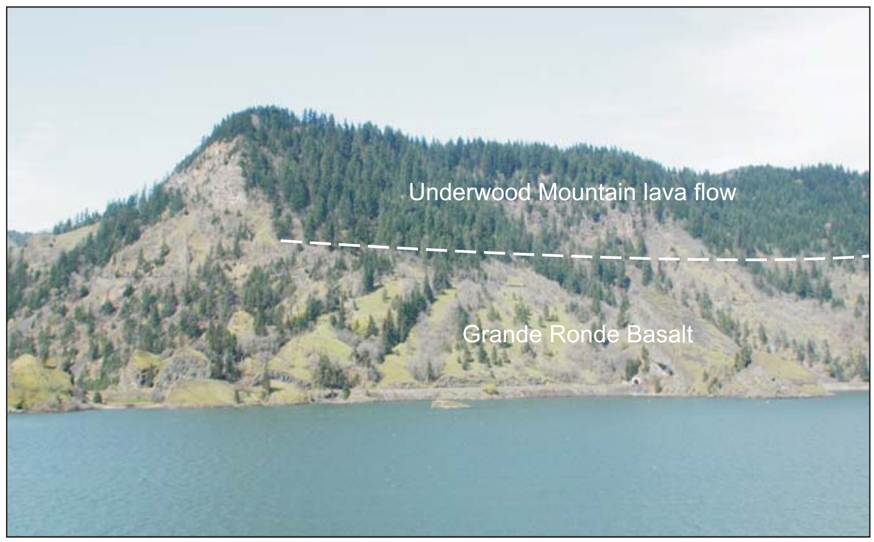

Figure 6. Lava flow from Underwood Mountain shield volcano, whose lavas unconformably overlie steeply east-dipping Grande Ronde Basalt a few hundred feet above the river level. View to the north.

MP61.5 East-dipping, bright-yellow palagonite tuff and breccia of Ruthton Point (Fig. 7). The tuff and breccia are the result of lava from a nearby intracanyon volcano, or possibly from Quaternary Underwood Mountain volcano across the river, pouring into a lake formed by a lava dam (Allen, 1979).

MP62 Hood River, Oregon. Hood River is an important agricultural area with many commercial fruit orchards and vineyards. Nathaniel Coe became the first white settler in Hood River during the early 1850s. The Hood River Valley extends for 20 miles (32 km) to the south with an average width of 5 miles (8 km). The east wall of the valley is a fault escarpment with a vertical displacement of more than 2000 feet (600 m). Abundant glacial till and outwash occupy the valley bottom and are exposed in roadcuts and in the youthful canyon of the river, which is incised 200 to 300 feet (60–90 m) below the valley surface. If the day is clear, it is possible to catch a glimpse of Mount Adams at nine o’clock (Allen, 1979). The Hood River Valley was inundated by backwater from the Missoula floods. Newcomb (1969) reported “fine-grained lacustrine deposits” as high as 800 feet (245 m), probably slackwater deposits of Missoula floods. The highest ice-rafted erratics in the Hood River Valley are between 840 and 880 feet (255 and 270 m). If this was the maximum stage achieved by the largest flood, the water surface dropped substantially through Bingen Gap (O’Connor and Waitt, 1994).

Note a change in vegetation, dictated by the Cascade Range rain shadow. Douglas fir and hemlock have given way to deciduous trees. The annual rainfall at Hood River is less than 30 inches (76 cm), as compared with more than 40 inches (102 cm) at Portland (Allen, 1979).

MP64 Bridge across Hood River. Thick quartzitic gravels (Pliocene Troutdale Formation) rest upon west-dipping basalt south of the bridge. We have just passed the axis of the Hood River–White Salmon River syncline, which trends northeast (Allen, 1979).

MP64.5 Bingen anticline, Washington. We approach the axis of the Bingen anticline, which can be seen across river at ten o'clock (Allen, 1979). The town of White Salmon is built on the north side of the river upon a large pendant bar in the lee of the downstream end of Bingen Gap. One of the larger bars in the Columbia River Gorge, White Salmon bar (Bretz, 1925), rests on a basalt platform. The bar is about 1.25 miles (2 km) long and ascends from 400 feet (120 m) elevation at its apex to almost 800 feet (240 m) at its downstream end (O'Connor and Waitt, 1994).

MP65.5 Columnar Grande Ronde Basalt colonnades form cliffs at three o'clock. Miocene-age Dalles Formation gravels are found on the east side of the Bingen anticline to the south at 2400 feet (732 m) elevation (Allen, 1979).

MP67 The axis of the Mosier syncline trends northeast up the Columbia River at eleven o'clock (Fig. 8). The base of the Dalles Formation beds in the center of the syncline a mile southwest of Mosier is at about 750 feet (230 m) elevation (Allen, 1979).

MP69 Approaching the town of Mosier. The synclinal axis is at ten o'clock (Allen, 1979).

MP69.7 Note the scabland surfaces on the dip slope of basalt across the river up to elevations of about 900 feet (275 m) (Allen, 1979).

MP77 Approaching the axis of the Ortley anticline across the river at nine-thirty. Flows thinned and folded to form vertical hogbacks and are down-dropped on the west side. The axis of the anticline is about one-half mile (0.8 km) east of the hogbacks. Note the large number of flows (at least 15) in the cliffs at nine o'clock (Allen, 1979).

MP78 Axis of the Ortley anticline at nine o'clock. Dalles Formation beds have been stripped off the crest of the anticline to the south. You are now entering the Dalles syncline, which was originally filled with Dalles Formation beds to an elevation of more than 1000 feet (300 m). To the south, they rise to 2000 feet (610 m). Still further to the southwest, they can be traced to an elevation of more than 3000 feet (915 m) before they are covered by lavas from the Cascade Range (Allen, 1979).

From The Dalles eastward to the confluence of the John Day River, the path of the Columbia River largely follows the Dalles–Umatilla syncline, which is flanked on the north by the Columbia Hills anticline. The wide valley of The Dalles is a large synclinal valley. The rapids and holes of 'The Dalles of the Columbia', now covered by the reservoir of The Dalles Dam, was formed where the river intercepted resistant basalt units that dip gently to the southwest into the syncline.

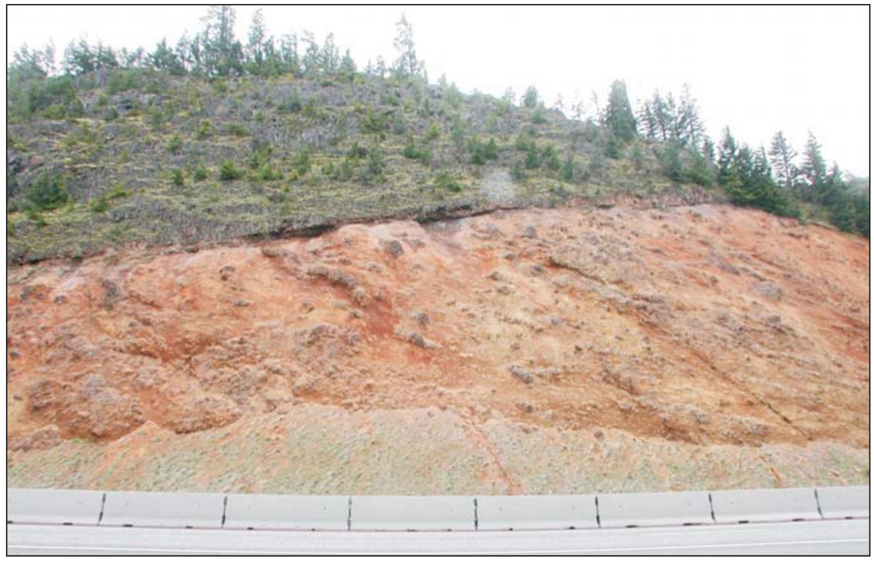

Figure 7. East-dipping, bright-yellow palagonite tuff and breccia of Ruthton Point.

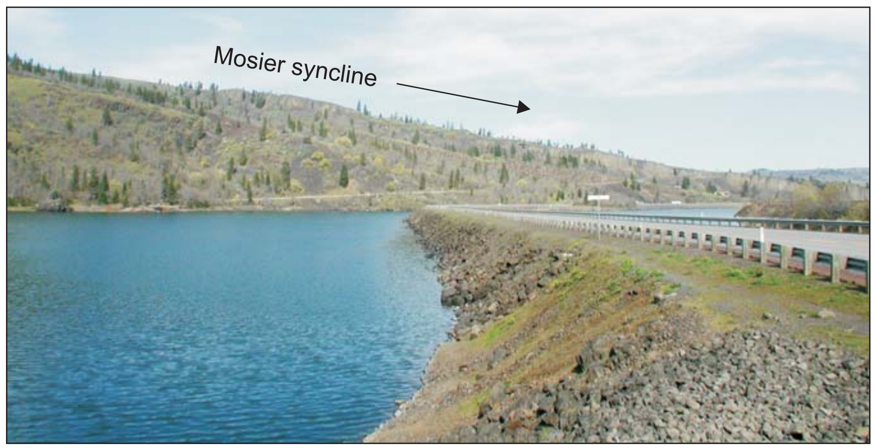

Figure 8. North limb of the Mosier syncline dipping into the Columbia River on the Washington side of the river trends. Syncline trends northeast up the Columbia River. View to the east.

MP82 The Dalles, Oregon. This city is named for the famous rapids called "La Grande Dalle de la Columbia" by the French canoemen employed by early fur traders. 'Dalle' means 'flagstone', which was often used to flag gutters, and the rocky chute with the great river swirling through it reminded the Frenchmen of a gutter (Spranger, 1985).

MP88 The Dalles Dam. The Dalles Dam is 44 miles (71 km) upstream of Bonneville Dam on the Columbia River. Its hydroelectric generating facility went into operation in 1957.

MP89 The Long Narrows, also known as Grand Dalles or Fivemile Rapids is now drowned by The Dalles Dam. When the Columbia River was in flood, this was some of the most violent water known, able to pluck rocks from the bottom of the channel nearly 200 feet (60 m) below sea level and hurl them over the rim of the Gorge. Impatient travelers sometimes attempted to run the swift water with tragic results. The Short Narrows or Tenmile Rapids were 5 miles (8 km) upstream and Celilo Falls was 5 miles (8 km) further (Fig. 9). The swift water provided profitable fishwheel sites, but the fishwheels were difficult to operate because of the great changes in water level; in the spring, the waters rose at least 45 feet (14 m). This area was the great aboriginal trade mart (Spranger, 1985).

MP92 Kaiser Ridge sand dunes. This significant sand dune area is on an old river terrace. These dunes have been covered with rock by the Oregon State Highway Department for safety reasons (Spranger, 1985).

MP95 Celilo Park, Oregon—Celilo Indian Village. Site of a historic Indian rendezvous near the fishing grounds now inundated by the reservoir of The Dalles Dam, it is a living remnant of a once-flourishing Indian village (Spranger, 1985).

MP97 Lower Deschutes River, Oregon, and Miller Island, Washington. The Deschutes is a significant and unaltered river that has been designated as a State Wild and Scenic River. Its headwaters are in the central Oregon Cascades, 30 miles (48 km) southwest of Bend. Miller Island, a large semi-natural island, is generally considered the eastern boundary of the Columbia River Gorge.

Proceed east to Biggs Junction, enter US 97 northbound, and cross the Columbia River. Ascend US 97, noting the replica of England's Stonehenge on the knob to the east and Maryhill Museum to the west.

US 97 MP12 Goldendale. Mount Adams may be seen at ten o'clock. Many cinder cones, remnants of the Simcoe Mountain lava field (0.9–0.5 Ma)(Wood, 1990), can be seen around the Goldendale area. Lorena Butte to the east of US 97 is a cinder cone that is currently being mined (Fig. 10).

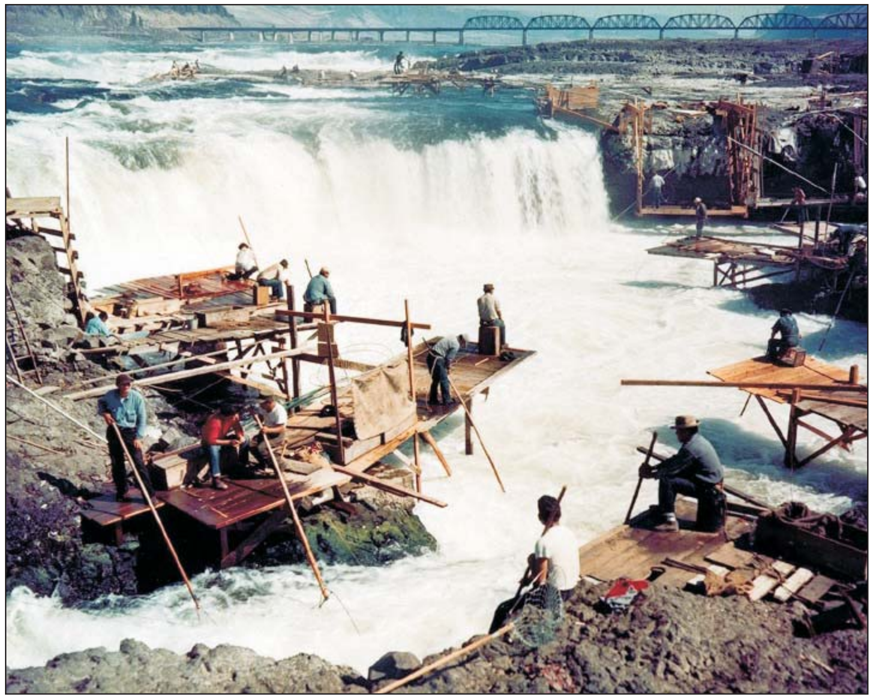

Figure 9. Historical photo of the rapids at Celilo Falls on the Columbia River before The Dalles Dam was built in 1960. Native Americans are fishing off platforms on the Oregon side of the river. *(Courtesy of the U.S. Army Corps of Engineers.)*

Figure 10. Lorena Butte, a young (900,000 yr B.P. to 5 my) Simcoe Volcanics cinder cone.

MP24.7 Brooks Memorial State Park.

MP27.2 Satus Pass (3107 feet; 947 m) is the highest pass across the Horse Heaven Hills. The Horse Heaven Hills are an anticline in the Yakima fold belt, which was formed by north–south compression of Columbia River Basalt Group lava flows. The next ridge to the north is Toppenish Ridge and then the Rattlesnake Hills, which are also anticlines in the Yakima fold belt. In the Zillah area, the Yakima Valley lies between the Rattlesnake Hills and Toppenish Ridge.

MP57 Toppenish National Wildlife Refuge lies just north of Toppenish Ridge.

MP61.44 Intersection of US 97 and SR 22. Proceed north through Toppenish on SR 22 toward I-82.

SR 22 MP4.0 Toppenish. This is a town of rebuilt false fronts and tidy brick. Railroad yards, Bureau of Indian Affairs offices, and a vacant sugar factory—plus outstanding historical murals—reflect aspects of its past. Toppenish is a Yakama Indian word meaning "sloping and spreading land". It refers to the broad plain that sweeps eastward from the Fort Simcoe area. The plain is made up of flat-lying rhythmite deposits that were deposited as ice-age floodwaters were dammed repeatedly at Wallula Gap.

MP2.0 Abandoned sugar factory.

SR 22 MP0.0 **I-82** MP50 Intersection of SR 22 and I-82. Enter I-82 at milepost 50 and proceed 2 miles (3.2 km) east toward Zillah. Leave I-82 at exit 52. Proceed north into Zillah on First Ave. Proceed to 7th St. and turn south. Proceed one block to Railroad Ave. Turn east and proceed one block and park at the top of the hill above the Zillah sewage treatment plant road.

Zillah. The Zillah area is home to a dozen wineries and is being considered for its own appellation at this time. Zillah's proximity to railroad tracks and a major irriga-

Figure 11. Outcrop of rhythmite beds at the Zillah sewage treatment plant. Note Mount St. Helens ash layers near top.

tion canal speak of its past. Like other communities in the lower Yakima Valley, the town thrived as an agricultural center and shipping point for local produce. From 1900 to 1910, when land sold for $55 per acre with perpetual water rights, the area attracted a sizeable influx of Dutch immigrants. A later wave of Mexican immigrants is reflected in the tortilla factory at the east end of town.

Stop 1. Zillah sewage treatment plant

Walk down the hill to the outcrop of Missoula flood rhythmite beds (Fig. 11). This outcrop is an excellent example of what underlies the terrace remnants in the Yakima Valley. These rhythmite beds underlie some of the better vineyard sites in the Northwest. At this outcrop, the rhythmite sediments are covered by 1 to 3 feet (1 m) of post-flood or ‘L1’ loess (McDonald and Busacca, 1992) and are cut by clastic dikes.

Outcrops of rhythmite beds near this one contain a ‘doublet’ of Mount St. Helens ‘S’ ash near the top that was deposited from eruptions that occurred simultaneously with outburst flood slackwater ponding events. Recent paleomagnetic and age dating of tephra layers indicate that decades separate each of the flood events (Clague and others, 2003).

The tephras correlate with tephras in slackwater sediments at Burlingame Canyon near the towns of Walla Walla and Touchet, Wash., and record two separate eruptions. The lower tephra is Mount St. Helens ‘Sg’ and the upper is Mount St. Helens ‘So’ (Clague and others, 2003). The Mount St. Helens ‘S’ tephra layer is radiocarbon dated at 13,000 yr B.P. (ca. 15,300 cal yr B.P.) at the volcano (Mullineaux, 1996). Thermoluminescence age dating of loess enclosing the same tephra (Busacca and others, 1992) yields a similar age estimate (Berger and Busacca, 1995). The Mount St. Helens S tephra set is also found in places near the base of the L1 loess across the Columbia Plateau (Busacca and others, 1992). This tephra and others in the loess have proven invaluable in correlating among loess outcrops because they can be geochemically fingerprinted.

Backtrack to 1st Ave. and turn west. Proceed to 5th St./Roza Drive and turn north. Proceed to 2 miles (3.2 km) to Highland Drive and turn east. Proceed 1 mile (1.6 km) to Vintage Lane and turn north. Proceed north on Vintage Lane 1.5 miles (2.4 km) to Silver Lake Winery.

Stop 2. Silver Lake Winery, Rattlesnake Hills wine growing area near Zillah, Washington

We will visit one outcrop at Silver Lake and eat lunch. This winery and its vineyards, like the Bonair Winery that we will visit next, is presently in the Yakima Valley AVA, but will be in the new Rattlesnake Hills AVA when its petition is approved. The outcrop is a finer facies of the Ellensburg Formation and contains pumice fragments. We will examine the soils that have formed over the volcaniclastic sediments and loess (Fig. 12). The Saddle Mountains Basalt crops out about 1 mile (1.6 km) to the north in the Rattlesnake Hills anticline. We will also discuss vineyard siting and grape varietals with winemaker and general manager Mike Haddox.

The Rattlesnake Hills are an east–west trending anticline with dissected canyons, terraces, and ridges running southward off the main ridge toward the Yakima River. Vineyards are typically located on ridges and terraces and in areas with good air drainage to avoid late spring and early fall frost and winterkill.

Elevation is one of the distinguishing characteristics of the Rattlesnake Hills. Vineyards in this area are the highest in the state. The minimum elevation in the Rattlesnake Hills is 850 feet (260 m) and the highest vineyard on Elephant Mountain tops out at 1600 feet (488 m). Growing vinifera below 850 feet (260 m) elevation in this region has proven to be difficult to impossible due to spring and fall frosts and winterkill, alkali soils, and (or) a high water table. If water is available, it is considered possible to grow vinifera at elevations up to 2000 feet (150 m) in the Rattlesnake Hills.

The primary soils suitable for vineyards in the Rattlesnake Hills area are the Warden series silt loams (on 0–30% slopes) and a landscape complex of the Harwood-Burke-Wiehl series silt loams (on 2–60% slopes). The Warden series soils are desert Aridisols that are formed on terraces in loess that is underlain by glacial fluvial sediments (Fig. 13)—landscapes that are highly prized for wine grape production because of good airflow and air drainage characteristics and good internal water drainage.

The Harwood-Burke-Wiehl series silt loams (Fig. 13) occur in a landscape complex of three distinctive units: ridge tops, side slopes of steeper hills underlain by old alluvium, and soft sediments of the Ellensburg Formation, all places favorable for grape plantings. This complex of soils, which is formed from loess that overlies remnants of the Ellensburg Formation, is common in the Rattlesnake Hills but is found only in isolated places elsewhere in the Yakima Valley. The Harwood series soils are Mollisols of former native grasslands and are stony and less than 30 inches (76 cm) deep over a lime-silica cemented hardpan; the Wiehl series soils are desert Aridisols that average only about 27 inches (69 cm) deep above soft sandstone; and the Burke series soils are also Aridisols that are about 25 inches (64 cm) deep above a lime-silica cemented hardpan. These soils are shallow and produce or exacerbate water deficit stress compared to deeper soils in other areas (controlled water stress, also called deficit irrigation, is positively correlated with grape and wine quality when judiciously applied). Therefore, they contrast strongly with the deep, uniform silt-loam and sandier soils that characterize the majority of planted acres in the remaining parts of the Yakima Valley. Other soils present in the area are Moxee, Starbuck, and Ritzville.

Silver Lake Winery is on a south-facing slope of the Yakima River valley. At an elevation of 1300 feet (396 m) above sea level, Silver Lake is one of the highest vineyards in the area. Its location would have been above the cataclysmic Missoula floods at the end of the last ice age. The ancient, well-drained, and nutritionally poor soil provides good conditions for vinifera grapes. The vineyards occur mostly on older Harwood-Burke-Wiehl soils developed on Miocene-age volcaniclastic sediments of the Ellensburg Formation (Waters, 1961; Bingham and Grolier, 1966; Smith, 1988).

Figure 12. Outcrop of Ellensburg Formation and loess at the Silver Lake Winery.

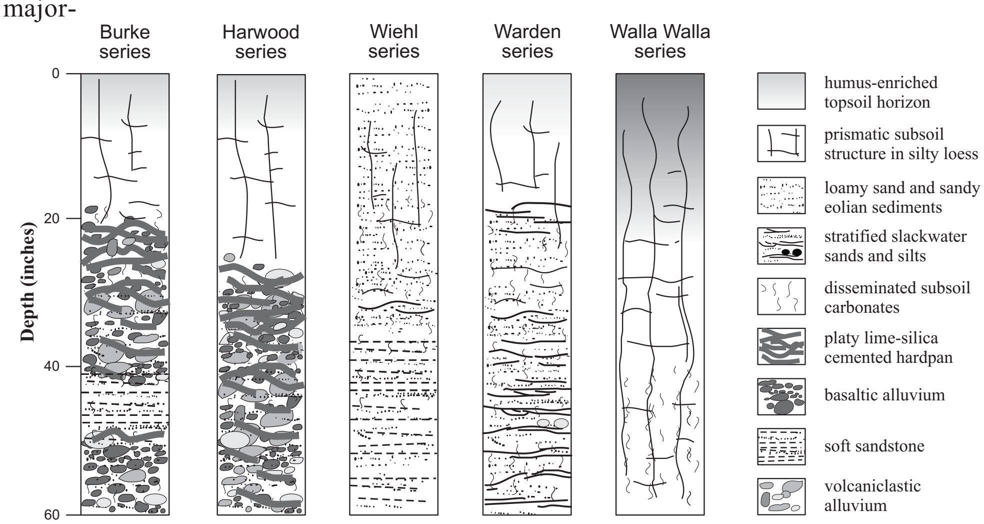

Figure 13. Representative profiles of the major soils in the Rattlesnake Hills appellation and Cascade Cliffs Vineyard. Shading of the topsoil is proportional to the content of humus.

Silver Lake has 330 acres of vineyards (Fig. 14). They crushed their first vintage in the fall of 1989. In the past 13 years, the winery's annual production has grown from 2000 cases to more than 25,000 cases. Silver Lake Winery is now the seventh largest winery in Washington. The winery has a capacity of 250,000 gallons, and it produces Merlot, Chardonnay, Cabernet, Fume Blanc, Riesling, Cabernet-Merlot, and Gewürztaminer.

Air drainage is important for successful vineyards, and Silver Lake is situated on a hill that provides good air drainage. Some vineyards in the surrounding lows tend to trap cold air and must rely more on fans to move air and smudge pots to keep vines from freezing.

Backtrack to the intersection of Highland and Roza Drives. From the intersection, proceed 1 mile (1.6 km) west on Highland Drive to Bonair Road. Turn south and proceed 0.3 mile (0.48 km) to Bonair Winery.

Stop 3. Bonair Winery and vineyards, Rattlesnake Hills wine growing area near Zillah, Washington

We will be meeting with Gail Puryear who will discuss the vineyard, soils, and various wine types produced at Bonair Winery. He is heading up an effort to have the Rattlesnake Hills area become its own appellation.

Bonair Winery has 30 acres of vineyards primarily on soils of the Warden series where Missoula flood rhythmite deposits have loess draped over the top (Figs. 11and 13). The winery is on a south-facing slope at an elevation of 900 feet (274 m), about 150 feet (45 m) above the Yakima River flood plain. It gets about 6 inches (15 cm) of precipitation per year and the ten-year average for degree-days is 2682 per year. The area is special because of the moderate temperatures. It is not too hot or cold, so there is not as much damage from extreme cold as in some other grape growing areas in Washington.

Bonair Winery is currently in the Yakima Valley appellation, but will be in the new Rattlesnake Hills AVA, if the new appellation is approved. Bonair produces Cabernet Sauvignon, Chardonnay, Merlot, Cabernet Franc, Malbec, Riesling, Touriga, and Gamay Beaujolais. The winery produces about 6000 cases annually with enough production capacity to double that amount.

Grapes around the winery are grown entirely on the soils formed above the Missoula flood rhythmite deposits (Warden soils), but vineyards to the north overlie Ellensburg Formation gravels (older Harwood-Burke-Wiehl soils)(Fig. 15).

Backtrack to the intersection of US 97 and SR 14 near the Columbia River. Enter SR 14 and proceed west.

SR 14 MP98.6 Maryhill Museum of Art. Maryhill Museum was originally a residence of Sam Hill, who started building it in 1914, apparently to fulfill a desire to live in a castle like those he had seen along the Rhine River in Germany. The museum contains an eclectic collection of European and American art, Native American artifacts, and the former crown jewels of Romania. It has an internationally recognized collection of Auguste Rodin sculptures and watercolors.

Maryhill Museum sits on a bench of nearly flat-lying lava flows of the 14.5-million-year-old Priest Rapids Member of the Wanapum Basalt.

Figure 14. Overview of the Silver Lake Winery vineyards and foothills of the Rattlesnake Hills. View to the north.

Figure 15. Outcrop of Ellensburg Formation gravels near the north end of Bonair vineyards.

Stop 4. Cascades Cliffs Vineyard and Winery

MP88.5 We will be meeting with Bob Lorkowski, owner of Cascade Cliffs Winery, and Anthony Fuller, Klickitat County Wine Association representative, to discuss vineyard siting and wine varietals.

Cascades Cliffs Vineyard and Winery was started in 1986 and currently has 23 acres of vineyards, most of which were planted in 1987. The climate at Cascade Cliffs is significantly different from that at the Yakima Valley wineries. This far east of the crest of the Cascades, the Gorge has hot, dry summers similar to the Yakima Valley, but summer high and winter low temperatures are moderated by the heat reservoir effect of the pool of Lake Celilo behind The Dalles Dam on the Columbia River. The vineyards do not suffer from early and late frosts and the average annual rainfall is about 14 inches (36 cm).

The winery is on a south-facing slope that receives increased solar radiation (relative to slopes with other orientations) in summer and promotes air drainage in winter. The vineyards are approximately 80 feet (24 m) above the river on a bench of Grande Ronde Basalt. The 500-foot (152-m) vertical cliff rising behind the vineyards to the north (Fig. 16), with its black color, keeps temperatures higher for longer periods of time.

Interestingly, the soils of the Cascade Cliffs Winery are mapped primarily as the Walla Walla series Mollisol soils of former grasslands (Fig. 13), which are defined as forming in deep loess deposits. We suspect that on this bench, which was inundated by Missoula floods, the soils have actually formed from massive flood slackwater sediments in the lower part with a thin cover of loess derived from the same materials.

Varieties of wine produced here are Barbera, Merlot, Zinfandel, Petite Syrah, and Cabernet.

As we travel westward from this point, loess influence in the soils diminishes rapidly because the lack of substantial flood slackwater sources west of this point (until the Willamette Valley) and prevailing westerly winds limit loess generation. Thus, soils west of the upcoming town of Dallesport are more commonly formed from colluvium and alluvium of the native bedrock types.

Rainfall increases dramatically with every mile traveled westward in the Columbia Gorge, from about 10 inches (25 cm) annually at Maryhill, to 14 inches (35 cm) at Cascade Cliffs, to about 60 to 70 inches

(152–178 cm) at Skamania Lodge. This, of course, has a dramatic impact on the progression of native vegetation we see as we travel west along the Gorge—from sagebrush-steppe, to pure bunchgrass grassland, to a mixed hardwood conifer parkland, and finally to a pure dense conifer forest.

MP 85.1 Horsethief Lake State Park, Washington. This site includes the Colowesh Bottom and Horsethief Butte archaeological sites, with several petroglyphs. It is near the site of a historic Wishram Indian village (Spranger, 1985).

MP83.5 Intersection of SR 14 with US 197. The Dalles Dam is to the south.

MP80–86 Dallesport sand dunes, Washington. This is an extensive sand dune area; the large gravel bar is mined for gravels shipped to Portland via barge.

Figure 16. Cascade Cliffs Vineyard and Winery. Note the vertical cliffs of Grande Ronde Basalt rising above the vineyard. View to the north.

MP75.75 Klickitat River at Lyle, Washington. The Klickitat River drains much of the area around Mount Adams. It is a traditional Indian dip-net fishing area and a modern-day recreational and fishing area. Lewis and Clark came to this river on October 28, 1905. "We landed to smoke a pipe with the people of a village of 11 houses we found those people friendly. Their village is situated immediately below the mouth of a River which heads in the mountains, the Indians inform us that 10 nations live on this river by hunting and on buries. The River we call Caterack River." On the return trip they stopped here to purchase horses but were unsuccessful. "They would not take the articles we had in exchange, they wanted an instrument which the Northwest traders call an eye-dag which we had not (Spranger, 1985)."

MP65 Bingen and intersection of Hood River Bridge.

MP6.9 White Salmon River.

MP49.3 Wind River.

MP44.6 Stevenson, Washington.

MP43 Intersection of SR 14 and Rock Creek Drive. Proceed on Rock Creek Drive 0.2 mile (0.3 km) to the entrance to Skamania Lodge.

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