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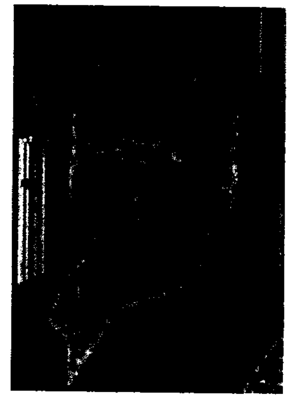

4 November 2004

Nancy Sutton
AVA Program Manager
Alcohol & Tobacco Tax and Trade Bureau
925 Lakeville Road #158
Petaluma CA 94952

Subject: Final Perfected Petition to Establish a New American Viticultural Area in Washington State– Proposed Name: Wahluke Slope

Dear Ms. Sutton:

On behalf of the Wahluke Slope Wine Grape Growers Association (Mr. Mike Mrachek, President, c/o Lucky Bohemian Vineyards, LLC, 4147 Hamlin Road, Malaga, WA. 98828, 509-662-9731 Office, mikem@nwi.net), I am very pleased to present this Final Perfected Petition to establish a new American Viticultural Area in Washington State with the proposed name 'WAHLUKE SLOPE'.

I am including 3 copies of the petition. The first two copies are bound; the third unbound should you need to make copies. I am including only one set of the topographic quadrangle maps with the boundary clearly marked, to go with copy 1, and only one copy of the Soil Survey of Grant County, Washington to go with copy 1 (you'll see why I did not include three copies of it!).

I will be the contact person for questions and corrections: my contact information is on this letterhead. In e-mail correspondence, please also copy Mr. Mrachek if you would. His e-mail address is in the first paragraph. Thank you so much for your positive and helpful guidance in the preparation of this petition. I look forward to working with you and your team of examiners as the process proceeds.

Sincerely,

Alan J Busacca

Alan J. Busacca
Geologist and Soil Scientist

xc: Mike Mrachek

COPY 1

Petition to Establish an American Viticultural Area - Proposed Name:

Wahluke Slope

Prepared by:

Alan J. Busacca, Ph.D.

Certified professional soil scientist no. 24928

Washington State licensed geologist no. 1112

State of Washington Licensed Geologist 1112 Alan Busacca PhD

SUMMARY:

In this petition, a new American Viticultural Area (AVA) in Washington State, the **Wahluke Slope**, is proposed. **1.** Evidence is provided that the name of the viticultural area is locally and/or nationally known as referring to the area specified in the application. **2.** Historical or current evidence is documented that the proposed boundaries of the viticultural area are the best and correct ones for the area. **3.** Evidence is presented relating to the geographical features (landform, slope, aspect, climatic characteristics, and soils) that distinguish the proposed area from surrounding areas. **4.** The specific boundaries of the viticultural area are described based on features that can be found on U.S.G.S. topographic maps of 1:24,000 scale. **5.** An appendix is attached to provide hard copies of evidence in support of Part 1 of the petition. **6.** A set of appropriate U.S. Geological Survey topographic maps, 1:24,000 scale, are included with the boundaries prominently marked.

The Wahluke Slope is in the eastern part of Washington State, east of the Cascade Mountain Range (Figure 1). The proposed Wahluke Slope AVA is contained entirely within the existing Columbia Valley AVA and it does not overlap with any other existing or proposed AVA. It comprises about 81,000 acres. About 5200 acres of wine grapes are currently in production (Table 1), which is close to twenty percent of the 28,000 acres of wine grapes grown in the state of Washington in 2002 (WASS, 2002). It lies northeast of the Yakima Valley AVA (Busacca and Meinert, 2003), north of the Red Mountain AVA (Meinert and Busacca, 2002), and northwest of the Walla Walla Valley AVA (Meinert and Busacca, 2000).

This unique area has been known from Native American times as the Wahluke Slope, is more geographically isolated (Figures 2a, 2b) than any other existing or proposed AVA in Washington state, is the only existing or proposed AVA that is entirely contained on a single geologic landform, and has climatic characteristics and soil qualities that together define a distinct *terroir* for wine grape production in Washington state. These characteristics justify recognition of Wahluke Slope as a legal AVA.

Figure 1. Map of Washington State showing existing American Viticultural Areas (AVAs) and the location of the proposed Wahluke Slope AVA. Map courtesy of the Washington Wine Commission; ttp://www.washingtonwine.org/).

Wilson (1998) defined the French term *terroir* (tehr-wahr) as the complex interplay of climate, soil, geology, and other physical factors that influence the character and quality of wine grapes. Meso-scale (vineyard district or AVA-scale) climatic factors, such as amount and seasonal pattern of rainfall, accumulation of heat units or growing degree days, contrast in daytime versus nighttime temperatures during the growing season, winter minimum temperatures, dates of first and last frost, air drainage, and wind can contribute to the potential of an area to produce superior and distinctive wine grapes. Site factors such as slope, aspect, and slope shape, and of soil factors such as soil type, depth, texture, and nutrients can also have strong influences.

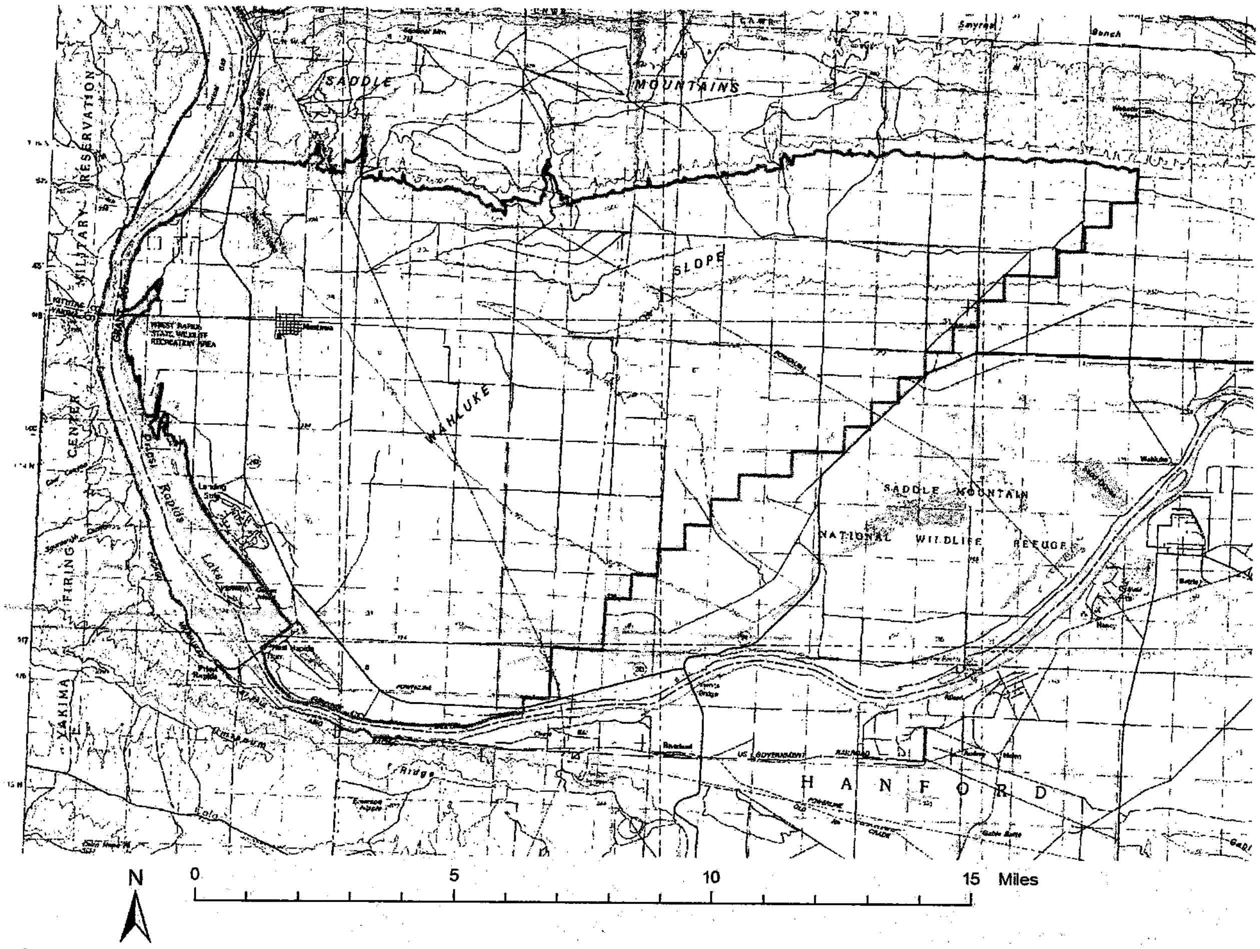

Figure 2a. Topographic map of part of the Saddle Mountains, Wahluke Slope and Columbia River near Mattawa, Washington. Taken from the 1:100,000-scale metric topographic map of Priest Rapids, Washington (U.S.G.S., 1979). Boundary of the proposed Wahluke Slope AVA shown in green.

PETITION:

As permitted in the Federal American Viticulture areas, 27 CFR, Part 9, the wine grape growers of **Wahluke Slope** area present the following:

1. **<u>Evidence that the name of the viticultural area is locally and/or nationally known as referring to the area specified in the application.</u>**

Listed below are 9 regional and national sources that refer to **Wahluke Slope** as a recognized geographic area on maps in the location of the proposed AVA, as a source of business names, as a destination for recreation, and as an area of production of high quality wine grapes. Hard copies of all sources listed below are included as Appendix I. A Google search performed on February 27, 2004, using the search terms "Wahluke Slope" returned almost 2000 references to that name for the area in Washington State consisting of the south-facing bench lands between the Saddle Mountains and the Hanford reach of the Columbia River (Figures 2a, 2b). Citations to this name range widely from information about the unique ecology of Wahluke Slope and the adjoining Saddle Mountains National Wildlife Refuge (now a part of the Hanford Reach National Monument), to high-profile articles in the U.S.'s premier wine magazines *Wine Spectator* and *Wine Enthusiast* on award-winning wines made from grapes grown on the Wahluke Slope, to an article in *Vineyard Winery Management* explaining the viticultural highlights of the Wahluke Slope, including its exceptional warmth.

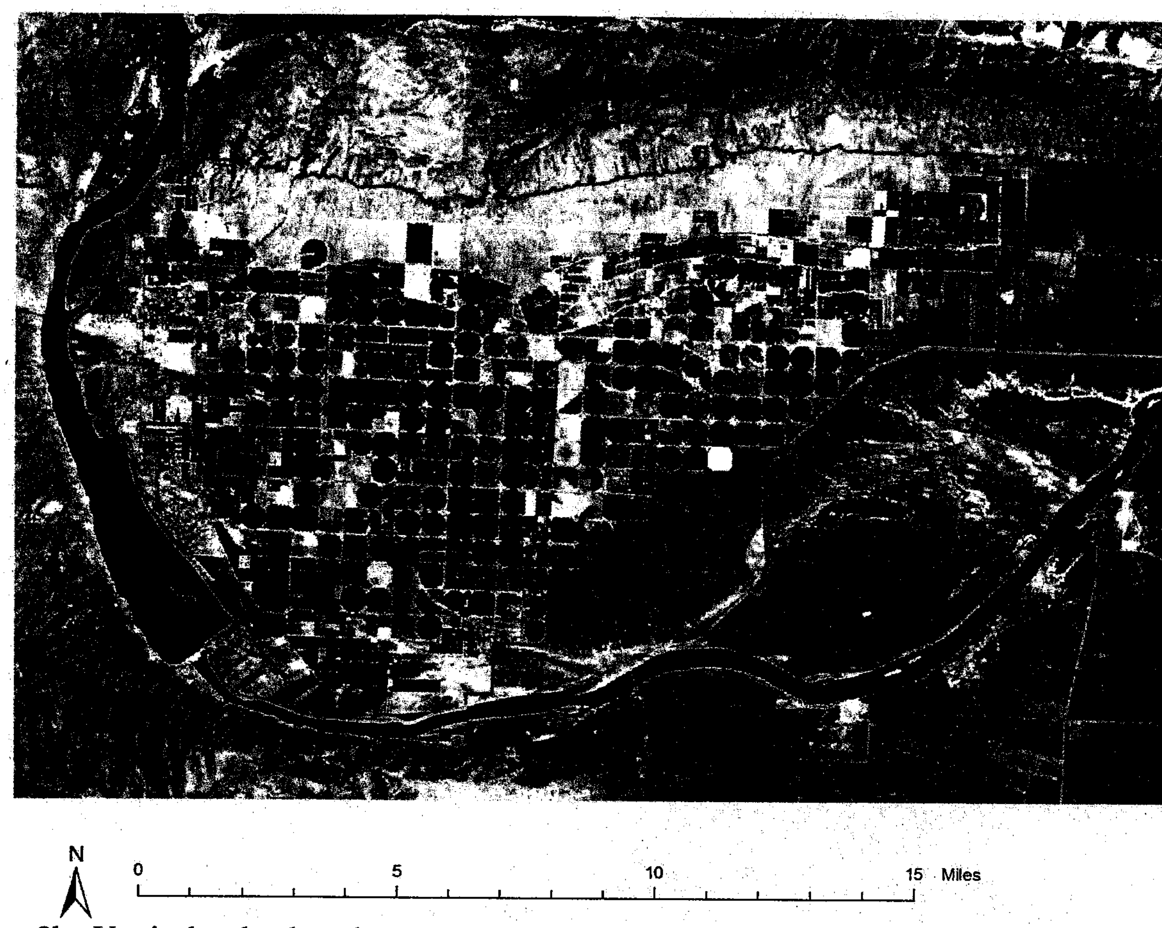

Figure 2b. Vertical orthophoto base map of the proposed Wahluke Slope AVA. AVA boundary shown in green. Center pivot irrigated circles are approximately 0.5 mi in diameter; wine grapes receive drip or sprinkler irrigation.

A. The name **'Wahluke Slope'** appears in the location of the proposed AVA on the U.S. Geological Survey 1951 edition 15 minute series (topographic) maps of the Priest Rapids and Coyote Rapids quadrangles (see Appendix I). This establishes that the name has a historical relationship to the area of the proposed AVA.

B. The Metsker map of Grant County, Washington, has **Wahluke Slope** printed prominently on the index map in the area of the proposed AVA (see Appendix I) and on individual map sheets 4, 5, 14, 15, 23, 24, 32, and 33 (not shown). (Metsker's Atlas of Grant County, Washington. 1948. Metsker Maps, Seattle, Washington). This further establishes that the name has a historical relationship to the area of the proposed AVA.

C. The DeLorme Washington Atlas and Gazetteer shows the words '**Wahluke Slope**' across the area of the proposed AVA on pp. 52-53 (see Appendix I). (Washington Atlas and Gazetteer. 2002. DeLorme, Yarmouth ME. Sixth Edition).

Table 1. Growers and Vineyard Acreages on the Wahluke Slope

Vineyard	**Name**	**Acres**	**Address**	**Phone (509)**	**Email**	**Zones**[1]
Riverbend Vineyard	Mike Wade /Gus Hienike	32	PO Box 920 Wenatchee	662-7153	mike@columbiafruit.com	1
D.A. Vineyard	Sahli, Wayne & Cathy	15	525 Desert Aire Dr. Desert Aire, 99349			1
Doebler	John Doebler	8				1
Duckpond Cellars	Douglas Friese	520				4
Fox Estate	Fox, Dan & Jerry	200	24962 Hwy 2433 Mattawa 99349	932-5818		1
Jones Vineyards	Jones, Greg	600	Po Box 487 Quincy, 98848	760-2080	greg@jonesproduce.com	1&3
Lucky Bohemian	Mrachek, Mike	245	4147 Hamlin Rd. Malaga	662-9731	mikem@nwi.net	2&3
Milbrandt	Milbrandt, Butch	453	PO Box 5336 George, 98824	750-1770	butchmwa@hotmail.com	1&3
Rosebud Ranches	Dobson, Roy & Sharon	230	21954 I Rd. SW Mattawa, 99349	932-4617	shar-dobs@hotmail.com	4
SBDW	Waliser, Kent	363.5	8930 W. Sagemoor Rd. Pasco, 99301	547-9718	crimsonkw@aol.com	4
Sargent	Tom Thorsen	100		967-8431	TomThorsen@earthlink.net	4
Shaw	Henriksen, Eric	464	PO Box 4549 W. Richland, 99353	531-0599	Eric.Hendriksen@gte.net	3
Stone Tree Vyd.	Wildman, Ted	190	11072 S. Griffin Prosser, 99350	786-4340	twild@bentonrea.com	3
Washington Fruit	Plath, Cliff & Mike Roskamp	360			cliff@washfruit.com	2
Wyckoff Farms/Coventry Vale Winery	McKinley, Reed	925	PO Box 249 Grandview, 98930	882-3934	reedm@wyckoff-farms.com	3
Zirkle Fruit	Tom Merkel & Bill Wangler	500			tom@zirklefruit.com	1
	Total	**5205.5**				

[1]Zones refers to the planted area zones on Figure 5

D. www.washingtonwine.org/survey.pdf; accessed on February 28, 2004. The 2002 Washington Wine Grape Acreage Survey by the Washington Agricultural Statistics Service on page 7 (see Appendix I) discusses the wine grape acreage in the Columbia Valley AVA as follows: "The Columbia Valley AVA was subdivided into the following regions: **Wahluke Slope**, Royal Slope, Columbia Basin/Snake River, Alderdale Ridge, Columbia Gorge, Canoe Ridge, Cold Creek, Mattawa, Wallula and Other…". This source establishes that the name has a current, publicly known relationship to wine grape production.

E. An apartment complex in the town of Mattawa, which lies within the proposed AVA, is named '**Wahluke Slope Apartments**', establishing name evidence in the form of a business name in the local phone book (see Appendix I). (http://yellowpages.superpages.com/listings.jsp?SRC=&C=wahluke+slope&R=N&STYPE=S&MC=1&T=&S=WA&F=2&CP=Real+Estate%5EApartment+%26+Home+Rental%5EApartment+Buildings%5E, accessed on August 8, 2004).

F. Promotional materials for the annual Sandhill Crane Festival in Othello, WA (http://www.othellosandhillcranefestival.org/about.htm, accessed on August 8, 2004) promote a birding tour of the **Wahluke Slope**/ shrub steppe, establishing further name evidence in tourist materials (see Appendix I).

G. Promotional materials from the Grant County Tourism Board dated 2/13/04 (http://www.tourgrantcounty.com/full_story.asp?id=226, accessed on August 11, 2004) highlight recreation opportunities in Grant County, WA, including wildlife and wildflower watching in the **Wahluke Slope** (see Appendix I).

H. The 'Hanford Reach' publication of the U.S. Department of Energy in its April 19, 1999 edition, announced the creation of a 90,000 acre **Wahluke Slope** national wildlife refuge in the area adjoining the eastern border of the proposed AVA to protect shrub steppe habitat along the Hanford Reach National Monument of the Columbia River (see Appendix I).

I. The website of the Washington Wine Commission describes the **Wahluke Slope** in its page of sub-Appellations of the state as a high plateau known for producing distinctive varietal character (http://www.washingtonwine.org/default.cfm?action=showfeature&story=subAppel.html&page=12, accessed on August 5, 2004) (see Appendix I). This source provides further name evidence that the proposed name has a current relationship to the geographic area.

2. Historical or current evidence that the proposed boundaries of the Wahluke Slope viticultural area are as specified in the application

This section summarizes historical and current evidence that the proposed boundary line of the AVA is the correct and best boundary for the AVA and specifically how the areas *immediately* outside it are different. It includes both *geographic* (landform, climate, soils, elevation, etc.) and *cultural* (land ownership, land use history) evidence. In this section the historical and modern uses for viticulture are documented and compared to viticulture outside the proposed boundaries. In section 3 of the petition can be found the *detailed* evidence that the proposed Wahluke Slope AVA has geographical features such as climate and soils that distinguish its vitcultural features from surrounding AVAs.

A. Geographic Evidence that the Proposed Boundary is the Correct and Best Boundary

From a geographer's or geologist's perspective, the Wahluke Slope defines the mega flood bar or mega alluvial fan formed by glacial outburst floods that came down the main stem of the Columbia River through Sentinel Gap (Figure 3). The boundaries of the proposed AVA enclose the entire portion of the mega fan that is in private ownership and thus is potentially available for vineyard development, plus small amounts of Federal and State land to simplify the boundary description.

The northern boundary is set at an elevation of 1480 feet to separate the Wahluke Slope AVA from the Saddle Mountains geographically. The boundary elevation is set high enough to include existing vineyard acreage at the eastern end of the proposed AVA (Figure 2b). The eastern boundary is set as the existing, permanent administrative boundary between private agricultural land and Federally owned national wildlife refuge land of the Hanford Reach National Monument. The southern and western boundaries are set as the normal and ordinary high water mark of the Columbia River.

Lands to the north of the proposed AVA boundary consists of the bedrock slopes of the Saddle Mountains (Figure 3) that have shallow or stony, non-agricultural soils such as Schawana, Starbuck, and Bakeoven series soils (Table 3). These areas above 1480 feet elevation also are far above the Wahluke Branch Canal and so have no access to water for irrigation. The combination of non-agricultural soils and lack of water for irrigation make them inappropriate for inclusion in the AVA. In addition, this area is geographically part of the Yakima fold belt ridges and not the Wahluke Slope.

Lands to the southeast of the proposed AVA boundary (southeast of the right-of-way of highway 24) consist largely of the Burbank and Quincy soils from sand dunes that are widespread within the proposed AVA. These lands differ from those within the proposed AVA in three important ways: First, the hummock and swale topography with closed depressions and the almost zero slope of the area (see the Coyote Rapids and Vernita Bridge 7.5 minute topographic quadrangle maps included in the boundary description) create unacceptable cold air pockets and large areas of stagnant air in winter with high frost danger. Second, these lands are in the outfall of the Saddle Mountain irrigation water wasteway from the Wahluke Slope several hundred feet in elevation higher, and as a result they have a high water table (evidenced by large and small bodies of standing water), which is incompatible with wine grape production.

Lands across the Columbia River to the south encompass the Hanford Nuclear Reservation. Little is known about the climate and soils of this reservation because of the classified nature of the reservation; however, the Hanford Reservation is part of the Hanford Flats geographic province and not the Wahluke Slope. More importantly, the classified activities and history of the reservation make it unsuited to agricultural development.

Lands across the Columbia River to the west of the proposed AVA consist of steeply sloping, rugged canyons. The shallow and stony non-agricultural soils are on slopes as steep as 100 percent, making these soils unfarmable for any crop. This area also is geographically part of the Yakima fold belt ridges and not the Wahluke Slope.

The nearest area of concentrated agriculture is the Royal Slope area about 10 miles to the north of Wahluke Slope, which has a large acreage of tree fruit and a small acreage of wine grapes. The Royal Slope is a separate province geographically and its climate is cooler (Table 2a, Royal City PAWS station) and it receives 350 fewer growing degree-days per year than does the Wahluke Slope (Table 2b).

B. Cultural and Historical Evidence that the Proposed Boundary is the Correct and Best Boundary

Over the last 25 years, private landowners in the Wahluke Slope area have individually experimented with viticulture by planting wine grapes. Collectively, they have found that the gently south-sloping bench lands that lie several hundred feet above the Columbia River provide growing conditions including excellent air and water drainage, suitable soils, ample growing degree days, and inexpensive irrigation water to produce wine grapes that have gained a regional and national reputation. The aggregate of the individual successes of farmers and ranchers in the Wahluke Slope is that today the area grows almost 20 percent of the state's wine grapes, which is strong evidence in the free market of a distinct terroir.

The native rainfall in the Wahluke Slope area is about 6 inches per year (Table 2a), which is insufficient to support rainfed agriculture. Agricultural development on the Wahluke Slope thus only dates back to the mid to late 1970s because the U.S. Bureau of Reclamation's Wahluke Branch Canal, a part of the vast Columbia Basin Irrigation Project, was not completed until then. First water delivery to new irrigation blocks in the Wahluke district commenced in the mid 1970s (Jim Blanchard, U.S.B.R., personal communication, 2004). Prior to that time, a few hundred acres of agricultural land on the Wahluke Slope were irrigated from deep wells (Mike Mrachek, Lucky Bohemian Vineyards, personal communication, 2004).

The first vineyard on the Wahluke Slope consisted of 20 acres of White Riesling and 20 acres of Chenin Blanc grapes planted about 1978 by Rosebud Ranches owned by Don and Norma Toci (Table 1; Irvine and Clore, 1998). About the same time, the first plantings of Weinbau vineyard (now part of SBDW, Table 1) were made in association with the first winery on Wahluke Slope, the short-lived Langguth Winery (Irvine and Clore, 1998). Rosebud Ranches planted the first red wine grapes on the Wahluke Slope, a block of Cabernet Sauvignon, in 1981. From 1979 to 2004, the acreage has grown steadily to the current total of more than 5000 acres.

Wine grape varietals grown on the Wahluke Slope include predominantly red grapes, in keeping with the climatic characteristics described in section 3 below and in keeping with the reputation of the proposed AVA for producing full-bodied, well-structured, tannic red wines with excellent fruit flavors. Varietals grown, in approximate order of decreasing acreage are: Cabernet Sauvignon (40%), Merlot (40%), Chardonnay (10%), Syrah (2%), Cabernet Franc (2%), Lemberger (1.5%), Riesling (1.5%), Sangiovese (1%), Semillion (1%), Sauvignon Blanc (0.5%), and Viognier (0.5%) (Mike Mrachek, Lucky Bohemian Vineyards, personal communication, 2004).

For more than 20 years, as grape and wine production has increased in Washington State, wine makers have increasingly recognized the high quality and special characteristics of wine made from grapes sourced from Wahluke Slope vineyards. As growers and winemakers have gained experience in growing wine grapes in the Wahluke Slope and making wine from them, the reputation of the Wahluke Slope for viticulture has increased dramatically. High-profile articles have appeared in the U.S.'s premier wine magazines *Wine Spectator* and *Wine Enthusiast* on award-winning wines made from grapes grown on the Wahluke Slope. An article in *Vineyard Winery Management* explains the viticultural highlights of the Wahluke Slope, including its exceptional warmth. More than two-dozen winery websites refer to their use of grapes from vineyards on Wahluke Slope to make premium wines, including Ste. Michelle Wine Estates (formerly Stimson Lane Vineyards and Estates), the state's largest winery company.

Other cultural and historical factors have also created the Wahluke Slope as an isolated island of wine grape production. *No vineyards are known to be planted within 5 miles in any compass direction from the borders of the proposed AVA.* This is for geographical reasons of unsuitable climates and soils outlined in the previous section above. In addition, however, the proposed boundary is the correct and best boundary because the lands bordering the proposed AVA on three sides are restricted-use lands in Federal ownership: Hanford Reach National Monument to the East, Hanford Nuclear Reservation across the Columbia River to the South, and the U.S. Army's Yakima Training Center across the Columbia River to the West.

In summary, geographical (poor air and water drainage, shallow and stony soils outside of the AVA boundaries) and cultural (special use lands in Federal ownership outside of the AVA boundaries) information converges to support the conclusion that the proposed boundary is the correct and best boundary for the Wahluke Slope AVA.

3. Evidence that the geographical features of the area produce growing conditions that distinguish the proposed area from surrounding areas

A. Background and Geography of Eastern Washington

Most Washington vineyards are situated on the Columbia Plateau in eastern Washington, the area of relatively low relief that 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 Mountains (Figure 1). The Cascade Range runs north to south through the state and forms the boundary between western and eastern Washington. It also creates the rain shadow that limits rainfall on the Columbia Plateau.

The entire Columbia Plateau is underlain by hard black basaltic lava bedrock that was erupted mostly between 17 and 11 million years ago. The basalts, which are many thousands of feet thick, were folded about 5 to 2 million years ago by north-south compression of the earth's crust to form a series of east-west trending ridges that are separated from one another by valleys. The basic geography of the different areas of wine production in eastern Washington, its AVAs, thus is controlled by their location relative to the Cascade Range, which determines rainfall, and by their location within the east-west trending valley-and-ridge systems, which controls elevation and heat accumulation, winds, slope, aspect, and air drainage. In eastern Washington, the major ridges from south to north are Horse Heaven Hills, Rattlesnake Hills, Saddle Mountains, Frenchman Hills, and Beezley Hills (Figure 1).

Figure 3. Perspective 3-dimensional view from the south looking north of the area of the proposed AVA (outlined in red) with 50-meter topographic contours. The triangular mega-fan landform created by giant glacial outburst floods that came down the Columbia River through Sentinel Gap (upper left) is highlighted by the area of irrigation development.

The south flank of the Horse Heaven Hills, which faces Oregon across the Columbia River, contains the Alder Ridge, Canoe Ridge, and Paterson wine grape production areas that comprise the proposed Horse Heaven Hills AVA. The Yakima Valley and its AVA is nestled between the north flank of the Horse Heaven Hills and the south flank of Rattlesnake Hills. A new Rattlesnake Hills AVA has been proposed in a part of the existing Yakima Valley AVA. The Pasco Basin, which is part of the Columbia Valley AVA, and the Walla Walla Valley AVA are also bounded by the Horse Heaven Hills. The proposed Wahluke Slope AVA forms the south-facing benchlands in front of the Saddle Mountains (Figure 3). Wine grape production is in an early stage of development in the valleys north of the Saddle Mountains, where elevations are higher and growing conditions are somewhat cooler.

Ice-age events have been very important to the formation of the soils in which Washington's vineyards are planted. For reference, the geologic history of the Columbia Plateau is described in some detail in Meinert and Busacca (2000). To summarize here: A lobe of the western Canadian ice sheet blocked the Clark Fork River in northern Idaho most recently between about 18,000 and 14,000 years ago and created the huge glacial Lake Missoula in western Montana. The glacial ice dam failed repeatedly, releasing the largest floods of water ever documented on earth. These floods overwhelmed the Columbia River drainage system and flowed out across eastern Washington, eroding huge channels, locally called 'coulees', into the basalt. The floods deposited immense gravel bars in the main basins, while backflooding in local river valleys deposited relatively fine-grained sandy and silty 'slackwater' sediments.

Strong prevailing winds reworked the glacial sediments both before and after the last glacial advance to form dunes, which are dominated by sand, and loess, which is the silty sediment accumulated from the fallout of dust. Windblown dunes and loess cover the glacial sediments in most places in a mantle that ranges from a few inches to many tens of feet thick. As a result, soils in which most vineyards are planted in eastern Washington have rooting zones that consist of either 1) deep, uniform windblown sand or silt; 2) windblown sediment over glacial sediments that can be silty, sandy, or gravelly; or 3) deep glacial sediments. Basalt bedrock thus rarely occurs within the rooting zone of vineyard soils.

Soils on the Columbia Plateau are dominantly in the Soil Orders *Mollisols, Aridisols, and Entisols*. 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. Soils used for wine grapes commonly are Aridisols in which the upper horizons are loess or sheet sands and 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 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.

The climate of the Columbia Plateau is influenced to a great extent by prevailing westerly winds and by the Cascade 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 to 40 inches of mean annual precipitation). The amount of precipitation is closely correlated with elevation and thus generally increases from west to east across the plateau. The Rocky Mountains protect this section of Washington from the coldest of the arctic storms that sweep down through Canada. During the summer, high-pressure systems prevail, leading to dry, warm conditions and low relative humidity. Average afternoon temperatures in the summer range from 75 to over 100 degrees. Most of the growing season is very dry and some vineyards experience no measurable precipitation during the summer months. 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.

Most vineyards in the AVAs of eastern Washington share the following characteristics, which are responsible for the regional 'macro-terroir': 1) Low winter temperatures that allow vines to go into full and complete winter dormancy; 2) A unique growing timeline, with bud burst later than it is in California; a warm-to-hot midseason with two hours more sunlight daily; and a long, slow ripening period through September and October; 3) Dramatic differences in fall daytime and nighttime temperatures; 4) Low rainfall year round, necessitating controlled irrigation in most areas; and 5) Extremely quick drainage for any water applied, either from precipitation or irrigation. (from 'Terroir comes to Washington's Wines' by Paul Gregutt, Wine Enthusiast Magazine, May, 2003; available at: www.winemag.com/issues/May03/Terroir.htm, accessed on April 5, 2004).

B. Geography of the Proposed Wahluke Slope AVA

The proposed Wahluke Slope AVA is a unique and *geographically isolated* area. It comprises the lower part of the south-facing flank of the Saddle Mountains and the south-facing bench lands or *slope* of the name (Figures 2a, 2b, 3). The proposed AVA is bounded on the north by the bedrock slopes of the Saddle Mountains, on the west and south by the Columbia River, and on the east by federal lands of the Hanford Reach National Monument (formerly Saddle Mountain National Wildlife Refuge). Elevation of the proposed AVA ranges from a low of about 425 feet along the Columbia River to 1480 feet on the slope of the Saddle Mountains; however, the majority of present and planned vineyards are between 425 and 1000 feet.

Rainfall is very limited in the proposed AVA; all parts receive an average of less than 7 inches per year (Figure 4; Table 2a). The small amount of rain, which principally falls in winter, and generally sandy soils mean that almost all the water available for vines during the growing season must be supplied by irrigation. Irrigation is supplied principally from the U.S. Bureau of Reclamation Columbia Basin Irrigation Project's Wahluke Branch Canal, though a small percentage of the proposed AVA is irrigated from wells (Mike Mrachek, Lucky Bohemian Vineyards, personal communication, 2004).

Soils of the proposed AVA that have formed in dune sands are Entisols and those that have formed in glacial flood sediments and loess are Aridisols. Those formed in deep windblown sand, the Quincy, Burbank, and Hezel series (Figure 5; Table 3), make up the largest area.

The geographical features of the proposed Wahluke Slope AVA produce growing conditions that distinguish it from surrounding areas. The remainder of section 3 is focused on three main lines of evidence that are discussed in turn below: ***C) single landform and geographic isolation, D) unique climatic characteristics, and E) unique patterns of soils.***

C). Wahluke Slope is on a unique single landform and comprises a totally isolated geographic area

The proposed Wahluke Slope AVA comprises a single landform *that is the product of giant glacial floods and it comprises a geographically isolated area.*

1. *The entire proposed AVA is contained on a single landform*, a mega gravel bar or alluvial fan. This is unique among all existing and proposed AVAs in Washington State: no other AVA is comprised of a single landform, with the possible exception of the tiny Red Mountain AVA. This mega fan is more than 15 miles long! It was formed by cataclysmic glacial outburst floods that traveled down the main stem of the Columbia River. The floods dropped their bed load sediments when they exited through Sentinel Gap in the upper left corner of Figure 3 and spread into the Pasco Basin to the east and south. In fact, in Figure 3, the area of irrigated agriculture in green corresponds exactly to the roughly triangular, bench-like top of the mega fan, which has its head at Sentinel Gap. In contrast, for example, the Yakima Valley AVA encompasses a complex geographic area in which wine grapes are grown on areas of slackwater terraces from the floods, on flood gravels, on old volcanic sediments from the ancestral Cascades, and on bedrock slopes of the Rattlesnake Hills. Similarly, in the Walla Walla Valley AVA, wine grapes are grown on flood terraces, gravel bars, young river alluvium, and deep rolling hills of Palouse loess. From a geographic and marketing perspective alone, the proposed AVA stands alone.

2. This single landform that encompasses the proposed AVA *produces vineyard sites that are predominantly smooth and gently south facing* (Figure 3). They lack the deeply cut canyons and north aspects that are common in some other Washington AVAs, such as the proposed Rattlesnake Hills AVA. This produces uniformity in vigor and ripening within vineyards, which is a hallmark for superior wine grapes. Another benefit and unique feature of this single landform is that the mega fan is several hundred feet high and drops away to lower elevations on three sides (Figure 3). This provides good air drainage from spring and fall freezes, as cold air can move to lower elevations. In common with all of the other AVAs in eastern Washington, the Wahluke Slope can experience deep freezes in times of strong winter inversions produced by frigid Canadian air masses about every 5 to 7 years.

3. *The proposed AVA is naturally the most geographically isolated area of wine grape production in the state*. It is bounded by the bedrock ridge of the Saddle Mountains on one side, the Columbia River on two sides, and U. S. National Monument lands on the fourth side. Because of this, at present no other area of wine-grape production lies closer than about ten miles from the Wahluke Slope. This means that there never will be grapes grown in a closely adjoining area, giving the Wahluke Slope a separate identity that is more than just a line on a map.

Table 2b. Ten-Year Average Growing-Degree Days[1] (GDD) for Selected PAWS Stations[2]

Year	*Wahluke*[2]	Royal City	Brew-ster	Wenat-chee	Benton City	Pater-son	Prosser	Roza	Walla Walla
	GDD								
1994	*3293*	2912	2741	2880	-	3298	2806	2792	3095
1995	*2817*	2542	2493	2518	-	2852	2475	-	2600
1996	*2769*	2410	2408	2443	2809	2938	2368	2367	2713
1997	*2892*	2644	2606	2563	2998	3016	2568	2537	2857
1998	*3366*	3018	-	3204	3348	3399	2877	2863	3020
1999	*2717*	2374	2551	2428	2712	2809	2243	2204	2488
2000	*2866*	2481	2676	2684	2918	2983	2492	2430	2629
2001	*3073*	2646	2725	2809	3064	3119	2619	2615	2829
2002	*2963*	2632	2816	2759	3024	3052	2526	2650	2707
2003	*3372*	2928	-	3139	3414	3400	2910	2879	3125
10-yr avg	***3013***	**2659**	**2627**	**2743**	**3036**	**3087**	**2588**	**2593**	**2806**

Date 2300 GDD Reached

Year	*Wahluke*[2]	Royal City	Brew-ster	Wenat-chee	Benton City	Pater-son	Prosser	Roza	Walla Walla
1994	*15-Aug*	31-Aug	8-Sep	29-Aug	-	16-Aug	3-Sep	6-Sep	22-Aug
1995	*3-Sep*	16-Sep	13-Sep	16-Sep	-	3-Sep	19-Sep	-	15-Sep
1996	*3-Sep*	1-Oct	29-Sep	28-Sep	1-Sep	29-Aug	7-Oct	7-Oct	8-Sep
1997	*28-Aug*	10-Sep	10-Sep	11-Sep	25-Aug	28-Aug	12-Sep	18-Sep	1-Sep
1998	*14-Aug*	27-Aug	-	19-Aug	15-Aug	15-Aug	31-Aug	2-Sep	28-Aug
1999	*7-Sep*	1-Oct	14-Sep	20-Sep	6-Sep	5-Sep	never	never	20-Sep
2000	*25-Aug*	17-Sep	1-Sep	3-Sep	24-Aug	23-Aug	17-Sep	25-Sep	11-Sep
2001	*27-Aug*	13-Sep	5-Sep	1-Sep	26-Aug	25-Aug	14-Sep	15-Sep	4-Sep
2002	*27-Aug*	12-Sep	30-Aug	1-Sep	24-Aug	25-Aug	15-Sep	11-Sep	7-Sep
2003	*18-Aug*	1-Sep	-	22-Aug	17-Aug	18-Aug	3-Sep	4-Sep	27-Aug
earliest	***14-Aug***	**27-Aug**	**30-Aug**	**19-Aug**	**15-Aug**	**15-Aug**	**31-Aug**	**2-Sep**	**22-Aug**
range (d)	***25***	**22**	**31**	**41**	**23**	**22**	**>31**	**>29**	**30**

[1]GDD=[(tmax + tmin)/2 - 50]. Values of tmin < 50 set equal to 50. Summed daily from April 1 to October 31.

[2]See Table 2a for locations of weather stations

D). Wahluke Slope has a unique combination of hot, dry, and windy climate

Background: Although many attributes of climate can be measured, four of the more important for wine grape production are temperature, precipitation, wind intensity, and growing-degree days. These and others are collected systematically by a variety of meteorological services but in the state of Washington the WSU Public Agricultural Weather System (PAWS) automatically and continuously collects climatic data for more than 80 key locations: http://frost.prosser.wsu.edu/ (accessed on April 5, 2004). Below is a discussion of these main four climatic attributes and others, with comparison of the proposed AVA with other significant grape growing and horticultural areas of eastern Washington. In all cases, the data in Tables 2a, 2b, and 2c have been compiled from the PAWS database. Whenever possible, ten years of climate data (1994-2003) was used. Eight stations were selected to compare and contrast to the PAWS weather station in the heart of the proposed AVA (Figure 4): Royal City is an area of tree fruit production about 15 miles north in the valley between the Saddle Mountains and Frenchman Hills; Wenatchee and Brewster are two fruit-growing areas to the north on the Columbia River where new plantings of wine grapes are being made; Benton City and Paterson represent the Red Mountain and proposed Horse Heaven Hills AVAs, respectively; Prosser and Roza are in the heart of wine grape production in the Yakima Valley AVA, and Walla Walla represents the Walla Walla Valley AVA (albeit the higher rainfall end of the valley).

Table 2c. Ten-Year (1994-2003) Average Chance of Precipitation During Harvest for Selected PAWS Stations[2]

	Wahluke				Benton City				Walla Walla				Prosser			
year	*days rain [1]*			*precip*	days rain[1]			precip	days rain[1]			precip	days rain[1]			precip
	>0.1	*>0.2*	*>0.5*		>0.1	>0.2	>0.5		>0.1	>0.2	>0.5		>0.1	>0.2	>0.5	
1994	*5*	*3*	*0*	*0.98*	ND	ND	ND	ND	7	4	2	4.04	6	4	2	1.6
1995	*5*	*1*	*1*	*1.39*	3	2	1	1.06	11	9	2	3.73	6	6	0	1.78
1996	*3*	*3*	*0*	*1.05*	4	3	0	1.43	4	3	0	1.54	5	3	0	1.5
1997	*3*	*3*	*0*	*1.22*	4	4	1	1.67	14	8	0	4.23	7	4	0	2.2
1998	*0*	*0*	*0*	*0.2*	1	1	0	0.33	13	4	0	5.31	2	1	0	0.51
1999	*1*	*1*	*0*	*0.37*	1	1	0	0.35	19	4	0	4.99	2	2	0	0.6
2000	*3*	*0*	*0*	*0.57*	5	5	0	1.64	7	3	1	3.27	5	4	0	1.22
2001	*1*	*1*	*0*	*0.47*	1	1	0	0.44	8	6	1	3.21	2	1	0	0.58
2002	*0*	*0*	*0*	*0.11*	0	0	0	0.11	4	1	0	2.31	0	0	0	0.05
2003	*1*	*0*	*0*	*0.2*	1	1	0	0.37	10	8	4	6.16	0	0	0	0.3
avg	***2.2***	***1.2***	***0.1***	***0.66***	**2.2**	**2.0**	**0.2**	**0.82**	**9.7**	**5.0**	**1.0**	**3.88**	**3.5**	**2.5**	**0.2**	**1.03**

[1] number of days with >0.1, >0.2, or >0.5 inches of precipitation from 9-1 through 10-31

[2]See Table 2a for locations of weather stations

Growing degree days for wine grapes is a measure of the amount of the growing season that the air temperature is above 50 degrees F, the minimum temperature for shoot elongation and fruit development. GDD is defined in the footnote to Table 2b. Higher values of GDD are associated with greater potential to ripen wine grapes to full maturity and flavor development. In particular, the higher range of GDD is associated with the ability to fully ripen several varieties of red wine grapes, whereas in general white wine grapes require fewer GDD for full ripeness.

The following climatic characteristics, taken individually or more distinctively, as a group, identify the Wahluke Slope as a unique area for wine grape production.

1. Mean annual precipitation in the proposed AVA is just 5.9 inches, making it the *driest site of the 9 included for comparison in Table 2a*, and indeed, perhaps *the driest site in Washington State*. The climatic attributes that produce growing conditions that distinguish the proposed Wahluke Slope AVA from surrounding areas can be seen in Tables 2a, 2b, and 2c. Stations such as Brewster, Wenatchee, Roza, and Walla Walla have 1.5 to almost 4 times as much rainfall as the Wahluke Slope. Very low rainfall favors the Wahluke Slope because it gives the vineyard manager complete control of deficit irrigation to induce controlled water stress during the growing season to improve grape quality (Russell Smithyman, Ste. Michelle Vineyards and Estates, personal communication, 2003). Very low rainfall also minimizes the chance of rainfall at harvest, discussed below, which can complicate harvest schedules and in extreme cases reduce grape quality.

2. The proposed Wahluke Slope AVA ranks *first in pan evapotranspiration (ETp)* of the nine stations selected (Table 2a). This means that transpiration and photosynthesis of wine grape plants, key to canopy and fruit production, are potentially higher here than at any other site in the state.

3. The ten-year average Growing Degree Days (GDD) on Wahluke Slope is 3013, third highest of all stations in the state. This value is just 2.5% and 1% less than the highly acclaimed Paterson (Horse Heaven Hills) and Benton City (Red Mountain) growing areas. GDD, also known as heat units, is a vital measure of the suitability of an area to produce high quality wine grapes. The high GGD of Wahluke Slope confirms why it excels at growing red wine grapes to full ripeness.

The Royal Slope, just a few miles away from Wahluke Slope and an area that many people might think is almost the same as Wahluke, receives less than 2700 GDD. In fact, Wahluke Slope, Paterson, and Benton City are the only sites in this analysis with more than 3000 GDD. In strong contrast, cooler sites like Brewster, Prosser, and Roza have less than 2600 GDD, a drop off of about 15% from the warmest sites. Grower experience on the Wahluke Slope confirms the long growing season and tremendous warmth here: more than 75% of the grape acreage is planted to coveted red grape varieties that generally bring a price premium over whites.

4. The proposed AVA ranks third highest in mean maximum temperature, mean annual temperature, and in solar radiation (Table 2a). It should be noted that the two sites that are warmer than Wahluke Slope represent the justly famed Red Mountain and proposed Horse Heaven Hills (which includes Canoe Ridge, etc.) AVAs. Taken together, these long-term measurements confirm the Wahluke Slope's reputation as one of the *very hot sites* in the state for wine grapes. That the Wahluke Slope ranks third in solar radiation (Table 2a) is a product of the nearly cloud-free growing season experienced by the Wahluke Slope. The proposed AVA lags the top sites only by very small amounts in these categories that denote high temperatures, for example less than 2% for solar radiation (Table 2a). In contrast, Brewster, with the lowest solar radiation of the comparison group, lags the top site by almost 20%.

5. Wahluke Slope is the *third windiest* site of the nine production areas used in this comparison (Table 2a). Wind stress can be similar to water deficit stress in that it is widely acknowledged as a fruit quality factor that can result in reduced shoot length and leaf size and can induce smaller and fewer clusters per vine. The Paterson area and Canoe Ridge, parts of the proposed Horse Heaven Hills AVA, have the second highest windiness index (the 'wind run', in miles) of the 9 stations (Table 2a) because they are downwind of the extremely windy Columbia Gorge along the river, but Wahluke Slope is recorded as the third windiest site even though this is not widely known.

6. Vineyards on Wahluke Slope *lie at lower elevation* than most nearby sites. For example, Royal Slope, known for tree fruit production, lies at higher elevation than the Wahluke Slope: irrigated crops on Royal Slope are planted there from about 1150 feet to almost 1500 feet, whereas the majority of irrigated cropland on the proposed AVA ranges from 425 to 1000 feet in elevation. This elevation difference shows in cooler temperatures, lower ETp, and lower solar radiation, and in slightly higher rainfall (Table 2a). The example of Royal Slope shows that sites even a few miles away from the proposed AVA are quite different.

7. Wahluke Slope *reached the critical minimum 2300 GDD,* key to successful harvests of fully ripened grapes, *every year from 1994-2003* (Table 2b). Wahluke Slope reached this critical minimum ripening parameter earlier than any other site about a third of the time. The calendar date at which 2300 GDD is typically reached in the fall is critical to successful harvests of fully ripened grapes, for the later full ripeness is reached, the greater the chance that grapes will still be on the vine when frosts or Fall rains arrive. In three of the ten years, it reached this benchmark *first* of the nine sites evaluated, and in 6 of the 7 remaining years, it reached 2300 GDD within 3 days of the Paterson and Benton City sites. Although cooler sites with between 2500 and 3000 GDD can still grow *vinifera*, 2300 GDD is the desired minimum number of GDD that must be reached in most years by mid September for successful harvests before the threat of significant frost. Cooler sites typically reached this threshold one to more than two weeks later and in 1999, the Prosser and Roza areas *never* reached 2300 GDD (Table 2b). Wahluke Slope is arguably the equal of the well-regarded Red Mountain and Paterson areas for consistent, early ripening high-quality fruit.

8. During the critical harvest window from September 1 to October 31, *the Wahluke Slope has the lowest 10-year average rainfall, 0.66 inches, of the 4 stations compared* (Table 2c). Rain during this critical time window can affect harvest operations when daily totals are 0.5 inch or more. Even smaller amounts of rain can cause some berries to swell and split and can lead to mildew and rot, reducing fruit quality. Walla Walla experienced one or more days with rainfall totals of >0.5 inch in *five of ten* years surveyed, whereas Wahluke Slope had rain in *only one of ten years*. Even for comparisons of numbers of days during harvest with >0.2 inches of rain, the Wahluke Slope has the fewest days. Compared to famous appellations in France such as Bordeaux and Burgundy, and even compared to the Napa Valley, the proposed Wahluke Slope AVA has an extremely low incidence of rainfall at harvest and this contributes to an almost unprecedented consistent quality of fruit *year to year*.

E) The soils of the proposed Wahluke Slope AVA stand apart from those of other AVAs based on the unique mega-fan landform on which they occur

Background: The soils of the proposed Wahluke Slope AVA have formed dominantly from deep (>60") wind blown sand. Alternatively, some of the soils have formed from wind blown sand or silty loess mantling sediments from giant glacial floods. The flood sediments in different parts of the proposed AVA have textures that range from gravel to stratified sand to silt. In regard to origin of the soils, the Wahluke Slope shares soil parent materials and some soil series with a number of other AVAs in Washington State. This is because there is almost an 80% correspondence between the areal extent of the giant glacial outburst floods and the outline of the Columbia Valley AVA (Figure 1) and all of the AVAs in eastern Washington, including the proposed Wahluke Slope, nest within the CV AVA. The Wahluke Slope also shares the ubiquitous cover of eolian materials that mantle the entire region.

Soils of the proposed AVA can be organized into several general soil map units based on the detailed soil survey of Grant County (Figure 5; Gentry, 1984). From most extensive to least extensive, the map units that support more than 95% of the wine grapes on the Wahluke Slope are: 1) Quincy-Burbank-Hezel, 2) Sagemoor-Kennewick-Warden, 3) Taunton-Timmerman-Quincy, and 4) Scoon-Taunton-Finley (Table 3). The remaining soil map units are in the northern part of the proposed AVA, (Figure 5) are generally shallow to hardpan or bedrock, are more stony because of steep bedrock-controlled slopes, and have relatively few wine grapes planted at present. These minor map units constitute less than 8% of the proposed AVA (Table 3).

Current plantings of producing wine grapes are concentrated in 4 zones (Figure 5), with approximately 2000 acres in zones 1 and 2, 2000 acres in zone 3, and 1200 acres in zone 4. Vineyards of zones 1 and 2 fall entirely in the Quincy-Burbank-Hezel map unit. Vineyards of zone 4 fall virtually entirely in the Sagemoor-Warden-Kennewick map unit, and vineyards of zone 3 include three of the soil map units (Figure 5).

Wahluke Slope soils stand apart from those of other AVAs based on the unique mega-fan landform on which they occur.

1. Soils of Wahluke Slope are characterized by their *uniformity* over large areas. This is especially true of the largest of the general soil map units, the Quincy-Burbank-Hezel soils (Figure 5), where, for example, contiguous areas as large as several square miles are mapped as Quincy soils series deep sands and other areas of similar size are mapped as Burbank series soils (e.g. map sheets 163, 164, and 169 *in* Soil Survey of Grant County, Washington, Gentry, 1984). This is in striking contrast to the much higher degree of soil variability found in parts of other AVAs, such as the Red Mountain AVA (Meinert and Busacca, 2002) or the Canoe Ridge area of the proposed Horse Heaven Hills AVA, where soil depth to bedrock can range from >100" to less than 10" within a vineyard block (Busacca and Meinert, unpublished data, 2003).

2. Soils of Wahluke Slope are unique in that they have a smooth landform shape, shallow slope angle (<8%), and nearly constant south-facing aspect over much of the AVA. This is because most of the AVA occupies the top of the mega fan. Climate variables important for wine grapes such as rainfall and GDD are almost constant across the proposed AVA because of the relatively small altitude range (functionally only about 600 feet for planted areas) and smooth landform. Some AVAs such as the proposed Rattlesnake Hills AVA are characterized by very large range in slope steepness, soil parent materials, and rainfall because of the complex meso-scale topography of the area. Other AVAs have as large as a 3-fold increase in rainfall *within* the AVA, such as the Walla Walla Valley's 9 to 25 inch rainfall range from west to east due to orographic effects of the Blue Mountains (Meinert and Busacca, 2000).

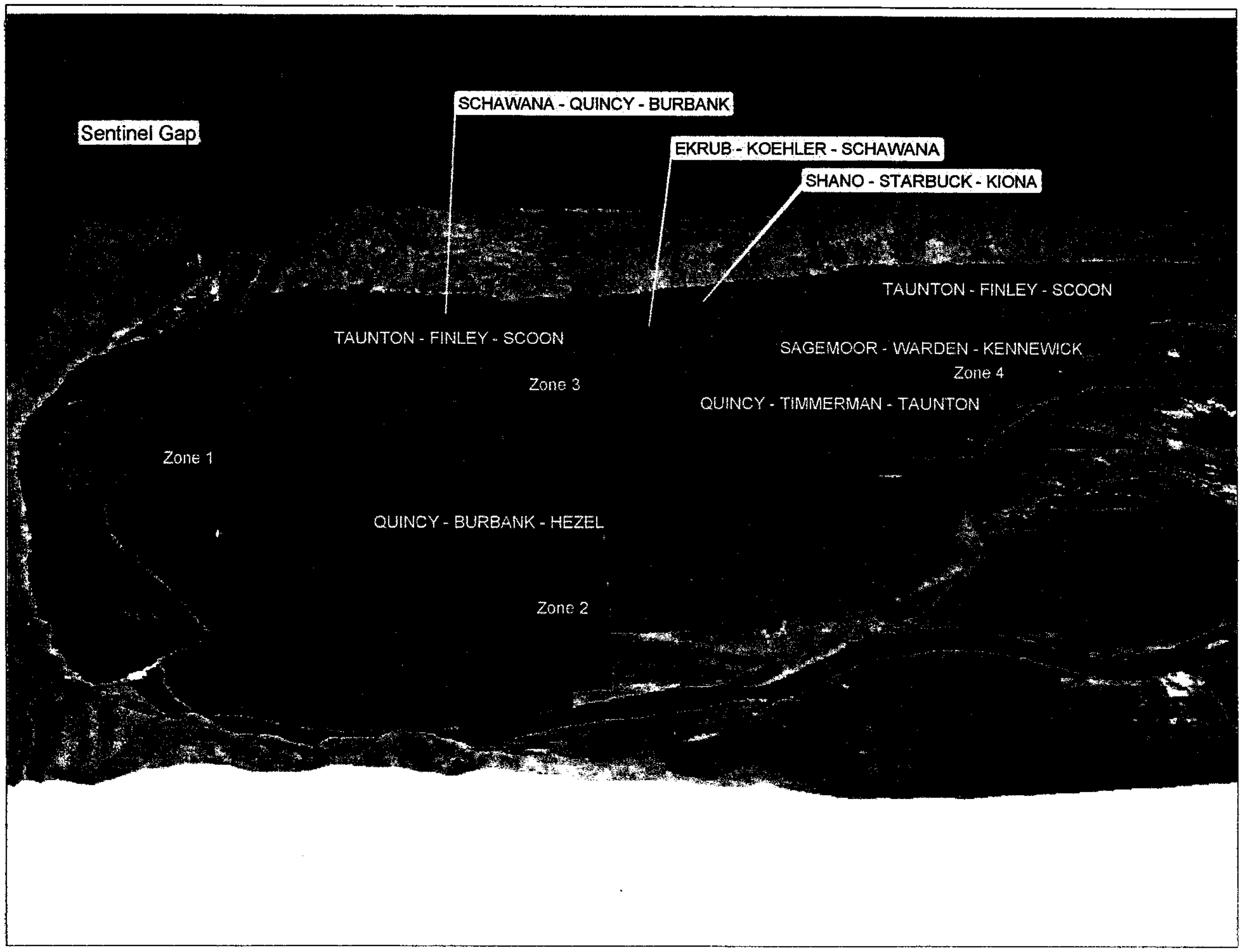

Figure 5. Perspective 3-dimensional view from the south looking north of the area of the proposed AVA with map units of the general soils map of Grant County (Gentry, 1984) draped over the topography and showing the 4 informally designated zones where wine grape production is concentrated.

3. The potential exists for subterroirs to eventually become recognized based on soils alone: Climate, landform, and aspect are very uniform across Wahluke Slope, so it can be argued that an AVA-wide terroir may in time become recognized in the wines made from its grapes. Over time as growers and winemakers gain more experience here, sub-terroirs then may come to be recognized from zones 1 to 4 based on differences in *soils* that are discussed below. No other AVA in the state has such low variation in climate and landform factors, except perhaps Red Mountain, which is 1/30th the size of Wahluke Slope, as to allow the isolation of wine grape flavor characteristics due to soil differences alone.

The following is a more detailed analysis of the characteristics of the soils of the proposed AVA, with a focus on properties such as rooting depth and texture that affect vine vigor and grape quality.

The soils of Wahluke Slope were formed on three geomorphic parts of the flood mega fan with different amounts and types of wind blown sediment cover on the three areas. The first geomorphic part of the mega-fan is the large area of Quincy-Burbank-Hezel soils (Figure 5). This represents the high-energy part of the mega-fan deposit where waters from cataclysmic floods were flowing very deep and very fast and the core of this part of the fan diminishes in size in downstream progression from Sentinel Gap from boulders, to melon-sized cobbles, to gravel, to coarse sand. A veneer of windblown sand from a few inches to tens of feet thick covers this part of the fan. The third geomorphic part of the mega-fan consists of the Taunton-Timmerman-Quincy soils, which is an erosional flat cut into the downstream part of the fan at a late stage of flood flows. This area forms a drainageway that slopes gently to the southeast. A variably thick veneer of wind blown sand covers the flood sediments to form the parent materials of these soils.

A. __Quincy-Burbank-Hezel__

The Quincy-Burbank-Hezel general soil map unit represents more than half of the potential available acreage in the proposed AVA (Table 3) and about 40 percent of the wine grapes are planted in soils of this map unit (zones 1 and 2; Table 1). It contains soils that are very deep, somewhat excessively drained and nearly level to steep. The soils are largely contained on the top of the terrace, which is mantled by sand dunes that were both stabilized and active before irrigation development. The native vegetation was mainly desert grasses and shrubs; however, some areas of Quincy and Hezel soils were active dunes that were nearly barren of vegetation in their native state. About 50 percent of this map unit is Quincy soils, about 30 percent is Burbank soils, and about 10 percent is Hezel soils, all of which have a rooting depth of 60 inches or more (Table 3). The remainder is soils of minor extent. None of these soils has measurable salinity (Table 3).

Quincy soils formed in deep sands of active and stabilized dunes that overlie the mega-flood terrace. These soils are very deep and somewhat excessively drained. The sand is from mixed mineral sources. Quincy soils have a very low available water holding capacity (ability to store water in the root zone during drainage after wetting) of about 0.1 inches of water per inch of profile depth (Table 3) and are somewhat excessively drained, having a permeability (rate of water intake when saturated) of up to 20 inches per hour (Table 3).

Table 3. Acreages and Selected Properties of Soils in the General Soil Map Units of the Wahluke Slope

Soil Series	Percent of Map Unit	Acres	MUID	Soil Depth (in)	Soil Texture surface	Soil Texture subsurface	Soil pH surface	AWHC (in/in) surface	AWHC (in/in) subsurface	Permeability (in/hr) surface	Permeability (in/hr) subsurface	Salinity (Mmhos/cm)
QUINCY	50	21331	WA018	60	FS, S	FS, S	6.1-8.4	0.08-0.12	0.06-0.09	6.0-20.0	6.0-20.0	<2
BURBANK	30	12798	WA018	60	LFS	CBV-COS	7.4-8.4	0.04-0.11	0.01-0.03	6.0-20.0	>20.0	<2
HEZEL	10	4266	WA018	60	LFS	SL & LFS	6.6-8.4	0.09-0.13	0.18-0.21	6.0-20.0	0.2-0.6	<2
Other Soils	10	4266										
SAGEMOOR	33	3147	WA082	60	SIL	SIL & VFSL	6.6-7.8	0.16-0.20	0.18-0.21	0.6-2.0	0.2-0.6	<2
KENNEWICK	29	2765	WA082	60	FSL, SIL	SIL & VFSL	7.4-8.4	0.11-0.21	0.18-0.21	0.6-2.0	0.2-0.6	<2
WARDEN	29	2765	WA082	60	SIL	SIL & VFSL	6.6-7.8	0.19-0.21	0.19-0.21	0.6-2.0	0.6-2.0	<2
Other Soils	9	858										
QUINCY	46	4600	WA083	60	FS	FS, S	6.1-8.4	0.08-0.11	0.06-0.09	6.0-20.0	>20.0	<2
TIMMERMAN	42	4200	WA083	60	COSL	COS, LCOS	6.6-7.8	0.10-0.13	0.03-0.06	2.0-6.0	>20.0	<2
TAUNTON	10	1000	WA083	20 to 40	FSL	GR-FSL	7.4-8.4	0.9-0.21	0.10-0.14	2.0-6.0	0.6-2.0	<2
Other Soils	2	200										
TAUNTON	50	6144	WA087	20 to 40	SIL, ST-SIL	GR-SIL	7.4-8.4	0.16-0.21	0.10-0/14	0.6-2.0	0.6-2.0	<2
FINLEY	48	5898	WA087	60	CB-VFSL	CBV-LS	7.4-8.4	0.10-0.14	0.03-0.05	2.0-6.0	>20.0	<2
SCOON	2	246	WA087	14 to 20	SIL, ST-SIL	GR-SIL	6.6-8.4	0.15-0.18	0.11-0.17	0.6-2.0	0.6-2.0	<2
EKRUB	66	836	WA088	10 to 20	FS	GRV-FS	7.9-8.4	0.09-013	0.03-0.05	6.0-20.0	6.0-20.0	<2
KOEHLER	20	253	WA088	20 to 40	LFS	GRV-FS	7.4-8.4	0.09-011	0.02-0.06	6.0-20.0	6.0-20.0	<2
SCHAWANA	7	89	WA088	8 to 20	CB-LFS, LFS	GRV-FS	7.4-7.8	0.05-0.11	0.09-0.13	6.0-20.0	2.0-6.0	<2
Other Soils	7	89										
SCHAWANA	65	2302	WA092	8 to 20	CB-LFS, LFS	GRV-FS	7.4-7.8	0.05-0.11	0.09-0.13	6.0-20.0	2.0-6.0	<2
QUINCY	11	390	WA092	60	FS	FS, S	6.1-8.4	0.08-0.11	0.06-0.09	6.0-20.0	>20.0	<2
BAKEOVEN	4	142	WA092	4 to 12	CBV-L	CBV-L	6.1-7.8	0.06-0.09	0.07-0.11	0.2-0.6	0.2-0.6	<2
BURBANK	4	142	WA092	60	ST-LS	CBV-COS	7.4-7.8	0.06-0.09	0.01-0.03	6.0-20.0	>20.0	<2
Other Soils	16	568										
SHANO	50	688	WA096	60	SIL	SIL	6.6-8.4	0.18-0.20	0.18-0.20	0.6-2.0	0.6-2.0	<2
STARBUCK	19	261	WA096	12 to 20	ST-SIL	GR-FSL	6.6-7.8	0.11-0.15	0.11-0.15	0.6-2.0	0.6-2.0	<2
KIONA	15	206	WA096	60	CB-VFSL	CBV-L	7.4-7.8	0.14-0.17	0.17	0.6-2.0	2.0	<2
Other Soils	16	222										
TOTAL ACRES		**80671**										

Notes: The data in this table is summarized from Gentry (1984) by soil series within a map unit. Soil depth is depth to rock or to cemented pan, whichever is shallower. AWHC is 'available water holding capacity'. Soil pH and salinity values are for the surface layer. Texture codes: SIL - silt loam; L - loam; LFS - loamy fine sand; FSL - fine sandy loam; VFSL - very fine sandy loam; FS - fine sand; S - sand; COS - coarse sand; COSL - coarse sandy loam; LS - loamy sand; LCOS - loamy coarse sand; UWB - unweathered bedrock; Modifiers for coarse fragments (> 2"): ST - stony; GR - gravelly; GRV - very gravelly; CB - cobbly; CBV - very cobbly; ST - stoney

Burbank soils are formed in gravel from the mega floods that have covering of wind blown sand about 20 inches thick. These soils are also on the top of the mega-flood terrace. Burbank soils are very deep (>60 in) and excessively drained because the surface layer is loamy fine sand and the subsurface layer is cobbly coarse sand. They similarly have a very low water holding capacity and very high permeability (Table 3) because of the sandy to cobbly textures. Hezel soils are formed in layered sandy to silty sediment from lower energy flows of floodwaters. The sandy to silty layers are covered with wind blown sands about 30 inches thick. Although the sandy upper layer of Burbank soils has similar water holding and permeability to the Quincy and Hezel soils, the subsurface layer has more water holding capacity and only about one tenth the permeability of the subsurface layers of the other soils (Table 3).

To reiterate, the Quincy, Burbank, and Hezel series soils in this map unit support about 40 percent of the wine grapes currently growing in the proposed AVA, or about 2000 acres of grapes. Since this map unit is about 42,500 acres in size, the potential for additional plantings of wine grapes is vast. These soils promote very deep rooting of vines in very droughty sandy and gravelly materials, which can be optimal for controlled water stress management of vines to promote high quality, and the soils are uniform over large acreages, promoting uniform ripening and quality within vineyard blocks.

B. Sagemoor-Kennewick-Warden

The Sagemoor-Kennewick-Warden general soil map unit represents about 12 percent of the 80,671 potential available acres in the proposed AVA (Table 3) and about 30 percent of the wine grapes are planted in soils of this map unit (zone 4 and part of zone 3, Figure 6; Table 1). The soils of this map are very deep, well drained, and nearly level to moderately steep, and also are on the top of the gently south-sloping terrace. The native vegetation was mainly desert grasses and shrubs. It is about 33 percent Sagemoor soils, 29 percent Kennewick soils, 29 percent Warden soils and about 9 percent of other soils. All three of these major soils have a rooting depth of greater than 60 inches and none has measurable salinity (Table 3).

The soils in this map unit are quite different from those in the Quincy-Burbank-Hezel unit, in that they formed mainly from silty loess in the upper part of the rooting zone and from silty and sandy, layered slackwater sediments in the lower part. This unit is located up against the flank of the Saddle Mountains and distant from Sentinel Gap (Figure 5) where water actually ponded to form a temporary lake during the mega floods, so the flood sediments are fine. Also, because it is located away from the main path of sand-transporting winds, the post-floods wind blown materials are mainly the finer silts from dust fall. The unit is similar to the Quincy-Burbank-Hezel unit in that the overall landscape position is still on top of the mega terrace and the landform is mostly smooth and gently south facing.

Sagemoor soils are very deep and well drained. The surface layer and subsoil are wind blown silt loam. The subsurface layer to a depth of 60 inches or more is silt loam and very fine sandy loam. Because the parent materials of the Sagemoor soils are silty, they have almost two times the water-holding capacity (about 0.18 inches of water per inch of soil depth) and about one tenth the saturated permeability of the sandy Quincy soils (Table 3).

Warden soils also are very deep and well drained and like the Sagemoor soils they formed in slackwater flood deposits that have a covering of silty loess. The surface layer is silt loam. The subsurface layer to a depth of 60 inches or more is silt loam and very fine sandy loam. Warden soils have similar water-holding capacity to the Sagemoor soils; they differ mainly in that the subsurface of the Warden soils is more highly layered with thin bands of sand and silt, which makes the subsurface more slowly permeable than the Sagemoor (Table 3).

The Kennewick series soils are very deep and well drained. The formed in slackwater flood deposits that do not have a loess cover. The soils are silt loam throughout. Their properties are similar to those of the Sagemoor soils and they perform similarly in wine grape production.

In summary, Sagemoor, Warden, and Kennewick soils in this map unit presently support about 1500 acres of wine grapes, or about 30 percent of the total in the proposed AVA. The map unit is 9535 acres in size, so a substantial net acreage of 8000 acres remains in other crops that could in part or entirely be converted to grapes. These soils promote good rooting of wine grapes, though with a shallower root pattern than soils of the Quincy-Burbank-Hezel unit because of the thinly layered sediments in the subsoil that impede roots moderately They hold more water in the root zone for vine growth because of finer textures. Grower and winemaker experience with wines made from grapes grown on Warden and similar soils suggests that Cabernet Sauvignon performs exceptionally well (Kevin Corliss, Stimson Lane, personal communication, 2002).

C. __Quincy-Timmerman-Taunton__

The Quincy-Timmerman-Taunton general soil map unit is about 10,000 acres or about 12 percent of the proposed AVA. It is more difficult to estimate the acreage of wine grapes currently being grown on these soils because grape-growing zone 3 (Fig. 6) covers 4 soil map units, but perhaps as many as 800 acres are included. About 46 percent of the map unit consists of Quincy soils, 42 percent Timmerman soils, and 10 percent Taunton soils (Table 3). The soils are moderately deep (20-40 inches) to a cemented pan in the Taunton soils and very deep (>60 inches) in the Timmerman and Quincy soils. The soils are well to somewhat excessively drained depending on the texture of the surface layer and they are nearly level. None of the soils has measurable salinity. These soils have formed on an erosional area on the downstream part of the fan that was cut by late stage flood flows. This area forms a drainageway that slopes gently to the southeast. The parent materials are generally medium to coarse flood sands with a thin to thick veneer of wind blown sand covers the flood sediments to complete the parent materials of these soils.

Quincy series soils have been described above. They are formed in windblown sands and thus offer unlimited rooting to grape vines, with low water holding capacity and high permeability. Soils of the Timmerman series have formed in generally coarse sands from the giant floods. They have a thin or nonexistent cover of wind blown sand and they become coarser with depth. As a result they are somewhat excessively well drained and have a very low water holding capacity and a very high permeability (Table 3). Taunton series soils are formed in a thin cover of loess in about the upper 25 inches that overlies a cemented pan in gravel at that depth. As a result, they have slightly higher water holding and lower permeability in the upper part than sandier soils (Table 3), and they restrict rooting depth.

To summarize, soils in the Quincy-Timmerman-Taunton general soil map unit perform similarly to those in the Quincy-Burbank-Hezel unit, allowing deep rooting at most sites and affording full utilization of controlled water deficit stress of the vines to optimize grape quality. The presence of the shallower Tauton soils in some areas introduces some variability. The soils of this map unit support perhaps about 15 percent of the grape acreage and cover about 12 percent of the area of the proposed AVA.

D. <u>Taunton-Finley-Scoon</u>

The Taunton-Finley-Scoon general soil map unit covers about 18 percent of the proposed AVA and supports perhaps 10 percent or about 500 acres of the grape acreage currently planted on the Wahluke Slope. The soils are very shallow (<10-20 in for Scoon) to very deep (>60 in for Finley), are well drained, and are gravelly to very cobbly. The soils in this map unit formed on the gentle to steep south-facing slope of the alluvial apron of the Saddle Mountains that merges into the mega fan to the south (Fig.3). Because of the influence of the Saddle Mountains on the pattern of development of topography, this area has a distinctive and more complex pattern of soils in N-S trending stringers of different soils (e.g. map sheets 160, 161, Gentry, 1984). The soils formed variably from flood gravels and slope alluvial gravels with a very thin cover of loess. The native vegetation was desert grasses and shrubs. About 50 percent of the area is Taunton soils, about 48 percent Finley soils, and about 2 percent Scoon soils.

Taunton soils have been described above. Finley soils are very deep and formed from gravelly to cobbly alluvium with low water holding capacity and high permeability (Table 3). Soils of the Scoon series are of minor extent in this map unit and are very shallow and shallow to a cemented hardpan in gravel. The hardpan is overlain by loess and gravelly loess that is from less than 10 inches to more than 20 inches deep. Although the soils have moderate water holding capacity, they restrict the rooting of grape vines, which can be another way to induce vine stress to favor concentrated fruit flavors and high fruit quality.

4. Description of the boundaries of the proposed Wahluke Slope AVA based on features that can be found on United States Geological Survey (U.S.G.S.) maps of the largest applicable scale

The proposed Wahluke Slope AVA is located in the State of Washington, entirely within the existing Columbia Valley AVA. The boundary of the proposed Wahluke Slope AVA is described in this section using landmarks and points of reference found on the U.S.G.S. 1:24,000-scale topographic maps of Beverly, WA (1965), Beverly SE, WA (1965), Smyrna, WA, (1986), Wahatis Peak, WA (1986), Coyote Rapids, WA (1986), Vernita Bridge, WA (1986), Priest Rapids NE, WA (1986), and Priest Rapids, WA (1978) (listed in order of progression along the boundary of the proposed AVA beginning in the NW corner and proceeding in a clockwise direction). Copies of these maps marked with the proposed boundary in pink highlighter are included in this petition as Appendix II.

1. **Map 1. Beverly Quadrangle**: All legal descriptions of township and range that follow are relative to the Willamette Base and Meridian (WBM). ***Point 1:*** Begin in the northwest corner of the proposed AVA at a point where the normal and ordinary high water mark of the Columbia River intersects the north boundary line of section 22, T.15N. R.23E. (WBM). Proceed eastward along the northern boundary of sections 22 and 23 to the point where this boundary line intersects the 1480 feet elevation contour in the NE 1/4 of section 23, T.15N. R.23E. This intersection is marked as ***Point 2*** on the topographic map. Approximately one-half mile east of ***Point 1***, the proposed AVA boundary crossed State Route 243. From ***Point 2***, the northern boundary of the proposed AVA then follows the 1480-foot contour line eastward along the Saddle Mountains, passing in turn through sections 23, 14, 13, 24, and then 13 again. The boundary on the 1480-foot contour line intersects the eastern edge of the Beverly Quadrangle in the SE 1/4 of section 13., T.15N. R.23E. This point is marked as ***Point 3*** on the Beverly Quadrangle, and this point is also marked as ***Point 3*** on the matchline of the adjoining Beverly SE Quadrangle.

2. **Map 2. Beverly SE Quadrangle: *Point 3*** is marked where the 1480 foot contour line intersects the western edge of the Beverly SE Quadrangle. From this point, the boundary line continues on the 1480-foot contour line eastward through sections 18, 19, 20, 21, 22, 23, and 24, T.15N. R.24E. along the Saddle Mountains to the eastern edge of the Beverly SE Quadrangle in the NE 1/4 of section 24. This point is marked as ***Point 4*** on the Beverly SE Quadrangle, and is also marked as ***Point 4*** on the matchline of the adjoining Smyrna Quadrangle.

3. **Map 3. Smyrna Quadrangle: *Point 4*** is marked where the 1480-foot contour line intersects the western edge of the Smyrna Quadrangle. From this point, the boundary line continues on the 1480-foot contour line eastward through sections 24 and 13, T15N R24E, and sections 18, 17, 16, 15, 14, and 13, T15N, R25E to the eastern edge of the Smyrna Quadrangle in the NE 1/4 of section 13, T15N, R25E. This point is marked as ***Point 5*** on the Smyrna Quadrangle, and is also marked as ***Point 5*** on the matchline of the adjoining Wahatis Peak Quadrangle.

4. **Map 4. Wahatis Peak Quadrangle: *Point 5*** is marked where the 1480-foot contour line intersects the western edge of the Wahatis Peak Quadrangle. From this point, the northern boundary line continues on the 1480-foot contour line eastward through section 13, T15N R25E and sections 18, 17, 16, and 15 T15N R26E until the 1480-foot contour reaches the eastern edge of section 15 in the NE 1/4 of section 15. This point is marked as ***Point 6*** on the Wahatis Peak Quadrangle. ***Point 6*** is where the 1480-foot contour meets the boundary of Federal lands of the Hanford Reach National Monument. At ***Point 6***, the boundary of the proposed AVA turns alternately south and west in one-half mile to one-mile increments to track the boundary between private lands to the west of the boundary that will be part of the proposed AVA from Federal wildlife refuge lands to the east of the

boundary. The private land-Federal land boundary is prominently printed on the U.S.G.S. topographic quadrangle maps used in this petition. Approximately 3.5 miles (actual border distance) southwest of ***Point 6***, the boundary of the proposed AVA crosses the Wahluke branch irrigation canal, that is, approximately 100 feet north of the SE corner of section 20, T15N R26E. The boundary of the proposed AVA continues from the canal crossing alternately west and south in one-half to one-mile increments for approximately 3.25 miles (actual border distance) to ***Point 7***. ***Point 7*** is where the boundary of the proposed AVA (still coincident with the private-land-Federal land boundary) reaches the southern edge of the Wahatis Peak Quadrangle in the NE 1/4 of section 36, T15N R25E. ***Point 7*** is also marked on the matchline of the adjoining Coyote Rapids Quadrangle .

5. **Map 5: Coyote Rapids Quadrangle.** ***Point 7***is marked on the Coyote Rapids Quadrangle where the proposed AVA and coincident private-Federal boundary intersects the northern edge of the Quadrangle. From ***Point 7*** the boundary continues south along the eastern boundary of section 36, T15N R25E to the eastern 1/4 corner of section 36, then the proposed AVA boundary turns west along the center line of section 36 to ***Point 8*** where the boundary reaches the western edge of the Coyote Rapids Quadrangle. ***Point 8*** is in the eastern 1/2 of section 36, T15N R25E and is also marked on the matchline of the adjoining Vernita Bridge Quadrangle.

6. **Map 6: Vernita Bridge Quadrangle.** ***Point 8*** is marked on the Vernita Bridge Quadrangle where the proposed AVA and coincident private-Federal boundary intersects the eastern edge of the Quadrangle. From ***Point 8*** the boundary continues alternately west and south in one-half to one-mile increments for approximately 10.75 miles (actual border distance) to ***Point 9***, which is where the proposed AVA boundary intersects the western edge of the quadrangle map in the eastern 1/2 of section 25, T14N R24E. The entire path of the proposed AVA boundary across the Vernita Bridge Quadrangle is coincident with the private-land-Federal land boundary. The proposed boundary touches the right of way of State Route 24 at four points: at the eastern and southern 1/4 corners of each of sections 2 and 10, T14N R25E. ***Point 9*** is also marked on the matchline of the adjoining Priest Rapids NE Quadrangle.

7. **Map 7: Priest Rapids NE Quadrangle.** ***Point 9*** is marked on the Priest Rapids NE Quadrangle where the proposed AVA and coincident private-Federal boundary intersects the eastern edge of the Quadrangle. From ***Point 9*** the boundary continues alternately west and south in one-half to one-mile increments for approximately 5.3 miles where it intersects the normal and ordinary high water mark of the Columbia River at ***Point 10***, which is in the northern 1/2 of section 10, T13N R24E. Approximately 500 feet north of ***Point 10***, the boundary of the proposed AVA crosses State Route 243. From ***Point 10***, the boundary of the proposed AVA turns west and the southern boundary is defined by the normal and ordinary high water mark of the Columbia River to ***Point 11***, which is where the normal and ordinary high water mark of the river meets the western edge of the Quadrangle, approximately 600 feet west and 200 feet south of the eastern 1/4 corner of section 6, T13N R24E. ***Point 11*** is also marked on the matchline of the adjoining Priest

Rapids Quadrangle.

8. **Map 8: Priest Rapids Quadrangle.** ***Point 11*** is marked on the Priest Rapids Quadrangle where the normal and ordinary high water mark of the river (the proposed AVA boundary) intersects the eastern edge of the Quadrangle. From ***Point 11*** the high water mark boundary continues in a northwesterly direction, passing along the face of Priest Rapids Dam, then in a northerly direction continuing to follow the normal and ordinary high water mark of Priest Rapids Lake to ***Point 12*** where the boundary intersects the northern edge of the quadrangle in the northeastern 1/4 of section 36 T15N R23E. ***Point 12*** is also marked on the matchline of the adjoining Beverly Quadrangle.

9. **Map 1: Beverly Quadrangle.** ***Point 12*** is marked on the Beverly Quadrangle where the normal and ordinary water mark of the pool of Priest Rapids Lake intersects the southern edge of the quadrangle. From ***Point 12*** the coincident proposed AVA boundary and high water mark continue in a northerly direction until the boundary meets the starting ***Point 1*** where the northern line of section 22 T15N R23E intersects the high water mark.

SUMMARY

In section 1, evidence has been presented that the proposed viticultural area is known as Wahluke Slope, with nine examples cited out of more than 2000 possible citations to demonstrate that the name Wahluke Slope refers in the public consciousness to the area on the south slope of the Saddle Mountains and north of the Columbia River. Dozens of citations not used refer to the high quality grapes produced here and the fine, award winning wines that are produced from these grapes.

Geographical, cultural, and historical evidence has been presented in section 2 to show that the proposed AVA boundary is the correct and best boundary. The geographical evidence shows that the boundary outlines the unique mega alluvial fan landform of the Wahluke Slope with uniform soils on gentle south-facing slopes highly suited to viticulture, and that areas outside of the proposed AVA are too steep, shallow and stony to the north and west and too wet, hummocky and frost prone to the southeast to allow any agriculture. The cultural and historical evidence in section 2 shows that areas to the southeast, south, and west of the proposed AVA are all Federal lands (Hanford Reach National Monument, Hanford Nuclear Reservation, and U.S. Army Yakima Training Center, respectively) with severe land use restrictions that preclude agricultural development.

In section 3, it has been demonstrated that the proposed AVA has geographical features that produce growing conditions that distinguish the proposed area from surrounding areas based on the area's geographic isolation and the fact that the proposed AVA is sited on a single geologic landform; climatic factors including uniformity across the proposed AVA, high GDD, lowest rainfall in the state, high wind energy, and low incidence of rainfall at harvest; and high spatial uniformity of soils, uniform site characteristics of south-facing aspect and moderate slopes, and the potential for sub-terroirs based on areas of different soils.

Finally, the boundary of the proposed AVA has been described in such a way that it can be located on U.S. Geological Survey 1:24,000 scale topographic maps.

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Wilson, J.E. 1998. Terroir: The role of geology, climate, and culture in the making of French wines. Mitchell Beazley. London, UK, 336 p.

LIST OF FIGURES, TABLES, APPENDICES, and ATTACHMENTS

Figure 4. Map of mean annual precipitation for a 6-county area around the proposed Wahluke Slope AVA, showing the uniform, very low rainfall of the AVA. Figure created from map data available on Spatial Climate Analysis Service, Oregon State University, http://www.ocs.oregonstate.edu/prism/, created 4 Feb 2004.

Figure 5. Perspective 3-dimensional view from the south looking north of the area of the proposed AVA with map units of the general soils map of Grant County (Gentry, 1984) draped over the topography and showing the 4 informally designated zones where wine grape production is concentrated.

Table 1. Growers and Vineyard Acreages on the Wahluke Slope.

Table 2a. Ten-Year (1994-2003) Climate Means for Selected PAWS Stations.

Table 2b. Ten-Year Average Growing-Degree Days (GDD) for Selected PAWS Stations.

Table 2c. Ten-Year (1994-2003) Average Chance of Precipitation During Harvest for Selected Paws Stations.

Table 3. Acreages and Selected Properties of Soils in the General Soil Map Units of the Wahluke Slope (from Gentry, 1984).

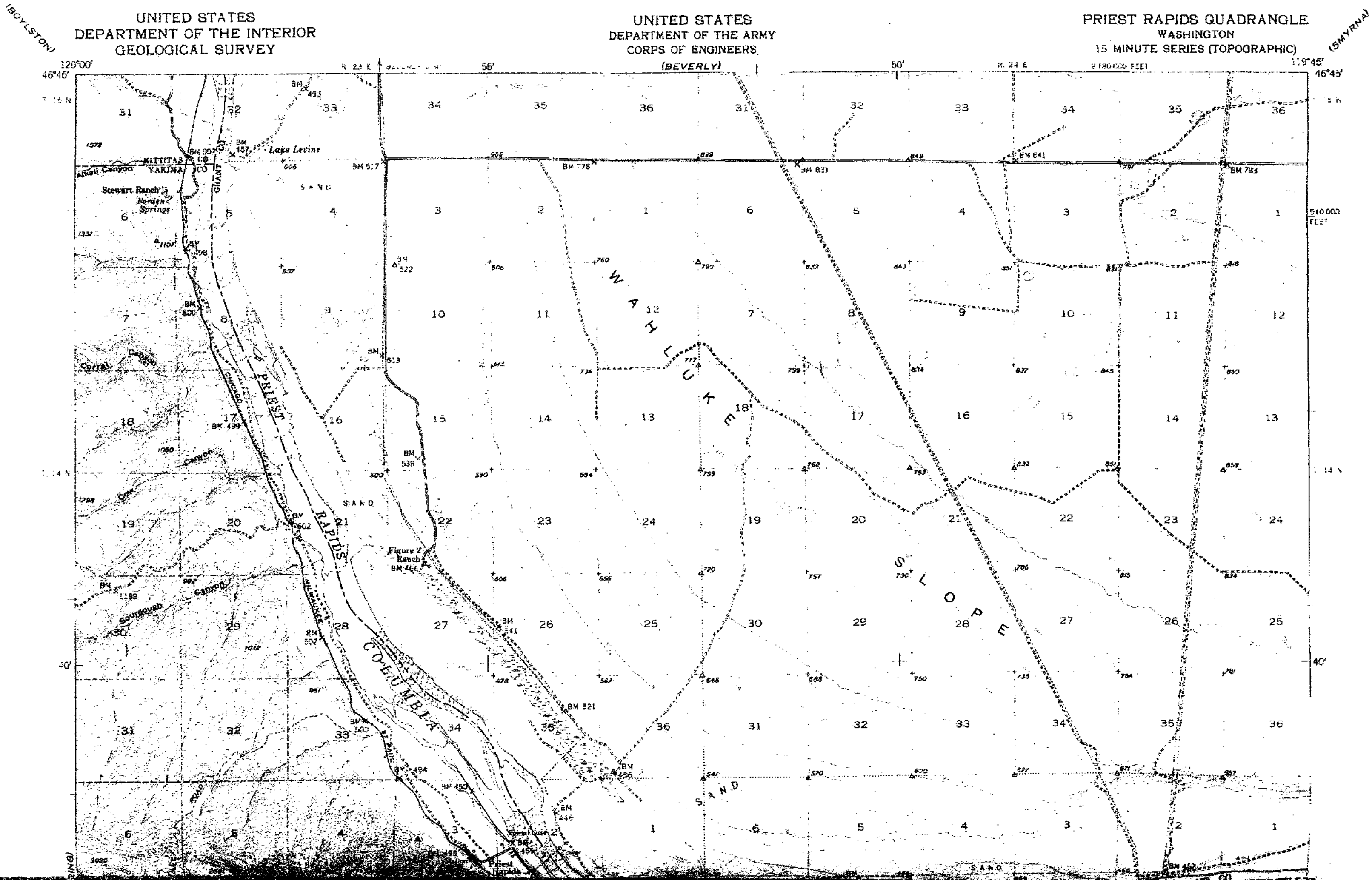
Appendix I. Photocopies of materials cited in section 1 of the petition as <u>evidence that the name of the viticultural area is locally and/or nationally known as referring to the area specified in the application</u>.

Appendix II. U.S. Geological Survey, 1:24,000-scale metric topographic maps of Beverly, Coyote Rapids, Priest Rapids, Smyrna, Vernita Bridge, and Wahatis Peak, Washington with boundaries of the proposed Wahluke Slope AVA clearly marked. U.S. Geological Survey, Reston, Virginia 22092. **Maps only included in copy 1 to TTB.**

Appendix III. Copies of works cited in the bibliography. **Soil Survey of Grant County, Washington only included in copy 1 to TTB.**

APPENDIX I

Photocopies of materials cited in section 1 of the petition


(BOYLSTON)
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DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
UNITED STATES
DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
(BEVERLY)
PRIEST RAPIDS QUADRANGLE
WASHINGTON
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(SMYRNA)
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46°45'
119°45'
46°45'
56'
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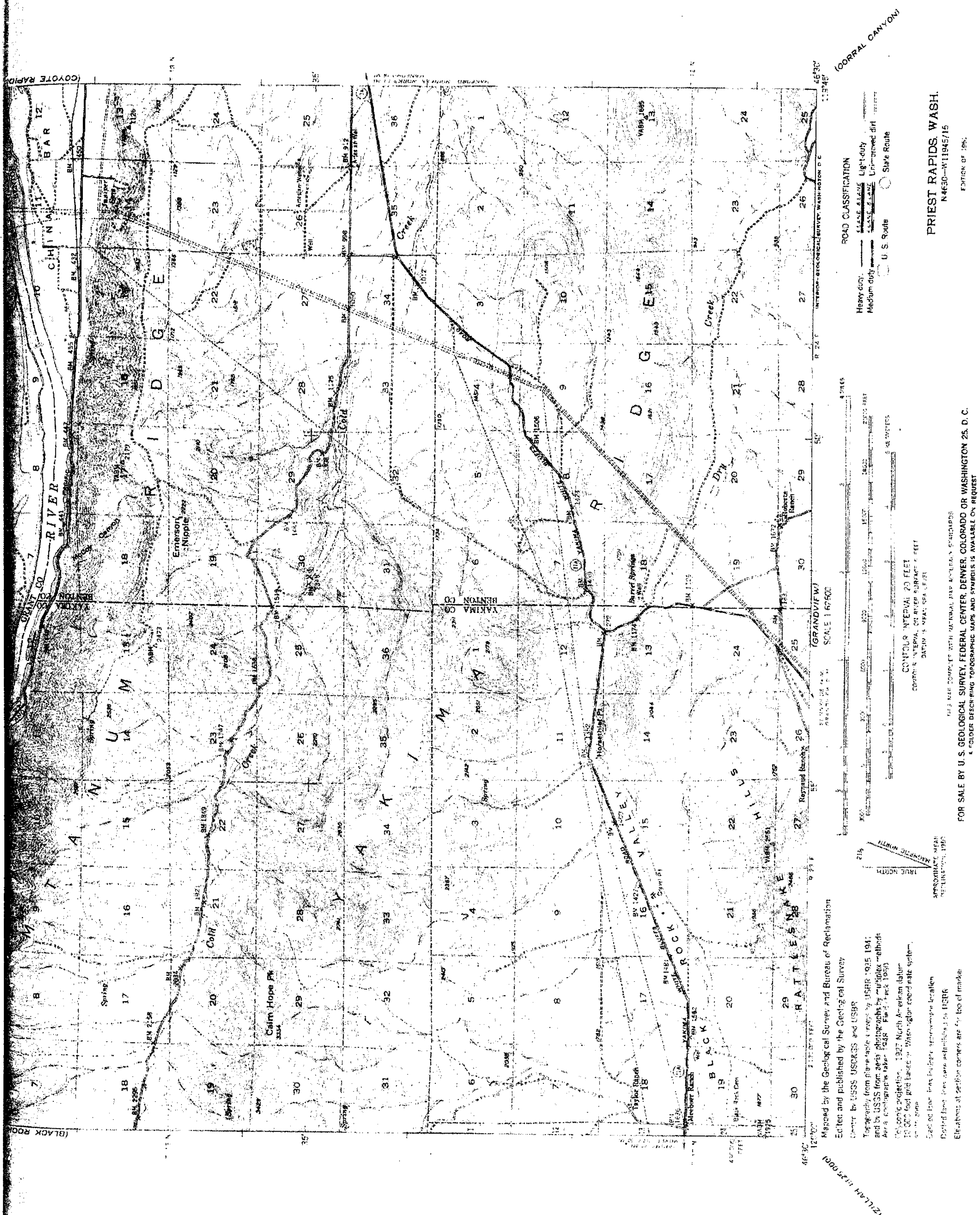
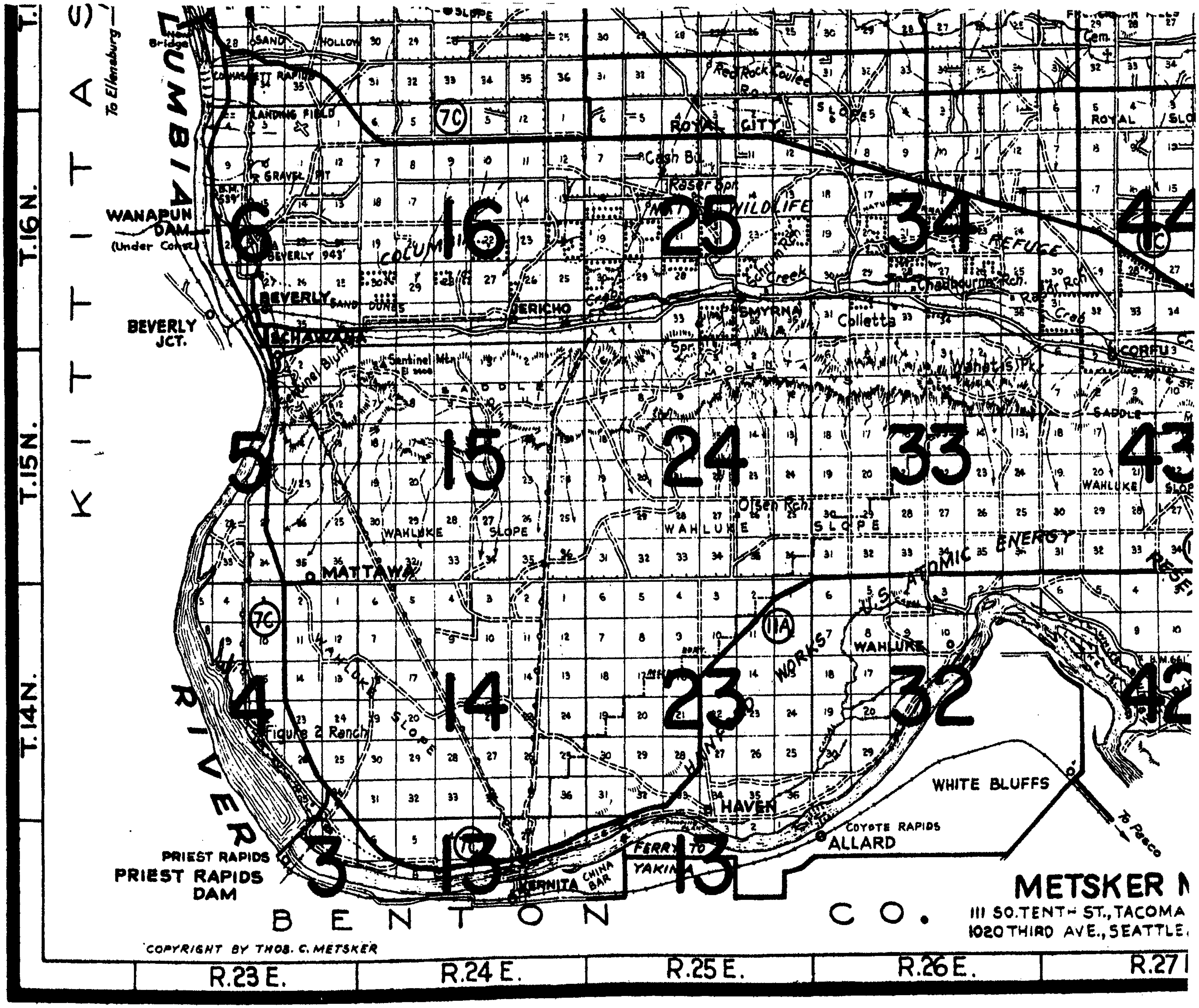
40'
Lake Levine
KITTITAS CO
YAKIMA CO
GRANT
Stewart Ranch
Norden Springs
Corral Canyon
Cow Canyon
Sourdough Canyon
PRIEST RAPIDS
COLUMBIA
SAND
Figure 2 Ranch
WAHLUKE
SLOPE
Priest Rapids



PRIEST RAPIDS, WASH.
N4630—W11945/15
ROAD CLASSIFICATION
Heavy-duty
Medium duty
Light-duty
Unimproved dirt
U. S. Route
State Route
FOR SALE BY U. S. GEOLOGICAL SURVEY, FEDERAL CENTER, DENVER, COLORADO OR WASHINGTON 25, D. C.
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
CONTOUR INTERVAL 20 FEET
(GRANDVIEW)
SCALE 1:62500
Mapped by the Geological Survey and Bureau of Reclamation
Edited and published by the Geological Survey
(CORRAL CANYON)
(COYOTE RAPIDS)
(BLACK ROCK)
RIVER
UMTANUM RIDGE
YAKIMA RIDGE
ROCK VALLEY
RATTLESNAKE HILLS
BLACK ROCK
Cold Creek
Dry Creek
Emerson Nipple
Cairn Hope Pk
Horsethief Pk
YAKIMA CO
BENTON CO
TRUE NORTH
MAGNETIC NORTH


KITTITAS
To Ellensburg
COLUMBIA
RIVER
WANAPUM DAM (Under Const.)
BEVERLY JCT.
BEVERLY
SCHAWANA
JERICHO
ROYAL CITY
Red Rock Coulee
WILDLIFE REFUGE
SMYRNA
Colletts
CORFU
Sentinel Mtn.
SADDLE MOUNTAINS
Wahatis Pk.
Olsen Rch.
WAHLUKE SLOPE
MATTAWA
Figure 2 Ranch
U.S. ATOMIC ENERGY RESERVATION
HANFORD WORKS
WAHLUKE
HAVEN
FERRY TO YAKIMA
CHINA BAR
VERNITA
ALLARD
COYOTE RAPIDS
WHITE BLUFFS
To Pasco
PRIEST RAPIDS
PRIEST RAPIDS DAM
BENTON CO.
METSKER
111 SO. TENTH ST., TACOMA
1020 THIRD AVE., SEATTLE
COPYRIGHT BY THOS. C. METSKER
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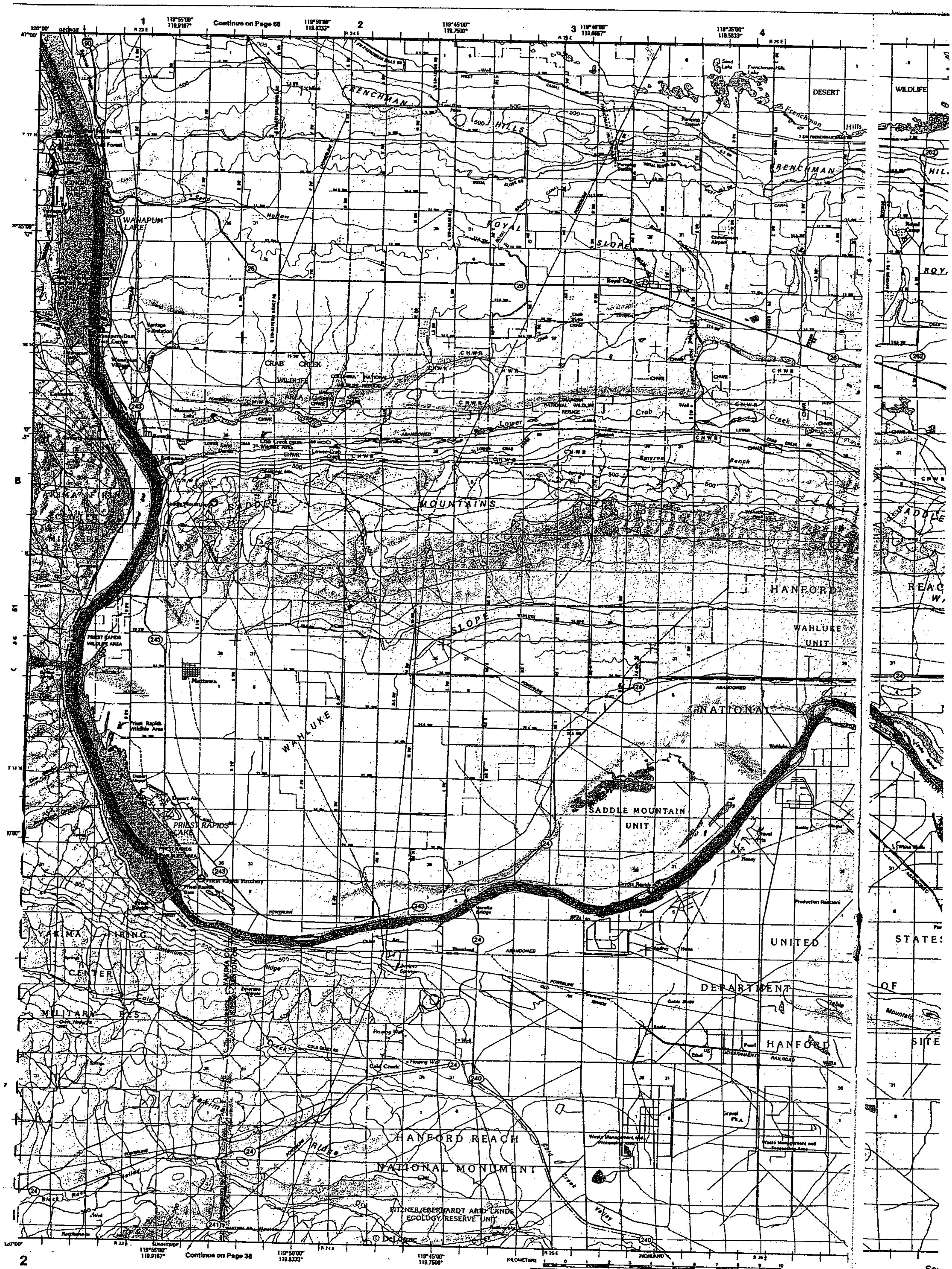
T.15N.
T.14N.
R.23E.
R.24E.
R.25E.
R.26E.
R.27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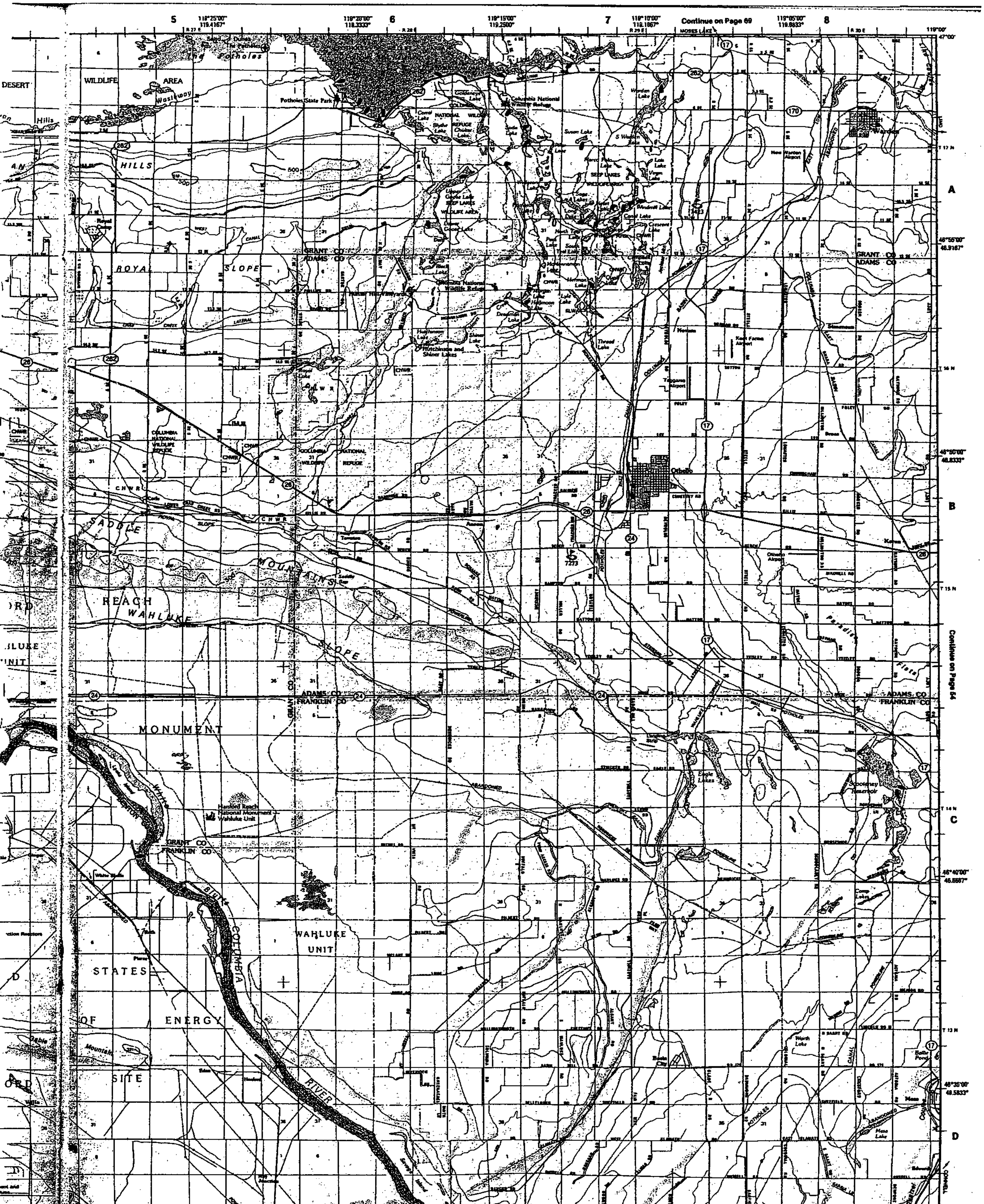
FRENCHMAN HILLS
Frenchman Hills
DESERT
WILDLIFE
WANAPUM LAKE
ROYAL SLOPE
Royal City
CRAB CREEK WILDLIFE AREA
COLUMBIA NATIONAL WILDLIFE REFUGE
Lower Crab Creek
Smyrna Bench
SADDLE MOUNTAINS
YAKIMA FIRING CENTER MILITARY RES
HANFORD
WAHLUKE UNIT
WAHLUKE SLOPE
PRIEST RAPIDS WILDLIFE AREA
Mattawa
NATIONAL
SADDLE MOUNTAIN UNIT
PRIEST RAPIDS LAKE
Priest Rapids Hatchery
POWERLINE
Production Reactors
UNITED
DEPARTMENT OF
HANFORD SITE
STATES
YAKIMA FIRING CENTER MILITARY RES
Umtanum Ridge
Cold Creek
HANFORD REACH NATIONAL MONUMENT
Yakima Ridge
FITZNER/EBERHARDT ARID LANDS ECOLOGY RESERVE UNIT
Cold Creek Valley
Waste Management and Processing Area
Gravel Pit
ABANDONED
© DeLorme
Continue on Page 38
KILOMETERS
MILES
RICHLAND



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WILDLIFE
AREA
Potholes State Park
HILLS
ROYAL
SLOPE
GRANT CO
ADAMS CO
Warden
Othello
SADDLE
MOUNTAINS
REACH
WAHLUKE
SLOPE
ADAMS CO
FRANKLIN CO
MONUMENT
Hanford Reach National Monument - Wahluke Unit
GRANT CO
FRANKLIN CO
WAHLUKE
UNIT
STATES
ENERGY
SITE
COLUMBIA
RIVER
Eagle Lakes
Scooteney Reservoir
Basin City
Mesa
CONNELL
Ringold
© DeLorme
ELTOPIA
Continue on Page 64
Scale 1:150,000
Contour Interval 100 meters
(100 meters = 328.08 feet)
Continue on Page 39
53

Columbia Valley AVA Wine Grape Acreage

The Columbia Valley AVA extends across the state line into the Oregon counties of Gilliam, Morrow, Sherman, Umatilla and Wasco. Approximnately 59 percent of the state's wine grape acreage is located in this region. The Columbia Valley accounts for 64 percent of the state's acreage of red varieties and 53 percent of the state's acreage of white varieties.

The Columbia Valley AVA was subdivided into the following regions: Wahluke Slope, Royal Slope, Columbia Basin/Snake River, Alderdale Ridge, Columbia Gorge, Canoe Ridge, Cold Creek, Mattawa, Wallula and Other. Acreage estimates by variety and subregion of the Columbia Valley are shown in the table below. Data for the Canoe Ridge, Cold Creek, and Wallula regions were combined to avoid disclosing information about individual operations.

Columbia Valley AVA Total Wine Grape Acreage, January 1, 2001 - by Region

Variety	Wahluke Slope	Royal Slope	Col. Basin/ Snake River	Alderdale Ridge	Columbia Gorge	Mattawa	Combined Regions 1/	Other	Columbia Valley Total
White Varieties:									
Chardonnay	290	160	650	370	40	350	520	1,000	3,380
Chenin Blanc	40	0	30	10	0	0	0	200	280
Gewurztraminer	20	0	40	0	40	0	0	130	230
Muscat Canelli	0	0	0	10	0	0	40	30	80
Pinot Gris	0	0	30	0	0	0	10	50	90
Sauvignon Blanc	40	0	100	40	0	10	20	230	440
Semillon	20	0	30	0	0	60	0	290	400
Voignier	10	0	10	50	0	10	10	30	120
White Riesling	130	0	220	30	0	50	190	640	1,260
Other White	10	0	0	20	0	0	0	0	30
Total White	**560**	**160**	**1,110**	**530**	**80**	**480**	**790**	**2,600**	**6,310**
Red Varieties:									
Cabernet Franc	60	190	60	100	0	50	60	130	460
Cabernet Sauvignon	640	0	400	660	10	600	710	1,140	4,360
Lemberger	0	0	0	30	10	0	0	20	50
Malbec	0	0	0	20	0	0	10	20	50
Merlot	380	170	430	500	10	700	790	700	3,680
Pinot Noir	10	0	50	0	10	0	0	10	80
Sangiovese	20	0	30	20	0	10	30	0	110
Syrah	250	120	150	230	10	130	120	340	1,350
Zinfandel	20	0	0	40	0	0	0	0	60
Other Red	10	0	30	40	0	10	0	0	90
Total Red	**1,390**	**480**	**1,150**	**1,640**	**50**	**1,500**	**1,720**	**2,360**	**10,290**
TOTAL ALL	**1,950**	**640**	**2,260**	**2,170**	**130**	**1,980**	**4,230**	**4,960**	**16,600**

1/ Includes Canoe Ridge, Cold Creek, and Wallula–for publication.

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Othello Sandhill Crane Festival

The Othello Sandhill Crane Festival began in 1998, sponsored by the Greater Othello Chamber of Commerce and the Columbia National Wildlife Refuge (U.S. Fish & Wildlife Service). Since the beginning the Festival has been financially supported by the City of Othello through tourism development funds (hotel/motel taxes) and logistically supported by the Othello School District and Othello Community Schools, reimbursed by Festival registration fees.

The Sandhill Crane Festival Committee plans, organizes and conducts the festival. The Committee includes Othello Conservation District staff, Othello citizens plus residents from the neighboring Columbia Basin communities of Ephrata, Moses Lake and Royal City.

The Festival is a three-day event at the end of March, Friday through Sunday. The 2005 event will be held March 18, 19, 20.

The Festival has many tours for crane viewing along with specialty tours. Specialty tours have included Columbia National Wildlife Refuge/Potholes area wildlife tour, Missoula Floods and the Channeled Scablands geology tour, Sage Grouse Lek tour, Lower Grand Coulee birding tour and Wahluke Slope/Shrub Steppe birding tour. Pre-registration is suggested to reserve your seat as some fill up quickly.

With admission price into the Festival on Saturday, you may attend free lectures which are repeated throughout the day. Lectures given in the past have included falconry, Missoula Floods and the Channeled Scablands, Woodland Park Zoo, Grouse of Washington, Othello History within the Drumhellar Channeled Scablands, Shrub-Steppe Flora and Fauna, Owls of Eastern Washington and Spring Migration in the Columbia Basin.

For more information please call 509-488-2802 extension 100.

Home

Grant County Tourism

Press Room

WASHINGTON STATE

Date: 3/24/2004

Outdoor Recreation in Grant County

FOR IMMEDIATE RELEASE 2/13/04

Grant County Outdoor Recreation

In an era of rapid human growth, wildlife areas represent some of the last best places in Washington State. The Washington Department of Fish and Wildlife owns or controls almost 800,000 acres around the state for fish and wildlife and related recreational opportunities. Grant County boasts 13 of the state's 65 preserved wildlife areas. These areas contain over 233,000 of the 800,000 acres preserved. That is nearly 30% of all the State's Wildlife areas and more than any other County in Washington State. In addition, Grant County is home to the Grand Coulee Dam, Sun Lakes and Steamboat Rock state parks, and two National Wildlife Refuge areas as well, the Columbia National Wildlife Refuge and the 30,000 acre Saddle Mountain National Wildlife Refuge. The Hanford Reach National Monument also runs adjacent to the Saddle Mountain Refuge and contains the last non-tidal 50 miles of the Columbia River that is not a dammed reservoir. In this stretch, the river has current and a channel width similar to what once existed throughout its length, providing habitat conditions similar to the era before dams. The abundance of native species, both large and small, is greater here than anywhere else on the Columbia River. The Reach and its environs provide great expanses of view, allowing river travelers a sense of wildness and isolation.

While Grant County offers so much in golfing, birding, fishing and hunting, those are only some of the outdoor recreation available to the Central Washington recreational traveler. There is so much else to do and see and over 300 days of sunshine per year to do it in.

The Grant County Tourism Commission can provide you with 4 DAYtour maps, the Grand Coulee, the Columbia Wildlife Refuge, the Columbia Basin & the Scenic Scablands. Call 800-992-6234 or email information@moseslake.com .

Moses Lake offers all the recreational amenities that a large lake should with all the convenience of a city, like hotels, parks and shopping. The lake itself is beautiful. The Neppel Land Trail is a great place to stroll along the water near the downtown area of Moses Lake.

The Sand Dunes Off Road Vehicle Park, one of the largest in the Northwest, is located just four miles outside Moses Lake on the southern tip of Moses Lake. Enjoy the excitement of "conquering" these rolling sand dunes. Rustic camping is available as is fishing and waterskiing.

How about rock climbing? A favorite spot is The Feathers. These basalt columns resemble feathers on an Indian Head Dress and are adjacent to the parking and free parking at Frenchman Coulee. Solid and safely bolted, this popular climb is an easy drive off I-90 at exit 143, the same exit for the Gorge Amphitheater.

Frenchman Coulee and its' beautiful basalt pillars are better known as a climbing venue, but it's also a prime place to follow old jeep tracks into the canyons. There is also rock climbing at Potholes, Banks Lake and Steam Boat Rock.

In addition to rock climbing, Steamboat Rock offers ice climbing and Nordic skiing in winter, as well as over 13 miles in hiking and biking trails, 10 miles of horse trails, and boating, water skiing, mountain biking, bird watching, wildlife viewing, even a volleyball field.

The scenic Dry Falls overlooks Sun Lakes State park where they provide swimming, boating, fishing, picnicking, horseback riding, hiking, interpretive viewing and canoeing as well as several resorts.

Classic coulee-country hiking can be found in the three parcels of the Quincy

Wildlife Area's 15,266-acres, all adjacent to and just upland of the east bank of the Columbia River south of Quincy. The most popular are hikes to Ancient and Dusty lakes in two small coulees within a larger coulee, rimmed by columnar basalt, decorated by waterfalls and carpeted by bunch grass, sage and, in season, pretty wildflowers.

A maintained trail will guide you to seven of the Lake Lenore Caves, just north of Soap Lake. Also created by the massive Ice Age Floods, these caves were home to the Sinkiuse (sing'-kee-ooz) Indians. There are also several hiking trails around the Grand Coulee Dam.

Visitors are drawn to the 23,000 acre Columbia National Wildlife Refuge for the scenic and recreational opportunities available. Take an auto tour of the refuge. Visit the Drumheller Channels National Natural Landmark overlook and interpretive site commemorating the glacial floods. Go for a walk and photograph flower or identify birds. Paddle a canoe from Hutchinson Lake to Shiner Lake and enjoy solitude and the antics of swallows building cliffside nest. Hike on of three different interpretive trails that highlight three different habitats. Columbia has a wide variety of wildlands-oriented activities from which to choose; Wildlife observation, camping, birding, photography, hiking and canoeing, as well as hunting and fishing.

The Wahluke Slope and the lands of the Hanford Reach National Monument are not true desert but more properly called "shrub-steppe" by scientists. The Hanford Reach National Monument is the U.S. Fish and Wildlife Service's only national monument. It is a place of sweeping vistas and stark beauty, of towering bluffs and delicate flowers. Wildlife abounds in this harsh landscape—rare is a trip along this protected strip of Columbia River that doesn't produce mule deer, coyotes, bald eagles, great blue herons, or white pelicans. A large elk herd hides in the canyons, and incredibly, porcupines are a common sight. Beautiful spring wildflower displays delight the visitors who venture into the field.

So, whether you're interested in history, sightseeing, wildlife, hunting, fishing, or just enjoying a bit of time away from the bustle of everyday life, the Wahluke Slope and adjacent Hanford Reach National Monument has something to offer you.

Not all of these public lands offer hiking in the classic sense, with well-marked, regularly maintained trails, there are some defined trails, but even more old rocky jeep tracks. Furthermore, the open terrain lends itself to cross-country walking for anyone with a basic knowledge of map and compass use. Not only are these areas open and intriguing, they usually are snow-free by late March and offer fine hiking opportunities in spring. Check in with Hanford Reach before making a cross-country hike.

Grant County offers inexhaustible opportunities for every kind of outdoor experience.

Further information on Grant County can be found at http://www.tourgrantcounty.com/

Columbia National Wildlife Refuge: http://www.recreation.gov/detail.cfm?ID=1212

Hanford Reach: http://www.pnl.gov/pals/resource_cards/reach.stm

Potholes: http://www.recreation.gov/detail.cfm?ID=1222

Sun Lakes and Dry Falls: http://www.parks.wa.gov/parkpage.asp?selectedpark=Sun+Lakes&pageno=1

Banks Lake & Steam Boat Rock: http://www.parks.wa.gov/parkpage.asp?selectedpark=Steamboat+Rock&pageno=1

Sunbanks Resort: www.sunbanksresort.com

For More Press Information:
Phone: 509.921.5579
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The HANFORD REACH

April 19, 1999

A publication of the U.S. Department of Energy's Richland Operations Office for all site employees

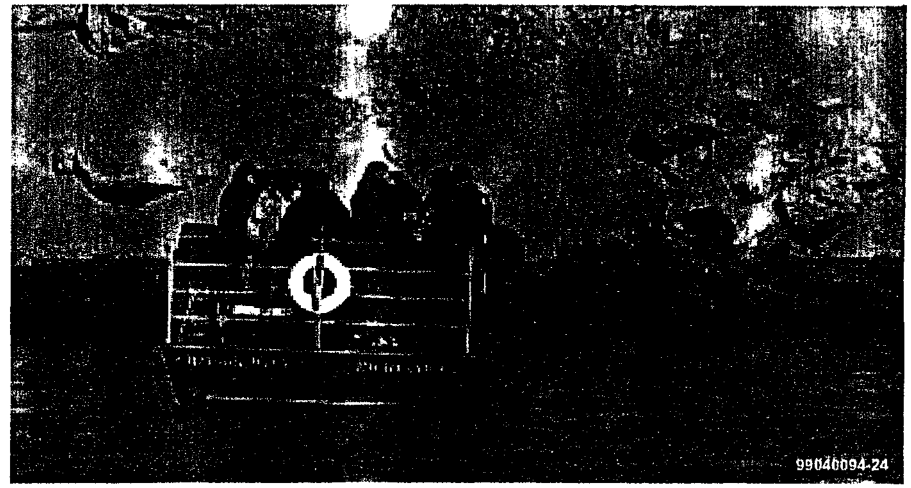
Wahluke Slope to be national wildlife refuge

On Saturday, April 10, Secretary of Energy Bill Richardson made a brief but activity-filled visit to the Tri-Cities and the Hanford Site.

After a boat tour of the Hanford Reach, Locke Island and the White Bluffs area, Richardson announced a proposal that will preserve more than 90,000 acres along the Hanford Reach of the Columbia River as a national wildlife refuge. The Department of Energy will soon issue a revised draft Hanford Remedial Action Environmental Impact Statement with a preferred alternative addressing the future of the Reach.

The area known as the Wahluke Slope would be managed by the U.S. Fish and Wildlife Service for DOE. The slope is a prime example of shrub-steppe habitat that is quickly disappearing in the Pacific Northwest. The slope has served as a safety and security buffer zone for Hanford operations since the inception of the Manhattan Project in 1943. The result is an ecosystem relatively untouched for decades.

"When it comes to protecting the environment, it is our responsibility as stewards of the Earth to take the longest possible view," said Richardson. "A national wildlife refuge will protect this unique ecological resource with its critical wildlife habitat, as well as preserve an area rich in cultural and historical resources. My proposal will help preserve for the next millennium the last section of free-flowing Columbia River."



Secretary of Energy Bill Richardson and other federal and local officials took a boat tour of the Hanford Reach, Locke Island and the White Bluffs area on April 10. The Secretary was in the Tri-Cities to announce a proposal that will preserve the Wahluke Slope area of the Hanford Site, north of the Columbia River, as a national wildlife refuge.

Richardson's approach for the Wahluke Slope is consistent with a 1996 Department of Interior "record of decision" that recommended the Wahluke Slope be designated a wildlife refuge and the

See **Wahluke**, page 3a

- **WWQA means truth in labeling** — The generic use of Champagne, Burgundy, Bordeaux and Chablis on labels will be disbanded.

WWQA is open to all wineries and wine grape growers. It is a commitment by Washington winemakers and wine grape growers to focus on quality wine producing in the state's growing industry.

CANOE RIDGE
Canoe Ridge is an optimal growing region. Some of the state's top wines are produced from fruit grown on the wide south-to-southeast facing slopes sited above the Columbia River, west of Paterson. Major varietals planted are Merlot, Cabernet Sauvignon and Chardonnay.

ZEPHYR RIDGE
Directly overlooking the Columbia River, Zephyr Ridge is a unique slope with varied exposures producing both high quality red and white wines. It is a moderately warm site with sandy loam soil providing good drainage and control over the vines.

COLD CREEK
A southerly facing slope of the Columbia River which enjoys on of the longest growing season in the Columbia Valley. The low rainfall and meager silt loam soils produce very intense and concentrated fruit. Cold Creek is part of a high plateau that runs along the south side of the Columbia River and is particularly noted for its distinctive Chardonnay and Cabernet Sauvignon.

COLUMBIA BASIN / SNAKE RIVER
This is where the Columbia, Yakima and Snake rivers meet. The area surrounding the Tri-Cities and including the broad hills bordering each side of the Snake River is blessed with a good climate and ample irrigation. Several large vineyards have achieved reputations for excellent Merlot, Sauvignon Blanc, Semillon and other varietals.

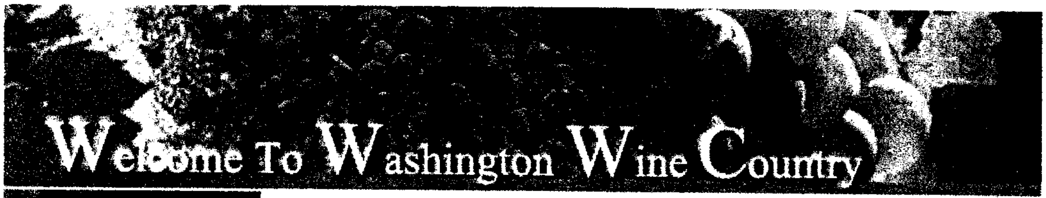
WAHLUKE SLOPE & MATTAWA
Sloping gradually toward the north side of the Columbia River from Vantage to Othello, is a high plateau known for producing distinctive varietal character. The Wahluke Slope on the north side of the Columbia actually includes Mattawa, one of the warmest sites in the state, known for Merlot and Cabernet Sauvignon. Its south facing slopes are bounded on the west by the Columbia River, on the north by the Saddle Mountains, and on the east by the Columbia River again. Further north on the next south facing slopes is the area that extends from the Frenchman Hills to Radar Hill near Othello

WASHINGTON WINE QUALITY ALLIANCE (WWQA)
The Washington Wine Quality Alliance (WWQA) is a voluntary, self-governed organization developed in 1999 by the Washington state wine industry to demonstrate the region's commitment and focus for producing world-class wines. The WWQA is first North American wine organization to spearhead the development of industry standards in winemaking and labeling. The organization's formation is a significant step in the state's evolution as a premier wine producing region.

WWQA members believe in the philosophy that quality is the foundation in making premium wines, and follow these industry standards:

- **WWQA defines "reserve"** — WWQA is the first U.S. organization to define the term "reserve". In Washington, this means only 3,000 cases or 10 percent of a wineries' production can be labeled as such and "reserve" indicates the winemakers' designation of the wine as a higher quality wine from the winery.

- **WWQA means 100 percent Washington fruit** — All wines labeled as being from Washington State must contain 100 percent Washington fruit or a Washington American Viticultural Area (AVA) or the label must identify the percentage of wine from each source. Varietal labeling will require that wines contain at least 75 percent of that variety.



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Sub-Appellations

As new vineyard sites are planted, and the resulting grapes and wines are evaluated, vintners discover which micro-climates are most suitable for particular varietals. Washington's vineyards include several sites that have distinguished themselves by producing perfect fruit and, ultimately, exceptional wines.

On the north banks of the Columbia River near the small town of Paterson lies a rapidly emerging premium grape growing area. The areas unique topography offers many advantages, such as steep south facing slopes and mitigation of temperature extremes because of its proximity to the Columbia River.

The outstanding sites that have been developed in this area are Canoe Ridge, Alder Ridge, and Zephyr Ridge. Alder Ridge shares the same soil composition as Canoe Ridge but with areas of fractured basalt and caliche. Also inland from the river ridges on the Horse Heaven Hills are a variety of more established vineyards such as the Champoux Vineyard (formerly Mercer Ranch), Destiny Ridge Vineyard and the Andrew Vineyard.

ALDER RIDGE
One of Washington's higher vineyard locations, Alder Ridge is a steep slope rising 1,000 feet from the bank of the Columbia River. Its proximity to the river also makes it one of the warmest vineyard sites. It shows promise for Washington's signature variety, Merlot, as well as other Bordeaux varieties and Syrah. Alder Ridge shares the soil composition of Canoe and Zephyr Ridges.

MORE WINE FACTS

Washington Reds
Washington Whites
Appellations
Sub-Appellations
Wine Appreciation
Wine Terminology
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Quick Facts

2002 ACREAGE REPORT

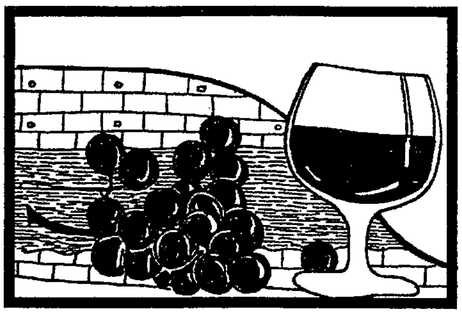
APPENDIX II

Maps only included in copy 1 to TTB.

APPENDIX III

Copies of works cited in the bibliography.
(Soil Survey of Grant County, Washington
only included in copy 1 to TTB)

SERIES



Geology and Wine 3: *Terroirs* of the Walla Walla Valley *appellation*, southeastern Washington State, USA[1]

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SUMMARY

Terroir of the Walla Walla Valley *appellation* of Washington State is influenced by 1) the rain shadow effect and volcanic tephra of the Cascade Mountain Range, 2) soils derived from Quaternary glacial sediments and wind-blown loess overlying Miocene basalt, and 3) a warm, dry climate with abundant sunshine and cool nights due to high latitude (45-48°N) and elevation. Wine flavours of Walla Walla Valley varietals (including Cabernet Sauvignon, Chardonnay, Merlot, and Syrah) appear to be influenced by low humidity, long growing season (1500-1800°C degree days), soil type and drainage, drip irrigation, pruning to restrict vine vigour, trellising methods, and overall topographic climatic setting of the vineyards. Microclimates within the Walla Walla Valley *appellation*, combined with variations in soil and bedrock stratigraphy, yield a range of wine styles as great as many larger regions and some countries.

RÉSUMÉ

Le terroir de la vallée de Walla Walla d'appellation de l'État de Washington est caractérisé par 1) l'effet parapluie de la topographie locale et la nature téphritique des dépôts de la chaîne des monts Cascade, 2) les sols issus de dépôts glaciaires et de loess éoliens recouvrant un basalte Miocène, et 3) un climat chaud et sec très ensoleillé, avec les nuits fraîches des hautes latitudes (N45° à N48°) et de l'altitude élevée. Les goûts des vins des variétés de la vallée de Walla Walla (incluant le Cabernet Sauvignon, le Chardonnay, le Merlot, et le Syrah) semblent dépendre de la faible humidité de la région, sa saison végétative longue (1 500°C à 1 800°C degrés-jours), de la nature de son sol et de son drainage, d'une irrigation goutte à goutte, de la taille de la vigne pour en restreindre la vigueur végétative, des méthodes de treillages et, des conditions topographiques et climatiques générales où baignent ces vignobles. L'effet combiné des microclimats de la région d'appellation de la vallée de Walla Walla avec les variétés de ses sols et de la stratigraphie du substratum rocheux régional permet la production de styles de vin aussi prestigieux que bien des régions reconnues et même de certains pays.

INTRODUCTION

Terroir is a relatively simple term to describe the complex interplay of climate, soil, geology, and other physical factors that influence the character and quality of wine. Although the term has long been used in France, recent publications such as Halliday (1993, 1999), Wilson (1998), Haynes (1999, 2000), and Tesic (2000) have explored the concept of *terroir* in other parts of the world with considerable success. The purpose of the present paper is to describe the *terroir* of the Walla Walla Valley *appellation*, a relatively small and young winemaking region in southeastern Washington and overlapping into northeastern Oregon (Fig. 1) that is producing some outstanding wines, particularly stout red wines such as Cabernet Sauvignon, Merlot, and Syrah.

Washington State is a region of superlatives, both oenological and geological, with exposures of some of the world's largest and most spectacular flood basalts, dune and loess fields, and glacial outburst flood deposits. All of these play a part in the *terroirs* of Washington State wines. In addition, recent volcanic

[1] Geology and wine is an international topic, much like *Geoscience Canada's* current series on Oceanic Lithosphere, and Economic Geology Models. Accordingly we are pleased to publish this third paper in the Geology and Wine series, on the Walla Walla Valley *appellation* of Washington State. Although the geology of the Walla Walla Valley *appellation* is unusual, with vast Miocene plateau basalts, slackwater flood deposits, widespread loess, and a variety of derived soil types, it is the *integration* of these geological attributes with climatic factors and viticultural practices that demonstrates the importance of *terroir* with all of its components. This third Geology and Wine series paper is a further example of the kinds of papers we are hoping to publish in *Geoscience Canada* as the series develops. R.W. Macqueen, editor.

activity such as the well-known 1980 eruption of Mt. St. Helens continues to shape the oenological and geological landscape. Most Washington vineyards lie in the rain shadow of the Cascade volcanic arc, and many vineyard soils have a component of ash from Mt. St. Helens and other Cascade volcanic eruptions such as the much larger Mt. Mazama eruption (6850 years B.P.) which formed present-day Crater Lake in Oregon (Busacca *et al.*, 2000).

Washington State is second only to California in terms of wine produced in the United States (Table 1). This is somewhat surprising in that Washington has a relatively short history of wine production by international standards. Although the first *Vitis vinifera* grapes were planted in 1825 by the Hudson's Bay Company along the banks of the Columbia River in southwest Washington (Peterson-Nedry, 2000), commercial production extends back only about 100 years and most of the state's 155+ wineries were started in the past 15 years (there were only 19 wineries when the first author moved to Washington in 1981).

Most Washington State wineries are located between latitudes 45°N and 48°N, well to the north of the more widely known California vineyards but parallel to some of the great French wine regions such as Burgundy and Bordeaux. This northerly latitude provides about two hours more summer sunlight than occurs in California wine regions. Wine quality is also influenced by the arid conditions created by the large rain shadow of the Cascade Mountains; almost all commercial vineyards lie east of the Cascade Mountain Range (Fig. 1).

Although there is considerable local variability, most Washington vineyards are located on Quaternary

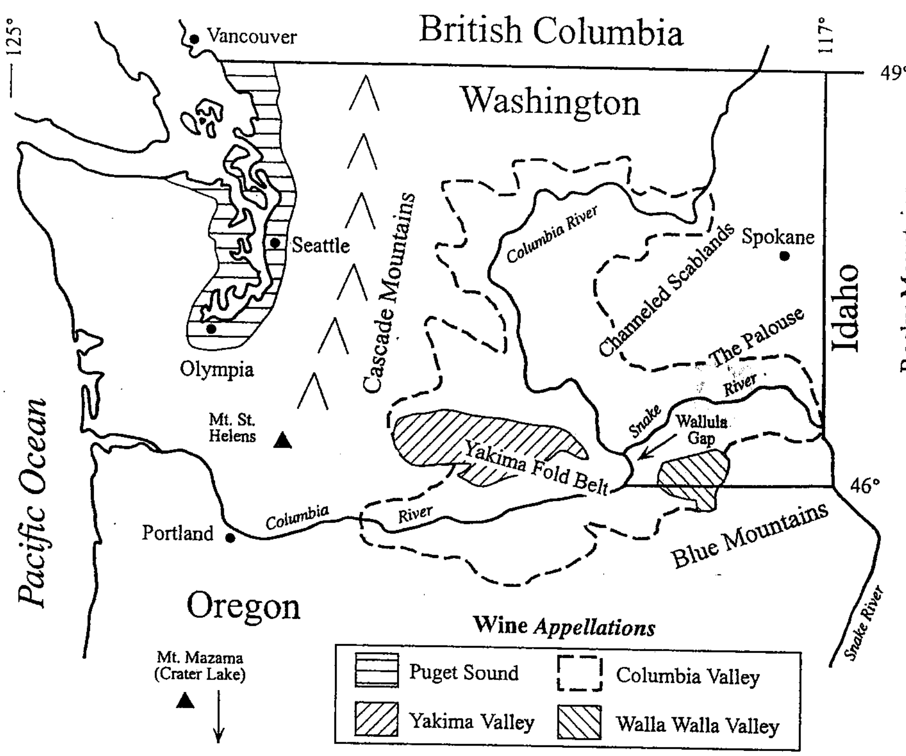

Figure 1 Location map of the Pacific Northwest showing wine *appellations* and major geologic features described in the text.

Table 1 US *vinifera* wine grape production 1997-1999. Data from http://www.nass.usda.gov/wa/graperpt.htm.

Rank	Variety	Tons Utilized 1997	Tons Utilized 1998	Tons Utilized 1999	Average Price (US$/ton) 1997	Average Price (US$/ton) 1998	Average Price (US$/ton) 1999
1	California	2,895,000	2,528,000	2,655,000	603	586	570
2	Washington	62,000	70,000	70,000	972	922	910
3	New York	44,000	36,000	50,000	328	392	348
4	Oregon *	18,500	14,700	17,900	1,120	1,180	1,310
5	Pennsylvania	6,000	11,500	13,000	350	303	325
6	Michigan	2,600	2,500	3,000	800	775	700
7	Missouri	1,800	2,050	2,600	480	535	583
8	Georgia	1,000	1,300	2,000	627	500	1,000
9	Ohio	1,000	800	2,000	492	679	725
	Other States	4,500	4,910	3,485	549	574	735
	United States	3,036,400	2,671,760	2,818,985	503	510	517

* Includes small quantities used for other processing (jam, jelly, *etc.*).

sediments and soils that overlie Miocene basaltic rocks of the Columbia River flood basalt province. Many of the Quaternary sediments are related to cataclysmic glacial outburst floods that formed the spectacular geomorphic features of the Channeled Scablands (cover photo). This in itself is one of the great geologic stories of all time, and the fact that it is intimately related to superlative wine makes a brief synopsis of the geologic history particularly worthwhile. The fact that some of the geological and soil features are unique to this part of the world suggests the possibility that Washington wines may develop flavour and quality characteristics that set them apart from other wine-producing areas.

OVERVIEW OF WASHINGTON STATE WINE

Washington State has four wine *appellations* called American Viticultural Areas (AVAs) by the Bureau of Alcohol, Tobacco, and Firearms (BATF), the chief regulatory agency of the wine industry in the United States (Fig. 1). Unlike *appellations* in many parts of the world, AVAs are not defined in terms of wine quality or even wine characteristics. An AVA is defined by the Bureau of Alcohol, Tobacco, and Firearms as "a delimited grape growing region distinguished by geographical features, the boundaries of which have been recognized and defined..." (http://www.atf.treas.gov/core/regulations/27cfr9.html). In Washington State the wine *appellations* (AVAs) are Columbia Valley, Yakima Valley, Walla Walla Valley, and Puget Sound (Fig. 1). Sub-*appellations*, that may someday become AVAs, include Alder Ridge, Canoe Ridge, Cold Creek, Columbia River Gorge, Horse Heaven Hills, Red Mountain, Wahluke Slope, and Zephyr Ridge (Peterson-Nedry, 2000). As with most other regions, AVAs can be nested such that the Columbia Valley *appellation*, which produces more than 90% of the state's wine grapes, includes the Yakima Valley and Walla Walla Valley *appellations*.

Total wine grape production in Washington State in 1999 was 70,000 tons from approximately 17,000 acres of bearing vineyards (Table 2). Wine grape production will continue to increase in that there are an additional 6000 acres of

Table 2 Washington State *vinifera* wine grape production 1995-1999. Data from http://www.nass.usda.gov/wa/graperpt.htm

Variety	Tons Utilized 1995	1996	1997	1998	1999	Acres Planted 1999	Acres Bearing 1999	Yield Tons/Acre 1999	Average Price (US$/ton) 1995	1996	1997	1998	1999
Chardonnay	15,000	8,000	17,700	20,500	22,900	6,100	5,030	4.6	732	1,240	1,055	971	882
White Riesling	11,000	8,800	10,100	11,500	9,800	1,900	1,780	5.5	385	478	489	533	547
Sauvignon Blanc	3,700	2,300	3,300	3,900	3,400	700	600	5.7	519	726	729	750	746
Semillon	3,600	1,800	2,800	3,100	2,600	600	590	4.4	502	642	661	625	598
Chenin Blanc	3,400	1,100	1,800	2,300	1,700	400	400	4.3	339	464	499	488	473
Gewürztraminer	1,700	700	1,700	1,600	1,300	400	310	4.2	413	541	552	629	706
Other (*)	600	300	600	600	800	400	290	2.8	546	755	789	952	777
Total White	39,000	23,000	38,000	43,500	42,500	10,500	9,000	4.7	542	786	794	772	753
Merlot	10,000	4,500	12,800	14,100	14,300	5,600	4,040	3.5	933	1,400	1,360	1,197	1,149
Cabernet Sauvignon	8,000	5,900	7,800	8,300	8,400	5,000	2,690	3.1	834	1,230	1,195	1,204	1,236
Cabernet Franc	500	600	1,100	1,700	2,000	700	510	3.9	834	1,170	1,120	1,102	1,066
Pinot Noir	1,200	400	1,000	1,100	1,000	200	200	5.0	520	698	653	661	647
Syrah	#	#	#	#	800	1500	290	2.8	#	#	#	#	1,398
Lemberger	400	300	500	500	500	150	110	4.5	565	844	757	760	785
Other (+)	900	300	800	800	500	350	160	3.1	917	1,110	1,400	1,386	1,152
Total Red	21,000	12,000	24,000	26,500	27,500	13,500	8,000	3.4	862	1,260	1,255	1,168	1,152
Washington total	60,000	35,000	62,000	70,000	70,000	24,000	17,000	4.1	654	948	972	922	910

* Includes muscat, pinot gris, and viognier
\+ Includes gamay beaujolais, grenache, nebbiolo, sangiovese, and zinfandel
\# Included in "Other" Red Varieties for 1995-1998

wine grapes planted that were not yet bearing fruit in 1999 (most grape varieties start producing in the third year). Projected production for 2000 is 88,500 tons (Roger Gamache, Washington Association of Wine Grape Growers, written communication, 2000). For comparison, to the north in British Columbia in 1999 there were 4200 acres of bearing vineyards, yielding 11,200 short tons of crops; just over 50% of the acreage under cultivation for wine grapes in British Columbia in 1999 was located in the Oliver-Osoyoos area of the Okanagan Valley region, about 320 km north of the Walla Walla Valley *appellation* (British Columbia Wine Institute, 2000).

In the early days of the Washington State wine industry most wine was made from Riesling and Gewürztraminer grapes because it was assumed that Washington was a cool-climate viticultural area due to its northern latitude, and therefore best suited to production of light fruity white wines. Although such grapes can produce excellent wine in Washington, it was quickly realized that varieties that benefit from warmer conditions also prosper in Washington (Clore and Nagel, 1969; Tukey and Clore, 1972; Nagel *et al.*, 1972). Of the wine produced in Washington State in 1999, 60% was white and 40% was red, a ratio which is almost identical in British Columbia (British Columbia Wine Institute, 2000). This ratio is likely to swing toward a predominance of red wine in Washington State in the future because of the increased plantings of red varietals. For example, in 1999 there were 9000 acres bearing white wine grapes and 8000 acres bearing red wine grapes, whereas in terms of planted but not-yet-bearing grapes, there are only 1500 acres of white wine grapes *versus* 5500 acres of red wine grapes. This trend appears to be accelerating with the newest plantings and those that are on the drawing boards (Norm McKibben, past president Washington Association of Wine Grape Growers, oral communication, 2000).

As shown in Table 2, white wine production is dominated by Chardonnay (54%) and Riesling (23%), whereas red wine production is led by Merlot (52%), Cabernet Sauvignon (31%), and Cabernet Franc (7%). Syrah currently is a fairly small part (3%) of Washington red wine production but is likely to grow in importance owing to spectacular early successes, as well as to the extensive new plantings of this grape. In 1999 only 290 acres of Syrah grapes were bearing commercial fruit but more than 1500 acres have been planted. This changing mix between red and white wine and among different grape varieties is to be expected in such a relatively young viticultural area. It is likely that further changes will occur as growers and winemakers learn more about which grapes are best suited to particular *appellations* and individual vineyards. Although at present about 85% of Washington State wines are blends of fruit from different vineyards, it is likely that single-vineyard wines will become more important in the future. This is one of the reasons why an understanding of *terroir* is so important as the Washington wine industry begins to mature. This is also the case in other Pacific Northwest viticultural areas such as the Okanagan Valley of British Columbia, where much experimentation with *vinifera* grape varieties is underway, following a major reorganization of the local wine industry, and the adoption of new high standards, in response to the Free Trade agreement of 1988 (*e.g.*, Aspler, 1999).

GEOLOGIC HISTORY

Columbia Plateau and Environs

The Columbia Plateau is bordered on the north and east by the Rocky Mountains, on the south by the Basin and Range Province, and on the west by the Cascade Mountains. The Walla Walla part of the Columbia Plateau is adjacent to the northwest flank of the Blue Mountains and is crossed by two of the largest rivers in North America: the Snake River that originates in Jackson Hole, Wyoming, and the Columbia River that starts in the Columbia Icefields of the Canadian Rockies.

The Blue Mountains (Fig. 1) are cored by an accreted terrain of late Paleozoic to early Mesozoic predominantly clastic and carbonate strata, intruded by late Mesozoic granitic plutons, and partly overlain by Tertiary volcanic rocks of the Columbia River Basalt Group (Hooper, 2000). The Columbia River Basalt Group covers an area of about 165,000 km^2. It was erupted mostly between 17-15 Ma (Early Miocene) from north-south fissures roughly paralleling the present-day Washington-Idaho border, and has individual flows with estimated eruptive volumes of at least 3000 km^3, making them the largest documented lava flows on earth (Baksi, 1989; Landon and Long, 1989; Tolan *et al.*, 1989). This dwarfs the erupted volumes of typical Cascade volcanoes: even the explosive eruption of Mt. St. Helens in 1980 yielded only about 1 km^3 of volcanic material (Pringle, 1993).

Stress Regime, South-central Washington State

Concurrent with Early Miocene volcanism were subsidence (*e.g.*, Pasco Basin), deformation (*e.g.*, Yakima fold belt), erosion (many of the valleys were later filled by intracanyon flows, Fig. 2a), and intraflow sedimentation (Fig. 2b). The north-south oriented compressional stress regime of south-central Washington State has existed from the Miocene to the present day. Some anticlines in the Yakima fold belt have developed as much as 100 m of structural relief in the past 10 m.y. (Reidel *et al.*, 1992), and the Walla Walla area experienced an intensity VII (approximate Richter magnitude 6) earthquake on 15 July 1936 (Brown, 1937), most likely caused by movement on the Wallula fault zone (Mann and Meyer, 1993), which is subparallel to the Yakima Fold Belt (Fig. 1).

Quaternary Processes and Products

The Quaternary Period brought a new group of processes. In the Pasco Basin were many sources for wind-blown detritus such as the Miocene Ellensburg Formation, the Pliocene Ringold Formation, sediment deposited by the Columbia and Snake rivers, and sediment from giant glacial outburst floods. The prevailing southwesterly winds transported silt from the Pasco Basin and deposited thick blankets of loess (Fig. 2c). Buried soils in the loess (Fig. 2d) indicate that deposition was intermittent during the Quaternary (Busacca, 1991).

Most of the basement geology has been masked and modified by a variety of features related to the Quaternary glaciation that affected much of the region. The vast continental ice sheet of the glacial maxima covered much of Canada, and the subsidiary Cordilleran Ice Sheet, which originated in the mountains of British Columbia, expanded southward into northern Washington, Idaho, and Montana. Of particular significance to the landscape of eastern Washington State was a lobe of the Cordilleran Ice Sheet which flowed along the Purcell Trench and blocked the northwest-flowing Clark Fork River near Cabinet Gorge on the Idaho-Montana border.

Lake Missoula and the Channeled Scabland

The Cordilleran Ice Sheet lobe dammed glacial Lake Missoula (Fig. 3), which covered 7800 km^2 of western Montana (Pardee, 1910). At the ice dam the water was approximately 600 m deep (Weis and Newman, 1989). The ice dam failed repeatedly, releasing the largest floods documented on earth (Baker and Nummedal, 1978). These floods overwhelmed the Columbia River drainage system and sent up to 2500 km^3 of water across the Columbia Plateau with each outburst (called jökulhlaups). The floods created a spectacular complex of anastomosing channels cut into southwest-dipping basalt surfaces. They also formed huge cataracts now seen as dry falls, "loess islands" that are erosional remnants of an early thick loess cover on the plateau, immense gravel bars, and ice-rafted erratic boulders at high elevations (Fig. 3, 12B).

In a series of early papers (Bretz, 1923, 1925, 1928a,b,c, 1932), J Harlen Bretz shocked the geological community and precipitated one of the most celebrated scientific debates in American geology with his studies of this enormous series of proglacial channels eroded into the loess and basalt of the Columbia Plateau. This region, which he named the "Channeled Scabland," contains erosional and depositional features that are unique among fluvial phenomena. With painstaking field work, before the advent of aerial photographs and modern topographic maps, Bretz documented the field relationships of the region. He argued that the landforms could only be explained as originating from a relatively brief, but enormous flood, which he called the "Spokane Flood." Considering

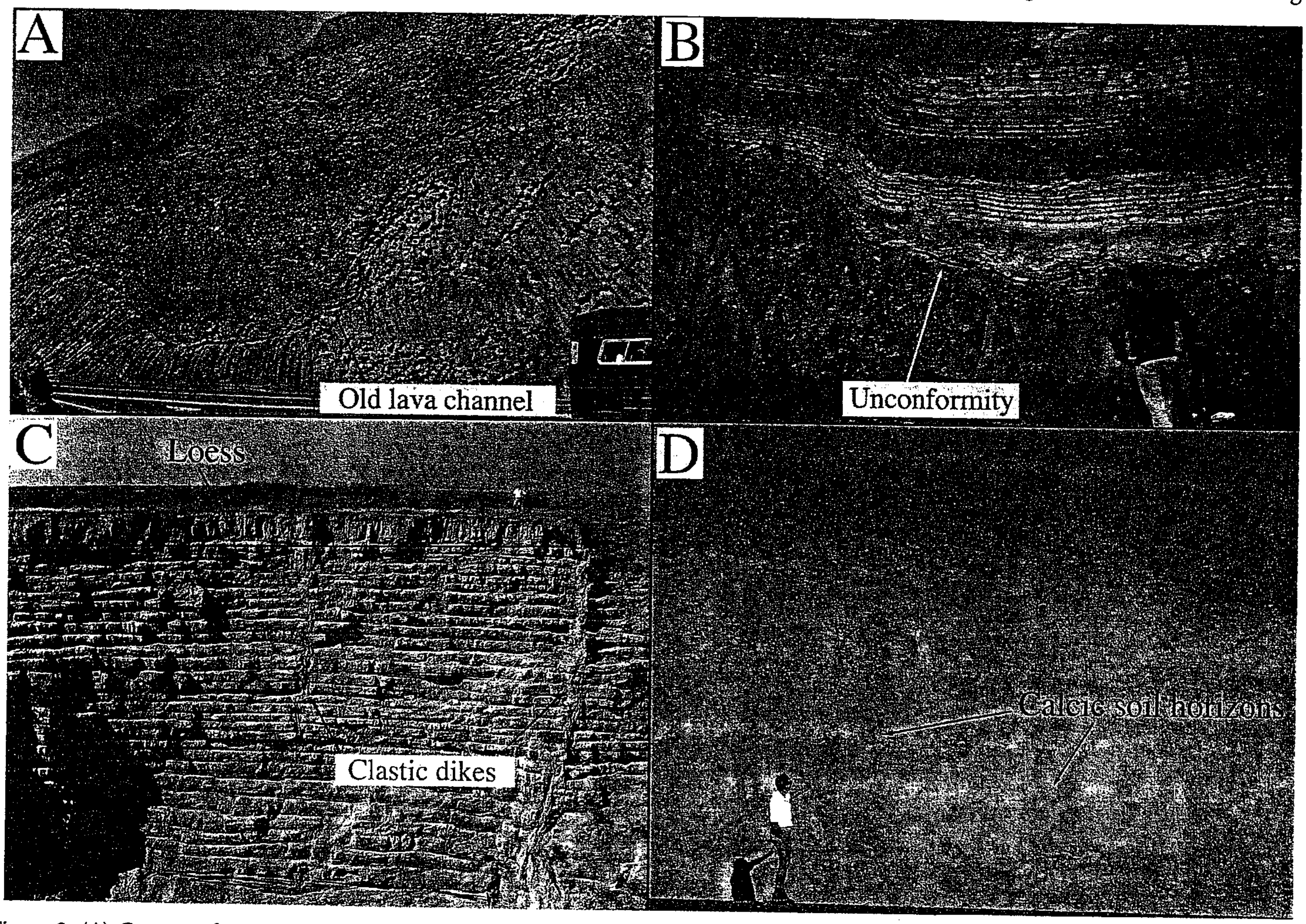

Figure 2 (A) Contact of intra-canyon lava flow with slightly older lava flow with well-developed columns. Both flows are part of the Miocene Columbia River Basalt Group. (B) Miocene sedimentary rocks deposited on unconformity developed within Columbia River Basalt Group. (C) Quaternary slackwater sediments (Touchet beds) deposited by backflooding of the Walla Walla Valley. Each horizontal layer represents a separate glacial outburst flood event. Touchet beds are overlain by 2 m thick loess bed with characteristic vertical prismatic structure. Entire sequence is cut by clastic dikes, thought to form by infill of surficial cracks (Alwin, 1970). Exposure is in Burlingame Canyon ~3km south of Touchet, Washington. (D) Multiple loess beds separated by calcic paleosol horizons. Exposure is on Hwy 12 ~3 km ENE of Walla Walla, Washington.

the nature and vehemence of the opposition to this outrageous hypothesis, the eventual triumph of his ideas constitutes one of the most fascinating episodes in the history of modern geomorphology (Bretz *et al.,* 1956; Bretz, 1969).

In south-central Washington State, the many paths of the onrushing floods converged on the Pasco Basin where floodwaters were slowed by the hydrologic constriction of Wallula Gap before draining out through the Columbia River Gorge to the Pacific Ocean (Figs. 1, 3). This caused *backflooding* up local river valleys and deposition of relatively fine-grained slackwater sediments characterized by rhythmically graded bedding (Bretz, 1928a,b,c); these graded rhythmites are locally called Touchet beds (Fig. 2c, cover), and multiple sets have been recognized (Flint, 1938). Waitt (1980, 1985) argued that each of about 40 Touchet beds resulted from separate catastrophic floods between 15,300 to 12,700 radiocarbon years B.P. Atwater (1986) determined that the interval between Missoula floods was 35-55 years based upon the number of flood deposits and varves in nearby glacial lakes. Mt. St. Helens "S" ash fell in eastern Washington about 13,000 years B.P., and is 10 rhythmites below the top of the Touchet beds, consistent with Waitt's (1985) age estimate. However, some researchers still prefer Bretz's original explanation of a single giant flood (Shaw *et al.,* 1999).

In recent decades, researchers have estimated the hydraulics of these giant flood flows (O'Connor and Baker, 1992; Smith, 1993) and explained the origin of many puzzling scabland features (Baker, 1973; Baker and Nummedal, 1978; Baker and Bunker, 1985). Other studies have shown that there were as many as 90 glacial floods (Waitt, 1980, 1984, 1985; Atwater, 1986) and that the floods were associated with not just one but at least six or seven major glacial advances in the Pleistocene (Patton and Baker, 1978). However, the detailed glacial stratigraphy is beyond the scope of the present paper.

Reworked Sediments/Loess

During the Holocene the prevailing southwesterly winds continued to rework Quaternary loess, slackwater, and other glacial sediments into the present thick blanket of loess (Fig. 2d) that covers much of the Columbia Plateau (45°30' to 48°N and 116°30' to 120°W). The core of this area, which is centered in eastern Washington, is called "The Palouse" (Fig. 1) and covers more than 10,000 km^2 with loess that is up to 75 m thick. Thinner and less continuous loess deposits cover an additional 30,000-40,000 km^2 in Washington, north central Oregon, and northern Idaho. As previously mentioned for the Quaternary, the presence of buried soils in the Holocene loess indicates that deposition was intermittent (Busacca, 1991).

Surface Soils, Columbia Plateau

Because of the Columbia Plateau's proximity to volcanoes of the Cascade Range, it is commonly assumed that the parent material of the loessial soils is predominantly volcanic tephra, or airborne volcanic material, and that the volcanic glass content of the soil is the cause of high susceptibility to wind erosion. However, the volcanic glass content is typically less than 8% in south central Washington (Fig. 4). In addition, the volcanic glass distribution in surface

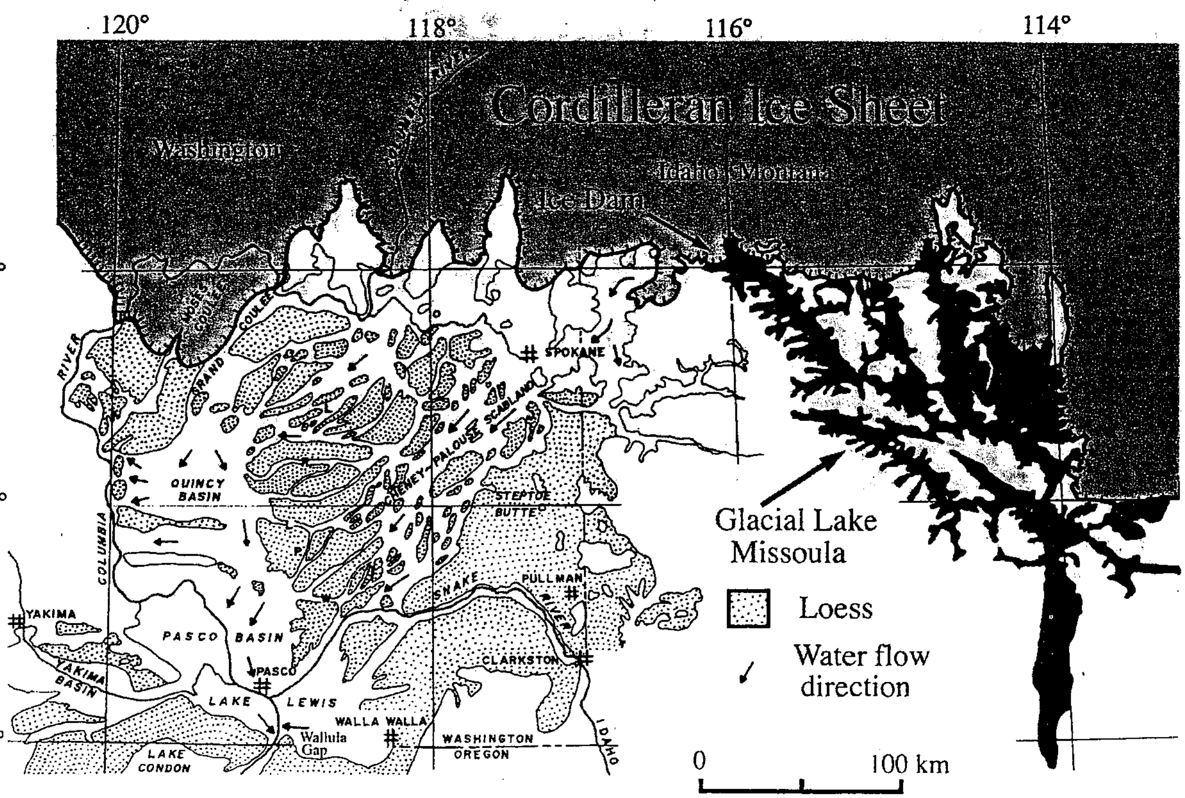

Figure 3 The Channeled Scabland of the Pacific Northwest showing Cordilleran ice sheet in its approximate position at 15,000 years before present, major outflow channels, and the distribution of loess. Modified from Baker and Nummedal (1978).

soils across the Plateau does not correspond to known patterns of tephra fallout from the 1980 Mt. St. Helens eruption. Electron microprobe analysis of glass composition confirms that the eruption of Mt. Mazama 6850 radiocarbon years B.P. contributed the majority of volcanic glass found in surface soils of the Columbia Plateau (Busacca *et al.*, 2000).

CLIMATE AND NATIVE VEGETATION

The climate of the Columbia Plateau is influenced to a great extent by prevailing westerly winds and by the Cascade and Rocky mountains. The Cascade Mountains create a rain shadow and as a result, the climate of the Columbia Plateau is arid to sub-humid (15-100 cm of mean annual precipitation; http://www.wrcc.dri.edu/climsum.html). The amount of precipitation closely correlates with elevation, generally increasing from west to east and southeast as elevation increases. The Rocky Mountains protect the Pacific Northwest from the coldest of the arctic storms that sweep down through Canada and this affects both vineyards and native vegetation.

During the summer, high pressure systems prevail in the Pacific Northwest, leading to dry, warm conditions and low relative humidity. Average afternoon temperatures in the summer range from 20°C to more than 35°C (http://www.wrcc.dri.edu/climsum.html). Most of the growing season is very dry and some vineyards experience no measurable precipitation during the summer months. The rainy season extends from October to late May or June, as frontal storms sweep across the area. In eastern Washington, most of the precipitation from mid-December to mid-February is in the form of snow.

Pre-agricultural Vegetation

As a result of the rainshadow and elevation effects, pre-agricultural vegetation in southeastern Washington ranged from sagebrush-steppe in the driest areas, to meadow steppe in areas of intermediate precipitation, to coniferous forest in areas of highest precipitation (Daubenmire, 1970). Xerophytic (drought tolerant) shrubs include several species of *Artemisia*, *Purshia*, and *Crysothamnus*. Perennial grasses include the major species bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*), Sandberg bluegrass (*Poa sandbergii*) and a host of less common annual and perennial grasses and forbs. Mesophytic (moisture loving) shrubs include *rosa* spp., Serviceberry (*Amelanchier alnifolia*), and Snowberry (*Symphoricarpos albus*). Several zones of conifer vegetation have been recognized with increasing effective moisture and decreasing temperature (Daubenmire and Daubenmire, 1984); no zone of hardwoods is interposed between steppe and conifer habitats. The semiarid climate and steppe vegetation which have persisted throughout the Quaternary Period, have produced the Aridisol and Mollisol soils that form the backbone of Washington State wine grape production.

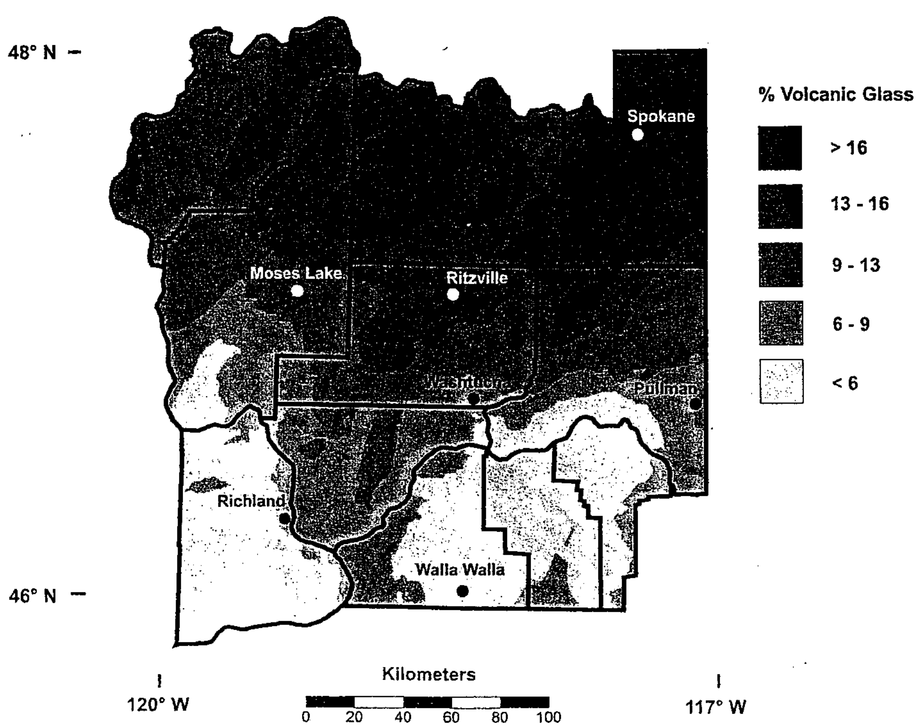

Figure 4 Map of volcanic glass content of Columbia Basin loess soils. From Busacca *et al.* (2000).

Climate and *Terroir*

Climate is one of the more important components of *terroir*. In some ways it is the most difficult to evaluate because it varies in both space and time. Adjacent vineyards may have quite different microclimates owing to factors such as wind direction, elevation, slope, and angle to the sun. Several of these factors can change within a single season and/or from year to year. For example, in years that are relatively warm and dry, vineyard "X" with a particular slope, elevation, sun angle, and soil type may produce better wine than vineyard "Y," whereas the reverse may be true in years that are cooler and wetter.

There are many weather variables that can be measured to describe the overall viticultural climate, such as average temperature during the growing season (warm temperatures promote plant growth and ripening), minimum temperature in winter (temperatures significantly below freezing can damage plant tissue and kill vines), and variation of temperature between day and night (cool nights preserve grape acidity).

Degree Days

Perhaps the most widely used temperature measurement is the concept of "degree days" (also called day-degrees, heat units, or heat summation) which is based on the observation, first made by de Candolle (1855), that relatively little plant growth and grape ripening occurs below 10°C (50°F).

Standard degree days are calculated based upon the amount of time above the 10°C (50°F) threshold. Conversion of degree days between °F and °C is difficult due to the variable number of days in a given summation. For example, if the mean temperature for a day, week, or month is 25°C, this would correspond to 15 (1x15), 105 (7x15), or 450 (30x15) degree days (°C), respectively (Winkler, 1936). The total degree days are summed for the entire growing season (sometimes approximated by April-October in the northern hemisphere) and the resulting number can be used to subdivide viticultural areas into five broad Regions: I (<2500°F day-degrees), II (2501-3000°F day-degrees), III (3001-3500°F day-degrees), IV (3501-4000°F day-degrees), and V (>4000°F day-degrees). Table 3 summarizes degree day information for representative viticultural regions of the world: Washington State vineyards are mostly in Winkler regions II and III. Annual variations for a particular Walla Walla Valley vineyard are shown in Figure 5. The concept of degree days can be further modified by excluding temperatures above 30°C when plant growth slows (Chas Nagel, written communication, 2000), or including only the time period from fruit ripening to harvest (Andrew Reynolds, written communication, 2000).

Table 3 Temperature summation during the growing season for representative viticultural regions of the world (data from Amerine *et al.*, 1980; Norm McKibben, written communication, 2000; Markus Keller, written communication, 2000; Dejan Tesic, written communication, 2000; and, for the Niagara Peninsula, the Niagara Agricultural Weather Network, St. Catharines, Ontario, Canada). Degree days °F and °C are not strictly convertible due to variable number of days of measurement, but approximately: degree days °C = degree days °F * 0.554.

Place	Degree Days (10°C)	Degree Days (50°F)	Winkler Region
Algiers, Algeria	2880	5200	V
Fresno, California	2590	4680	V
Hunter Valley, Australia	2340	4220	V
Naples, Italy	2220	4010	V
Davis, California	2000	3620	IV
Florence, Italy	1950	3530	IV
Walla Walla, Washington (high)	1830	3300	III
Napa Valley, California	1820	3280	III
Barossa Valley, Australia	1710	3090	III
Asti, Italy	1650	2980	II
Walla Walla, Washington (low)	1480	2670	II
Coonawarra, Australia	1450	2620	II
Niagara Peninsula, Canada	1440	2590	II
Bordeaux, France	1400	2520	II
Burgundy, France	1330	2400	I
Hawke's Bay, New Zealand	1300	2350	I
Otago, New Zealand	1000	1800	I
Geisenheim, Germany	950	1710	I

Related Climatic Factors

Minimum temperatures are also of interest in Washington State, such as during the depths of winter, during bud break and fruit set in the spring, and during grape ripening (*véraison*) in the summer. Temperatures that are too cold can kill new vine growth or even the entire plant. This occurs in some vineyards in Washington about once a decade, and was responsible for the drastic drop in grape production in 1996 (Table 2).

Another measure of climate is continentality, which is defined as the difference between mean July and January temperatures (reversed for the southern hemisphere). For most Washington vineyards the continentality index is about 23°C, which is on the high end of regions with a typical Mediterranean climate of winter rain and summer drought, that is generally favourable for wine grapes. Some wineries have used the latitudinal similarity of Washington vineyards to suggest similarities of wine characteristics to famous European viticultural areas such as Burgundy and

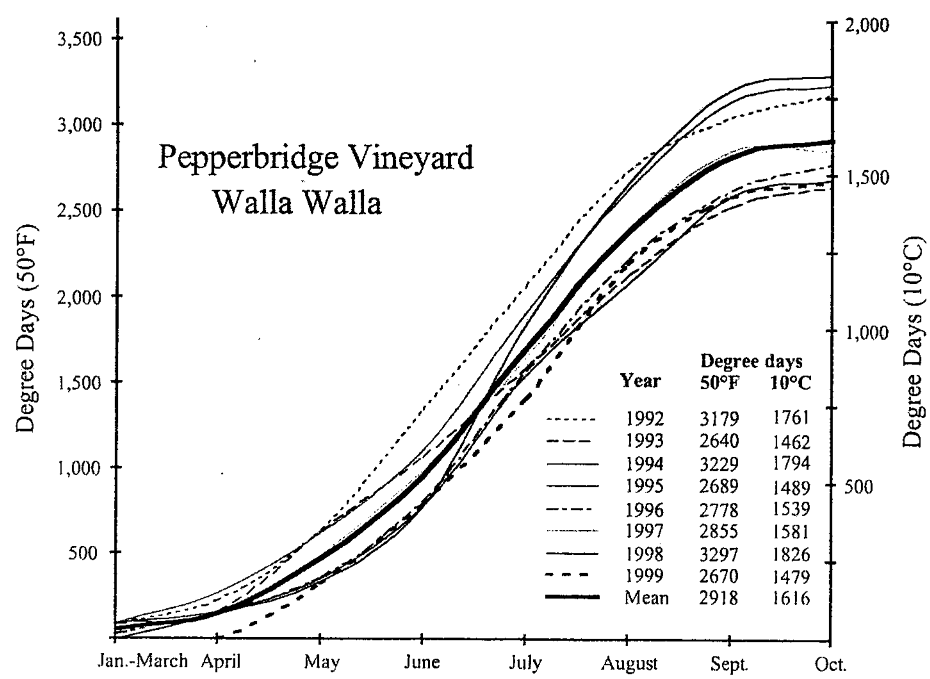

Figure 5 Annual variations in accumulated growing degree days for the Pepperbridge Vineyard in Walla Walla Valley. Data from Norm McKibben (co-owner, written communication, 2000).

Bordeaux or even Germany, but the degree day information in Table 3 makes it clear that even though the Walla Walla Valley of Washington State occurs at high northerly latitudes, it is in fact a warmer climate than comparable latitudes in Europe.

Most of the vineyard areas in Washington State are also blessed with abundant sunshine, due to the long summer days of northerly latitudes and to the generally cloud-free conditions during much of the growing season. During summer months most Washington vineyards experience more than 90% sunny days without measurable precipitation, in contrast to the generally cloudier conditions that prevail in much of northern Europe. Sunshine, precipitation and soil fertility are the natural controls on grapevine growth, but there are additional steps that can be taken in the vineyard to optimize the quality and/or quantity of the grapes produced. This is generally termed "canopy management" (control of the growing parts of the vine such as leaves and canes).

Importance of *Terroir*

There are a multiplicity of factors that contribute to the total quality of the grape that is then used as the raw ingredient in the process of making fine wine. To focus on a single factor of temperature, sunshine, rainfall, soil, bedrock, or viticultural practice, is to miss the essential synergy that marks the difference between an average wine and one that is exceptional. This is not to say that any one component is *insignificant*, but merely to assert that no one factor is *transcendent*. Thus, we return to the essential character of the term *terroir* in its influence on the quality of the grape and hence the quality of the wine. Lest this seem an impossible task, one has only to taste a single example of magnificent wine to be motivated to try to understand *terroir*. To better understand the concept of *terroir* in Washington State, the rest of this paper will focus on a single *appellation*, the Walla Walla Valley, and the features of geography, geology, pedology and climate that make it such a special place.

THE WALLA WALLA VALLEY *APPELLATION*

Walla Walla is a Native American name meaning "many waters" or "small, rapid streams." Many diverse tribes, including the Walla Walla, Nez Perce, Cayuse and Umatilla, inhabited the region prior to European settlement. The Walla Walla Valley was one of the first areas between the Rockies and Cascades to be permanently settled. Lewis and Clark traveled through the area in 1805 and 1806 as part of the initial exploration of the American West. Fur traders carved out early settlements, trading posts, and forts in the early 1800s. With the lure of nearby gold in the Blue Mountains in 1860, Walla Walla quickly became a commercial, banking and manufacturing center, and soon became the largest city in Washington Territory. The City of Walla Walla was incorporated in 1862. After the gold rush ended, farming anchored the community and remains vital to the current economy. Early settlers planted wine grapes for personal vinification and consumption but no commercial production was attempted. Some of these now-wild vines can still be found, such as near the junction of Prunedale Road and County Road 517 south of Walla Walla (Gary Figgins, oral communication, 2000). In addition to wine grapes, the Walla Walla Valley is a major production area of alfalfa seed in the United States. Ground-dwelling native alkali bees are required to pollinate the alfalfa flowers and may also be important for wine grapes. The Green Giant cannery (now owned by Seneca) in Dayton on the edge of the Walla Walla Valley is the world's largest asparagus cannery, and formerly was a world leader in peas as well (Donald Turner, Manager of the Port of Columbia, oral communication, 2000). Thus, the Walla Walla Valley is in many ways a hub of agricultural activity in the state of Washington.

Location and Geology of the Walla Walla Valley *Appellation*

The Walla Walla Valley *appellation* is defined by elevation contours on the south and east and by lines approximating drainage divides on the west and north (Fig. 6). The valley is underlain by Miocene basalt flows of the Columbia River Group, consisting of parts of the Saddle Mountains, Wanapum and Grande Ronde formations, from youngest (~8.5 Ma) to oldest (~16.9 Ma) (Schuster, 1994). These units are exposed only in deep stream-cut valleys, but do crop out to the south and east on the slopes rising to the Blue Mountains (Figs. 2a, 7).

Overlying the basalt in the Walla Walla Valley are Quaternary sediments consisting of loess, dune, and flood deposits related to glacial processes, and alluvium from the streams that drain the Blue Mountains and the valley itself. As described previously, the draining of glacial Lake Missoula in Montana created cataclysmic floods across eastern Washington that scoured much of the scabland topography and backflooded the Walla Walla Valley. Sediments deposited from these slackwaters range from gravels near Wallula Gap on the western side of the valley, to massive silts and sands with local bedding in the central and eastern parts of the valley (Figs. 2c, 7). On the higher slopes above the slackwater deposits are thick mantles of loess (Fig. 2d). Rivers and streams have downcut into the loess and slackwater deposits during the Holocene (last 10,000 years) and, in some cases, the underlying basalts, to yield an overall dendritic pattern of Quaternary sedimentation (Fig. 7). Terrace remnants of the rhythmically bedded slackwater deposits form "islands" within the modern drainage network (Fig. 11b). Present-day drainages and flood plains consist of a mixture of reworked loess, slackwater deposits, and basalt (Carson and Pogue, 1996). Most of the basaltic cobbles are restricted to the larger streams that can carry relatively fresh pieces of basalt from the surrounding hillsides.

Soils of the Walla Walla Valley

Each of the rock units in the Walla Walla Valley is associated with distinctive soils, some of which are excellent for the production of wine grapes and some of which are not suited at all to grape production. Because of this, geographically adjacent vineyards can exhibit radically different *terroir* even though their major climatic features may be very similar.

Figure 8 is a generalized map of the associations or general groupings of major soils in the Walla Walla Valley. Detailed soil surveys for Walla Walla County, Washington (Harrison *et al.*, 1964), and Umatilla County, Oregon (Johnson and Makinson, 1988) name more than 75 different soils in the area. Many of the soils share a number of properties such as silty textures and a mixed mineralogy. Silty textures are characteristic of some of the slackwater sediments, of the loessial soils that were derived by wind reworking of these sediments (Busacca and McDonald, 1994), and of some of the alluvial soils that were formed by water erosion and transport of the same materials into valley bottoms. Similarly, a mineralogy dominated by quartz, feldspars, micas, and illitic clays is characteristic of the slackwater sediments and thus of the loessial and alluvial soils as well (Busacca, 1991). Composition and mineralogy of typical loess and slackwater soils are contrasted with underlying Columbia River Group basalt and granite boulder erratics in Table 4. The lack of correlation of the composition and mineralogy of the basalt with the overlying loess and slackwater soils (Table 4) reinforces the concept that almost all of the eastern Washington soils are ultimately derived not from basaltic bedrock but from glacial material related to the outburst floods, including ice-rafted boulders, water-born sediments, and wind-reworked sands. Not each one of the 75 soils found in the region is different enough to create a distinctive *terroir* for grape production; nevertheless, when grouped into the eight associations shown in Figure 8, several contrasts in soil properties become apparent that affect the choice of optimal grape varietal and the qualities of the wine produced. Note that the general soil map units in Figure 8 contain multiple soil series and that in some cases, a soil series occurs in more than one general soil map unit.

Walla Walla Valley Appellation *Soil Groups with Wine Production*

Soils in **map unit 1** (Fig. 8) are cobbly, loamy, and silty soils formed in recent alluvium on flood plains and terraces of the Walla Walla River and its tributary streams such as Dry Creek, Mill Creek, and Cottonwood Creek. Soils such as the Freewater and Yakima are deep, well drained to excessively drained, and formed in cobbly alluvium along ancestral channels of the Walla Walla River. These have beer planted intensively for many years to apples and other orchard crops. These soils are very low in organic matter, are very well drained, and have no water table, so grape vigour can be controlled successfully with water and nutrient management. Catherine and related soils are formed in silty alluvium,

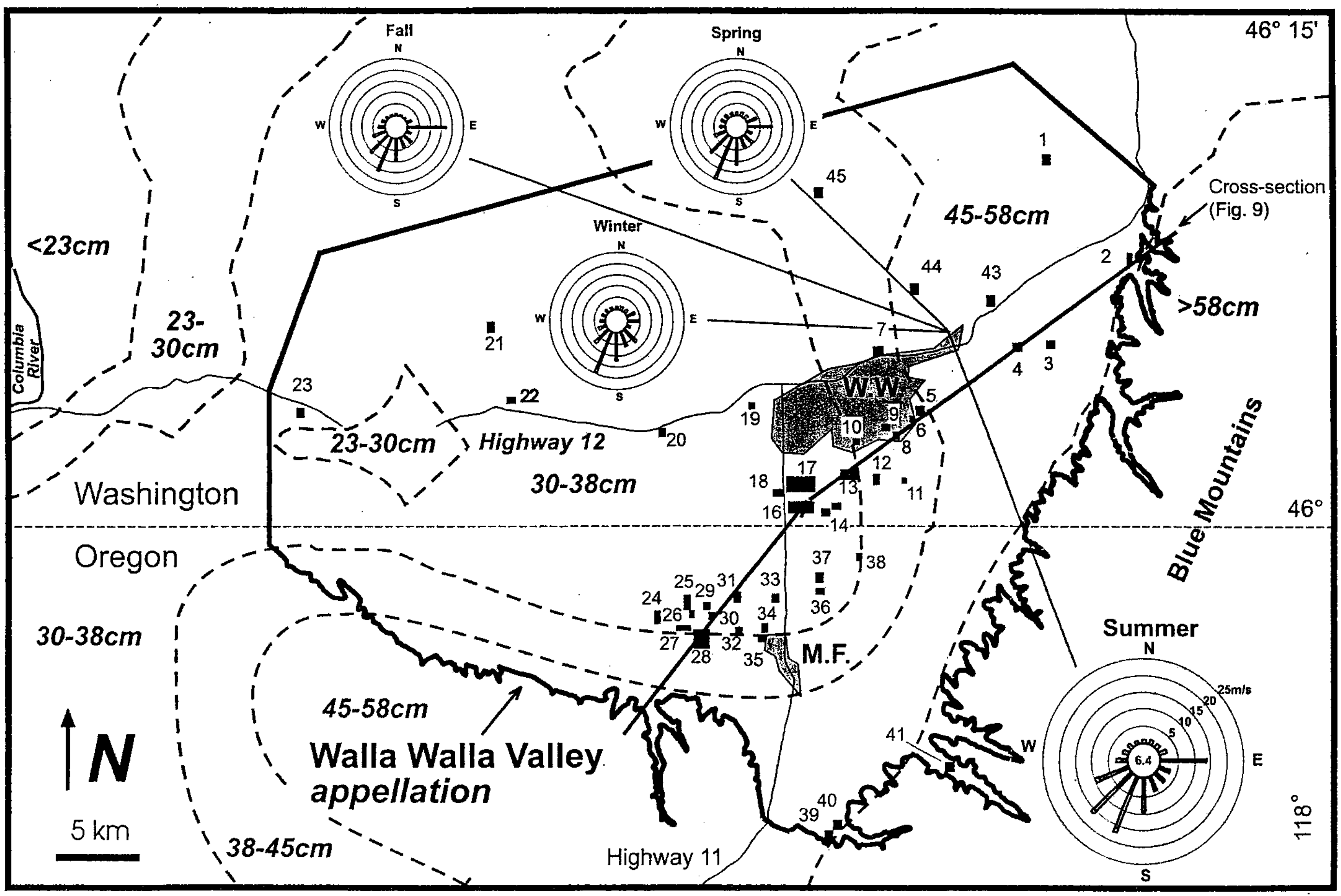

Figure 6 Precipitation, wind velocity in metres/second, and location of vineyards within the boundaries of the Walla Walla Valley *appellation*. Vineyard information in Table 4. Bars on wind roses represent percentage of the time that winds of a given velocity blew from the compass direction shown. Value in the centre of the wind rose is the percentage of time in the season that there was no sensible wind. Wind roses generated from PAWS (Public Agricultural Weather System) data at http://index.prosser.wsu.edu for the Walla Walla weather station at Latitude 46.06, Longitude 118.27, for the period July 1992 to December 1999. Precipitation contours modified from Oregon Climate Service (http://www.ocs.orst.edu/pub/maps/Precipitation/Total/Regional/West/westus_precip.GIF). WW = city of Walla Walla.

are somewhat poorly drained, have higher organic matter contents than do Freewater soils, and have a seasonal water table that has formed mottles in the lower part of the soil. Soils like the Ahtanum are similar to the Catherine soils but are not suited to grape production because of a saline-alkali condition and a hardpan at shallow depth.

Soils in **map unit** 3 are silty and formed in loess that overlies stratified slackwater sediments from cataclysmic outburst floods. These soils are located mainly to the northwest of Walla Walla and generally receive between about 23 cm and 30 cm of mean annual precipitation (Fig. 6). Where the loess is greater than 150 cm thick, soils of the Ritzville series are recognized, which have deep, uniform silty profiles and low organic matter content. Where the loess is about 60 cm deep over stratified flood sediments, Ellisforde soils occur. The Woodward Canyon Vineyard (#21, Fig. 6, Table 5) is planted on Ellisforde and related soils. The characteristics of these soils are similar to those of the Sagemoor and Sagehill series in map unit 4. Cost of water development may limit the development of these soils for vineyards, as rainfall is insufficient for dryland production on these upland soils.

Soils in **map unit** 4 have been and are being intensively developed for vineyards, particularly to the south and southeast of Walla Walla. The soils formed in thin to thick loess overlying slackwater sediments on flat-topped, dissected terraces. These soils are silty and uniform in texture down to the fluvial sediments, and consist of stratified sands and silts below that. They have low to moderate contents of organic matter. The soils receive from 30 cm to 45 cm of annual precipitation (Fig. 6). Soils of the Sagemoor, Ellisforde and Sagehill formed in only about 50-75 cm of loess over stratified sediments. Erosion on the sideslopes of terraces in these soils commonly exposes white subsoil carbonates in the slackwater materials. Soils of the Oliphant series formed on about 125 cm of loess overlying stratified sediments. Soils of the Walla Walla and Athena series formed on more than 150 cm of loess and may or may not be underlain by slackwater sediments.

The soils in **map unit** 7 are also formed in deep silty loess on uplands. Soils in this map unit, such as the Athena, Palouse, and Calouse, are differentiated from those in unit 6 mainly in receiving more rainfall, about 38-58 cm annually (Fig. 6), which has promoted lush growth of the native bunchgrasses and allowed them to accumulate large amounts of organic matter. The Athena and Palouse soils are the classic Mollisols (prairie soils) of dryland grain production in eastern Washington State. Only one vineyard, the Mill Creek Upland Vineyard (#3, Fig. 6, Table 5), has been planted on these

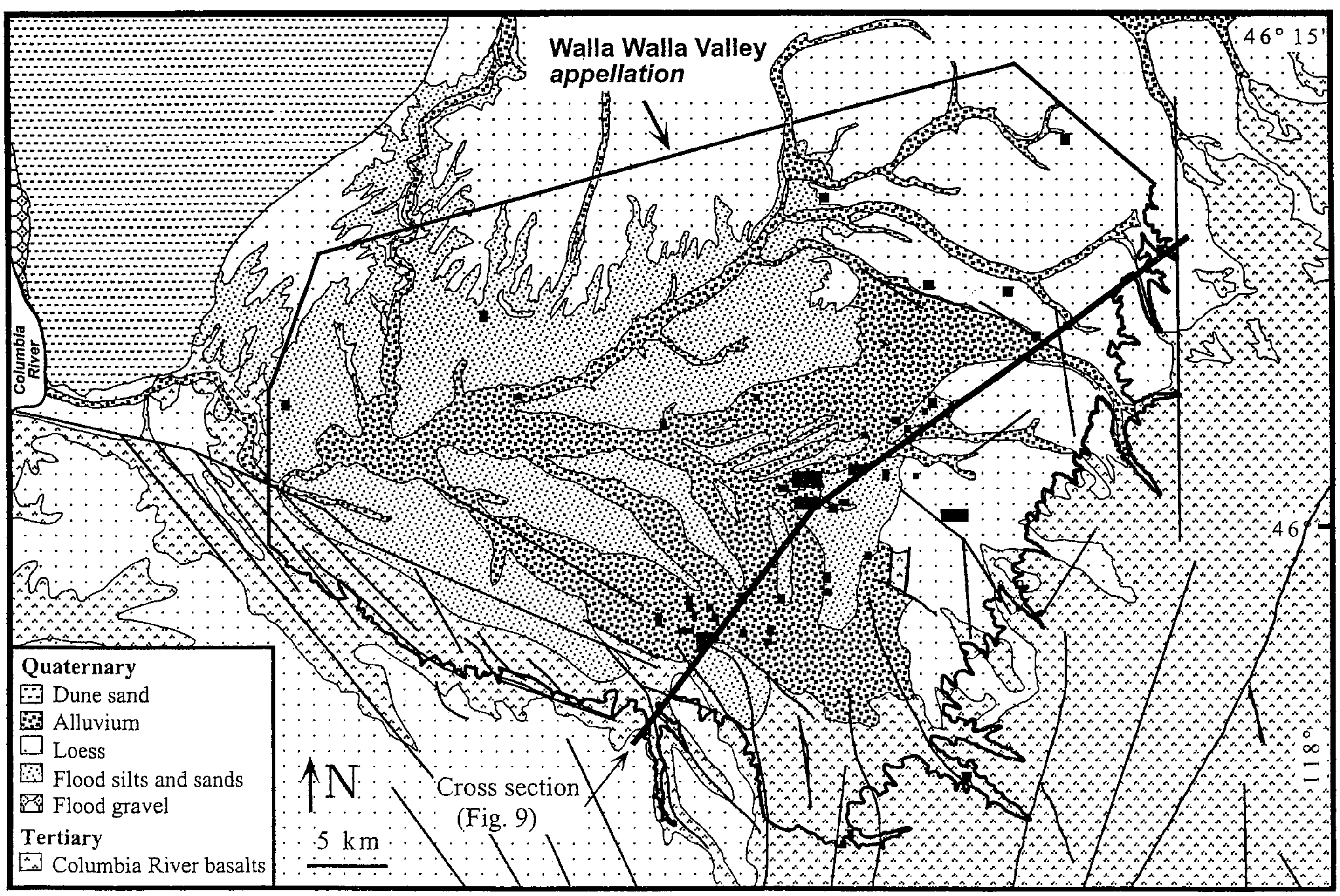

Figure 7 Surficial geology of the Walla Walla Valley region. Modified from Schuster (1994) and Schuster *et al.* (1997). Vineyards are identified in Figure 6 and Table 4.

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soils at the present time; however, these soils may have potential for further vineyard development because of favourable soil moisture and other soil properties.

Walla Walla Valley Appellation Soil Groups Mostly Lacking Wine Production

Soils in map unit 2 lie along floodplains to the west of Walla Walla and are poorly drained, saline-alkali soils unsuited to grape production. The saline-alkali conditions result from excessive evaporation and wicking of salts from a standing water table at shallow depth. The Three Rivers Vineyard (#20, Fig. 6, 12f, Table 5) is on well-drained terrace soils close to these marginal alkaline soils.

Adkins and Quincy soils dominate the area of map unit 5 on the lower end of Eureka Flat to the northwest of Walla Walla (Fig. 8). These soils are well drained to excessively drained and formed in dune sands under less than 30 cm of rainfall (Fig. 6). No wine grapes are planted on these soils at the present time, although several thousand acres of table and juice grapes are plantcd on these soils along the Snake River outside the Walla Walla Valley *appellation* area.

Soil Groups Mainly or Completely Outside the *Walla Walla Valley* Appellation

Walla Walla and Ritzville series soils, formed in deep loess on uplands to the north and south of the Walla Walla Valley (Fig. 8), are the major soils in map unit 6. These soils receive from about 23 cm to 38 cm of annual rainfall, depending on location (Fig. 6). These soils have a uniform silty texture to more than 150

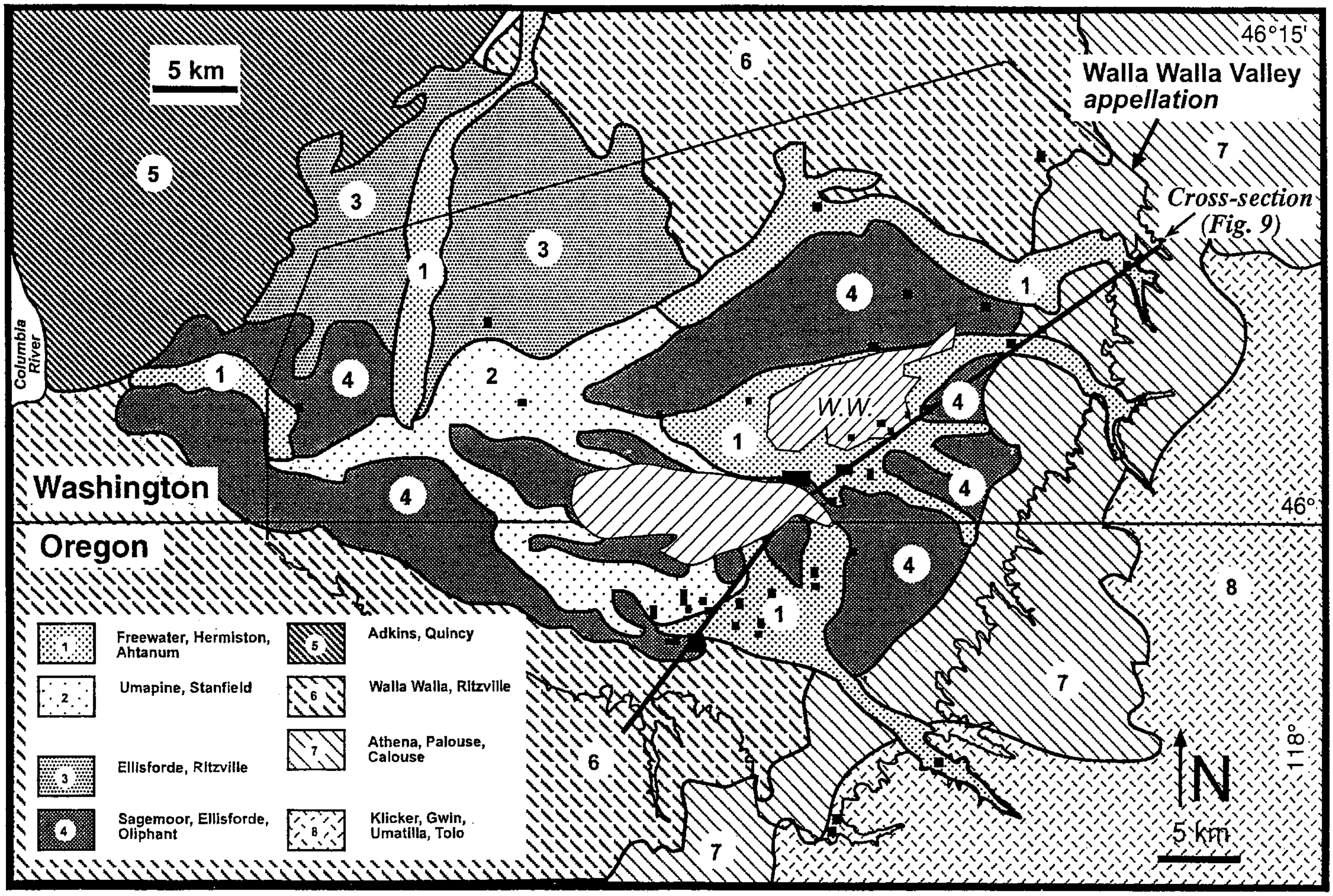

Figure 8 Generalized map of the soil associations of the Walla Walla Valley region. Modified from Harrison *et al.* (1964) and Johnson and Makinson (1988). Note that only one to three soil series are named for each association, although other soil series can and do occur in the associations. For example, a variant of the Athena soil series with slackwater sediments deeper than 150 cm occurs in unit 4, but it also is dominant in unit 7 where it is a named component. **Unit 1**: Freewater, Hermiston, Ahtanum: Cobbly to loamy, moderately well to well drained soils formed in alluvium, on floodplains and low terraces. **Unit 2**: Umapine, Stanfield: Loamy to silty, poorly drained saline and alkali soils formed in alluvium, on floodplains and low terraces. **Unit 3**: Ellisforde, Ritzville: Silty, well drained soils formed in thin to deep loess overlyng stratified silty to sandy outburst flood deposits, on dissected terraces and uplands. **Unit 4**: Sagemoor, Ellisforde, Oliphant: Silty, well drained soils formed in moderately deep to deep loess overlying stratified silty to sandy outburst flood deposits, on dissected terraces. **Unit 5**: Adkins, Quincy: Sandy, excessively drained deep soils formed mainly in dune deposits on high terraces. **Unit 6**: Walla Walla, Ritzville: Silty, well drained soils formed in deep loess on uplands in 20-38 cm rainfall zone. **Unit 7**: Athena, Palouse, Calouse: Silty, well drained soils formed in deep loess on uplands in 38-58 cm rainfall zone. **Unit 8**: Klicker, Gwin, Umatilla, Tolo: Loamy to cobbly, well drained soils formed mainly in loess, volcanic ash, and basaltic bedrock, on steep mountain slopes. WW = city of Walla Walla

Table 4 Comparison of chemical composition and mineralogy of representative samples of vineyard soil, loess, slackwater sediment, granitic glacial erratics, and Columbia River Group basalt. Data from Ross (1989), McCreery (1954), and the present study.

Unit	Basalt	Granite erratic	Touchet 2m below loess	Touchet 5m below loess	Loess regular	Loess calcic	Loess soil
Location	1	2	3	3	4	5	6
SiO_2	54.08	67.07	63.55	67.16	63.51	56.65	63.80
Al_2O_3	13.58	15.90	13.75	12.99	14.26	12.16	13.94
TiO_2	2.94	0.54	1.14	1.11	1.24	0.78	1.22
FeO(t)	13.20	3.90	5.64	2.44	6.73	4.32	6.16
MnO	0.21	0.11	0.11	0.04	0.12	0.07	0.12
CaO	6.45	4.20	4.50	2.49	2.88	10.00	3.14
MgO	3.13	1.54	2.43	1.15	1.96	1.87	2.02
K_2O	2.41	3.37	2.22	2.62	2.22	1.71	2.35
Na_2O	3.20	2.87	2.21	2.10	2.08	1.72	2.08
P_2O_5	0.80	0.26	0.25	0.47	0.24	0.15	0.26
L.O.I.	n.d.	n.d.	4.03	7.26	4.58	10.38	4.73
	100.00	99.77	99.81	99.83	99.82	99.83	99.82
Ni	n.d.	20	36	18	27	27	26
Cr	6	14	59	41	51	53	46
Sc	26	5	21	13	18	12	18
V	233	69	141	91	149	84	145
Ba	2848	848	704	636	668	626	673
Rb	43	119	82	82	84	63	81
Sr	268	754	280	246	263	355	265
Zr	415	186	277	282	268	262	264
Y	43	27	35	31	36	28	34
Nb	23	18	16	15	15	15	15
Ga	23	19	15	17	16	14	17
Cu	0	5	24	21	28	20	22
Zn	117	58	76	63	88	61	87
Pb	n.d.	12	17	10	16	9	17
La	n.d.	38	30	32	29	38	37
Ce	n.d.	58	60	74	70	72	69
Th	n.d.	10	13	11	12	8	10
quartz	0	25	30	30	40	40	40
orthoclase	0	20	0	0	12	10	12
plagioclase	48	43	1	1	2	1	2
olivine	2	0	0	0	0	0	0
pyroxene	21	3	<1	<1	<1	<1	<1
amphibole	0	3	<1	<1	2	2	2
muscovite	0	1	8	8	10	10	10
biotite	0	3	7	7	9	9	9
Fe-Ti oxides	11	1	0	0	1	1	1
apatite	1	1	0	0	n.d.	n.d.	n.d.
clay	2	0	10	10	10-15*	10-15*	10-15*
calcite	0	0	3	3	n.d.	10	n.d.
glass	14	0	n.d.	n.d.	1	0	1
rock fragments	0	0	35	35	n.d.	n.d.	n.d.
other	1	0	1	1	6	5	6

1) Bear Creek member of Saddle Mountains Basalt, Ross (1989), 2) Seven Hills Vineyard (Fig. 15b), granitic glacial erratic, mineralogy estimated from CIPW norm, 3) Seven Hills Vineyard, mineralogy from Alwin (1970), Touchet bed WW 3-13, 4) Seven Hills Vineyard (Fig. 15a), mineralogy from McCreery (1954), 5) Lower calcic paleosol (Fig. 2d) ~3 km ENE of Walla Walla, mineralogy estimated from CIPW norm, 6) Seven Hills Vineyard, Block 16, * Montmorillonite>illite>kaolinite, n.d. = not determined

cm depth and low to moderate organic matter contents. No vineyards are planted within map unit 6 at this time; however, with irrigation to supplement the scant rainfall, these soils should be capable of producing quality wine grapes because low soil moisture and a favourable rooting zone should allow the grower to control vine stress with judicious irrigation.

Map unit 8 consists of soils that are not in vineyard development at this time. This unit is formed on steep slopes of the foothills of the Blue Mountains, and a wide variety of soils developed in loess, volcanic ash, and basaltic bedrock have been recognized.

Soils Summary

In summary, the soils of the Walla Walla Valley *appellation* have formed from four different types of surficial sediments or bedrock. Various combinations of soil parent materials and a strong gradient of mean annual precipitation across the *appellation* are key to determining vineyard potential performance. Soils formed from young alluvium vary tremendously in their properties, such as texture (cobbly to clayey), salt effects, and presence or absence of a water table within the rooting zone of vines. Soils formed from loess more than 150 cm deep are found around the margins of the Walla Walla Valley *appellation* and have dominantly silty, uniform soil profiles. Mean annual rainfall varies widely depending on location in the *appellation*, and this, along with slope steepness and aspect, determine suitability or potential for development of dryland or irrigated vineyards. Soils formed from thin to moderately thick loess overlying slack-water sediments have been the main focus of vineyard development up to the present time in the *appellation*. Finally, soils located on steep slopes of the Blue Mountains that have bedrock at shallow depth have not been fully evaluated to determine their potential for vineyard development.

Walla Walla Valley Vineyards

The first commercial vineyard planting in the Walla Walla Valley was in the early 1950s by Bert Pesciallo who produced wine from Black Prince, Muscatel and Concord grapes under the Blue Mountain Vineyards label. This was a short-lived

Table 5 Vineyards in the Walla Walla Valley *appellation* (data from Myles Anderson, written communication, 2000; Norm McKibben, written communication, 2000)

Map #	Name	Grapes	First planted	Owner
1	Spring Valley	m, cf, sy, cs, pv	1994	Dean & Sherry Derby
2	Biscuit Ridge	7 g, 1 cf	1982	Duane & Mary Wollmuth
3	Mill Creek Upland	11cs, 3m, 1sg, 1pv	1997	Gary Figgins
4	Titus Creek	3cs, 3sy, 1v	1999	Ken Harrison
5	Leonetti estate	m, sy, sg, cf	1974	Gary Figgins
6	Patrick M. Paul	cs	*	Mike Paul
7	Waterbrook	chard	1998	Eric & Janet Rindal
8	Keiler	m	*	Fritz Keiler
9	Myson	cs, m	*	Steve Paul & Mark Colvin
10	Whitney	cf	*	Mike Paul
11	Morrison Lane	sy	1985	Dean & Verdi Morrison
12	Forgotten Hills	m, sy, cs	1999	Jeff and Kathyrn Hill
13	Cottonwood Creek	5 cf, 28 c	1989	Scott Byerly
14	Pheasant Run	cs, m	1998	Greg Basail
15	Via Piano	m, cs,	1999	Justin Wiley
16	Pepperbridge south	m, cs, sy	1991	Premier Partners IV
17	Pepperbridge north	m, cs, sy	1999	Premier Partners IV
18	Double River Ranch	*	2000	Kyle Mussman
19	Bunchgrass	m, cf, sy, cs, pv	*	Roger Cockerline
20	Three Rivers	c	2000	Steve Ahler, Bud Stocking, Duane Wollmuth
21	Woodward Canyon	cs, m, cf, c, b, d	1977	Rick & Darcie Small
22	Dunham	cs	1999	Eric Dunham & family
23	Ash Hollow	9 merlot, 1 cs	1999	Matt Tucker
24	Windrow	cs	*	Scott & Rebecca Hendricks
25	Veterinarian	*	*	California veterinarian
26	Hart	*	*	Ken Hart
27	Seven Hills west	cs, m, sy	1985	Walla Walla Valley *Appellation*
28	Seven Hills east	m, cs, sy, sg, gv, cf, s	1997	Blue Mountain Farm
29	Cayuse	syrah	1997	Christophe Barón
30	Seven Hills west	cs, m, sy	*	Blue Mountain Farm
31	Caillouxe	sy, v	1997	Christophe Barón
32	Cerise	sy, v	1997	Christophe Barón
33	Lefore	cs, sg	1987	Jack Lefore
34	Lefore	*	1999	John Lefore
35	Waliser	cs, cf, m	1998	Tom Waliser
36	Vanessa's	m, cs, s	1999	Terry & Diane Farley
37	Farley	m, cs, s	1999	Terry & Diane Farley
38	Mint Condition	cs, m	1999	Bob Buchannan
39	Couse Creek	pn	*	*
40	Alder Banks	pn, c	*	Mike & Maryann Banks
41	Wells	pn	*	Sam & Nancy Wells
42	Les Collines	cs, m, sy	2000	Norm McKibben
43	Homestead	g	*	Steve Ahler & Jeff Kolke
44	Minnick	cs, m, cf, sy	2000	Laura Minnick
45	Valley Grove	*	*	Henderson Orchard

Wine abbreviations: b = Barbera, ca = Carignane, cf = Cabernet Franc, cs = Cabernet Sauvignon, c = Chardonnay, d = Dolcetto, g = Gewürtztraminer, gv = Grand Vidure, m = Merlot, pn = Pinot Noir, pv = Petite Verdot, s = Semillon, sb = Sauvignon Blanc, sg = Sangiovese, sy = Syrah, v = Viognier, * not known effort as a deep freeze in 1955 killed all the vines, and the winery did not reopen (Bert Pesciallo, oral communication, 2000). Commercial production did not resume in the Walla Walla Valley until 1974 when half an acre of Cabernet Sauvignon grapes was planted at the Leonetti homestead. Early success was assured when the first vintage, a 1978 Leonetti Cellars Cabernet Sauvignon, was pronounced the "best Cabernet Sauvignon made in America" by the Wine and Spirits Buyers Guide in 1982. At present there are about 45 vineyards supplying grapes to 32 wineries in the Walla Walla Valley *appellation* (Table 5.) Another 15 vineyards have been planted, with more planned (Myles Anderson, Director of the Walla Walla Institute for Enology and Viticulture, oral communication, 2000).

The vineyards of the Walla Walla valley are located on four fundamentally different substrates including slackwater terrace (Fig. 2c), loess (Fig. 2d), river gravel, and flood plain silt (Fig. 8). Of the 45 vineyards listed in Table 5, the majority are planted in loess either overlying deep bedrock basalt or as a thin veneer on top of slackwater deposits (Fig. 2c), which in turn overlie basalt. Figure 9 is a cross section through six representative vineyards illustrating the considerable range of terroir and microclimate in the Walla Walla Valley. These six vineyards and their settings may be described as follows.

Pepperbridge Vineyard

Since no vineyards in the Walla Walla Valley are located directly on basalt, the Pepperbridge Vineyard (#16, #17, Fig. 6; Table 5), planted in a thin mantle of loess overlying slackwater terrace deposits, is the stratigraphically lowest vineyard (Figs. 7, 9). The slackwater terrace deposits in this area range from 10-50 m in thickness and are mantled by 0-2 m of loess (Fig. 10). Given the ability of grape roots to penetrate to depths of 10 m or more in such unconsolidated sediments (observation made in construction trenches, roots at 4 m depth shown in Fig. 11e), most Pepperbridge vines are rooted in the slackwater deposits. Soils of the Pepperbridge Vineyard are in the Oliphant, Walla Walla, and Sagemoor series (Fig. 8, map unit 4). The low organic content and good drainage of these soils make it relatively easy to control vine vigour and grape yield with modern viticultural techniques, particularly drip irrigation (Fig. 11a). This setting and these techniques contribute to the fruit intensity and concentration of grape flavours for which wines made from this vineyard are known. The main grape varieties planted at Pepperbridge are Merlot (83 acres), Cabernet Sauvignon (72 acres), and Syrah (12 acres) (Table 5). In contrast, the immediately adjacent but overly fertile flood plain soils (Fig. 11b) do not produce grapes of the same quality because of strong vegetal flavours (Norm McKibben, oral communication, 2000). This is one of several places in the Walla Walla Valley where a direct connection can be shown between soil characteristics and wine quality.

Like most Walla Walla Valley vineyards, Pepperbridge is relatively dry (<50 cm annual precipitation), sheltered from wind, with intense sun exposure (1,400 W/m^2 of annual solar radiation), and moderate wintertime temperatures (Table 6). The long growing season in most years exceeds 3000 (50°F) degree days and yields fully ripe fruit with good tannins (Fig. 5). In addition, the low humidity further concentrates fruit flavours through evaporation. A standard measure of humidity is the mean for July measured at 9 a.m. For the Pepperbridge vineyard in 1999 the mean humidity for July at 9 a.m. was 50.5% at an average temperature of 20.7°C (Table 6).

Another important feature of the Pepperbridge Vineyard is good air drainage. The slackwater terrace deposits have been dissected by strands of the Walla Walla River so that the vineyards are elevated above the valley floor on slackwater terrace "islands" (Fig. 11b). This allows cold air to drain away from the vines, thus avoiding excessive problems with frost during the growing season.

Cottonwood Creek Vineyard

Less than one kilometre east of the Pepperbridge Vineyard, the Cottonwood Creek Vineyard (#13, Fig. 6; Table 5) represents a completely different *terroir*. Cottonwood Creek is located on fine silty sediments of the floodplain of Cottonwood Creek (Figs. 8, 9, 11c). The floodplain soils contain more humified organic matter and have poorer drainage than the slackwater and loess soils (#1, Fig. 8; Fig. 10). In some places the water table and infiltration from Cottonwood Creek saturate the sediments at relatively shallow depths, such as in the Catherine series soils. This means that deep-rooted grapevines can tap ground water during the growing season, making supplemental irrigation unnecessary in most years, but also making it more difficult to control the natural plant vigour (Fig. 11c). Uncontrolled plant vigour makes it difficult to fully ripen the crop in some years and also increases vineyard management costs in terms of pruning, spraying, and general canopy management (Scott Byerly, vineyard owner, oral communication, 2000).

The wet soils also warm more slowly in the spring, due to the high heat capacity of water, delaying new plant growth and further exacerbating the problem of ripening the grapes in a normal growing season. The main variety planted at Cottonwood Creek vineyard is Chardonnay, which has produced award-wining wine in some years, proving that even in this difficult location exceptional wine can be produced. But in general, grapes from this vineyard produce wines with pronounced vegetal characteristics such that in some years the grapes are sold to the bulk juice market rather than being made into wine (Scott Byerly, vineyard owner, oral communication, 2000). This is another vineyard in which a direct connection can be shown between geological characteristics and wine quality.

Caillouxe Vineyard

The Caillouxe Vineyard (formerly called Cobblestone Vineyard) (#31, Fig. 6; Table 5) further to the West is perhaps the most unusual *terroir* in Walla Walla Valley (Figs. 7, 10, 11). At this site, very coarse but well rounded cobbles (1-10 cm) of basalt make up the gravel bed of the Walla Walla River. The surface of the vineyard is literally a pavement of stone (Fig. 11d). The stony nature of the soil forces the grapevine roots to go deep in search of water (Fig. 11e), and calcic soil horizons add further stress to the grape plant. These gravelly soils have extremely good drainage so that like Pepperbridge, supplemental drip irrigation can be used or withheld to control vine vigour and grape yield. Typical yield from this vineyard is kept to about 2 tons per acre to concentrate the fruit flavours. The basalt cobbles also perform another function in that they soak up the sun's heat and radiate it back to the vines. The Caillouxe Vineyard is planted predominately to a single grape variety, Syrah, because Syrah is a heat-loving grape. *Vigneron* Christophe Barón has accentuated these unique *terroir* features by trellising the plants very close to the ground and the hot basalt cobbles (Fig. 11f). The wine produced from this vineyard is an extremely concentrated, flavourful Syrah with excellent tannins. In only the vineyard's second year it has already won awards and promises great things for the future.

Seven Hills Vineyard

One of the oldest (first planted in 1981) and most prestigious vineyards in the Walla Walla Valley is Seven Hills (#27, #28, Fig. 6; Table 5). The vineyard is on a gentle north-facing slope of loess (Fig. 7, 12a) overlying slackwater terrace deposits (Figs. 9, 12b). This southernmost location within the Walla Walla Valley benefits from the strong southwesterly prevailing winds, which promotes excellent air drainage and avoids frost problems. The loess soil is well drained and, like Caillouxe and Pepperbridge, allows supplemental drip irrigation to be used or withheld to control vine vigour and grape yield. The main grape varieties planted at Seven Hills are Cabernet Sauvignon (91 acres), Merlot (61 acres), Syrah (19 acres), and Sangiovese (9 acres), with a further 2.5 acres of Viognier planted for blending with Syrah to make a classic Rhone-style wine. Grapes from this vineyard have produced many of the award-winning wines from L'Ecole No. 41, Leonetti Cellars, Seven Hills, and Woodward Canyon wineries. The Leonetti Cellars reserve Cabernet Sauvignon, which some feel is one of the best red wines made in the United States, draws most of its fruit from the oldest vines of the Seven Hills vineyard (Fig. 12c). This bodes well for future vintages from this vineyard as the younger vines mature.

Mill Creek Upland Vineyard

On the other side of the Walla Walla Valley and at significantly higher elevation lie two vineyards of completely dissimilar character, Mill Creek Upland Vineyard (500 m; #3, Fig. 6; Table 5) and Biscuit Ridge Vineyard (550 m; #2, Fig. 6; Table 5). Mill Creek Upland Vineyard is a new effort by Leonetti Cellars, one of the pioneer wineries of the Walla Walla Valley. It is located on a moderately steep south-facing slope of very deep (>50 m) loess (Figs. 7, 9). The soils are in the Athena series (Figs. 8, 10). The steep hillside provides excellent air drainage making it virtually a frost-free location (Fig. 12d). The occurrence on the eastern side of the Walla Walla valley means that there is more natural precipitation (56 cm per year, Fig. 6) but the well-drained loess soils still allow supplemental drip irrigation to be used to control vine vigour and grape yield. Natural grape yield at this site is about 3.5 tons per acre but this is usually reduced to 2 tons per acre with a combination of irrigation practice, canopy management, and bunch thinning (Chris Figgins, vineyard manager, oral communication, 2000). In most seasons, no additional water is needed. The water budget of the vineyard is monitored by neutron probe soil sensors that allow the vineyard manager to carefully control soil moisture for optimum grape maturity and flavour concentration (Fig. 13). The neutron probe measures soil water content with depth (usually in 0.3 m increments) and allows the infiltration of irrigation water to be tracked through the soil profile (Fig. 13).

Biscuit Ridge Vineyard

This vineyard is similar to the Cottonwood Creek Vineyard in that it is located on a silty flood plain (Figs. 7, 9, 10). The easterly location also means that it has the highest rainfall of any of the Walla Walla vineyards. Cold air collecting in the

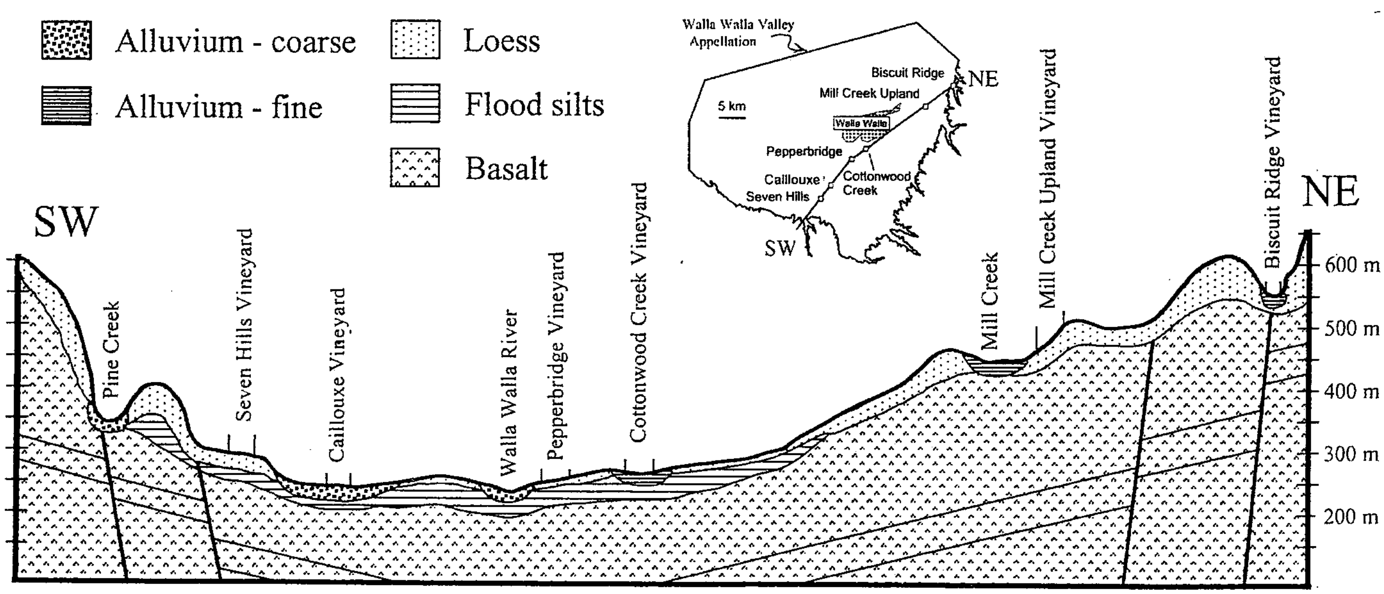

Figure 9 Cross section through Biscuit Ridge, Mill Creek Upland, Cottonwood Creek, Pepperbridge, Caillouxe and Seven Hills vineyards. Vertical exaggeration 25x. Thickness of surficial units is not to scale.

canyon bottom can be a problem for frost, and the high elevation (550 m) results in one of the coolest microclimates in the Walla Walla Valley (Fig. 12e). This vineyard is best known for Gewürztraminer, a grape that thrives in cool climates such as the Alsace region on the French-German border.

CONCLUSIONS

The range of grapes grown in the six vineyards summarized in the previous section illustrates the variability of microclimate and *terroir* of the Walla Walla Valley. In this relatively small *appellation* within the much larger Columbia Valley *appellation* of Washington State there is as much variation as is seen in entire regions, and in some cases, entire countries, in other parts of the world. It cannot be said that a single variable of bedrock, soil type, precipitation, or temperature is essential for fine wine in Walla Walla. But it is very clear that there is a direct correlation between the *terroir* and the grape varieties and wine styles that do best in a particular location. For example, the Biscuit Ridge Vineyard produces outstanding Gewürztraminer but probably could not fully ripen Cabernet Sauvignon or Syrah in even the warmest vintage of the century. Conversely, the Seven Hills vineyard, which is acclaimed for Cabernet Sauvignon, Merlot, and Syrah, is not as favorable for Chardonnay, much less for a cool climate grape such as Gewürztraminer.

Based upon the quality of wines produced from different *terroirs* in Walla Walla Valley there are a few generalizations that can be drawn to guide future grape plantings. One of the key considerations is controlling the natural vigour of the grape vine so that the resulting wine has concentrated fruit and a complex flavour profile. The generally low precipitation of the Walla Walla Valley, combined with soils formed from well-drained loess, slackwater sediments, and cobbly alluvium, provide the dominant control on plant vigour and yield. Judicious application or withholding of supplemental irrigation water allows the vineyard manager to restrict yields and optimize the quality of the grapes produced. The highest quality vineyards in Walla Walla Valley are managed for yields of only 2-3 tons per acre, in contrast to the state-wide average of 4-5 tons per acre (Table 2). The extended daylight hours due to the northerly location combined with generally sunny, arid conditions (1500-1800°C degree days) promote grape ripeness and the generation of intensely flavoured wines (Keller *et al.*, 1998). The cool nights, due both to elevation and latitude, preserve natural grape acidity to produce crisp wines with long complex finishes.

Within these overall characteristics of the Walla Walla Valley, the increase in precipitation from west to east and the differences in organic content, level of the water table, and drainage characteristics of the loess, slackwater, flood plain, and river gravel soils provide individual *terroirs* of distinction that vary in their suitability for particular grape varieties. As an example of this, the Pepperbridge Vineyard, developed on loess overlying slackwater deposits, is planted with classic Bordeaux varietals such as Cabernet Franc, Cabernet Sauvignon and Merlot, whereas immediately adjacent flood plain soils (Fig. 11b) do not produce grapes of the same quality. Instead, these flood plain soils are planted with vidalia onions, a crop known locally as Walla Walla Sweets, for which the region is also

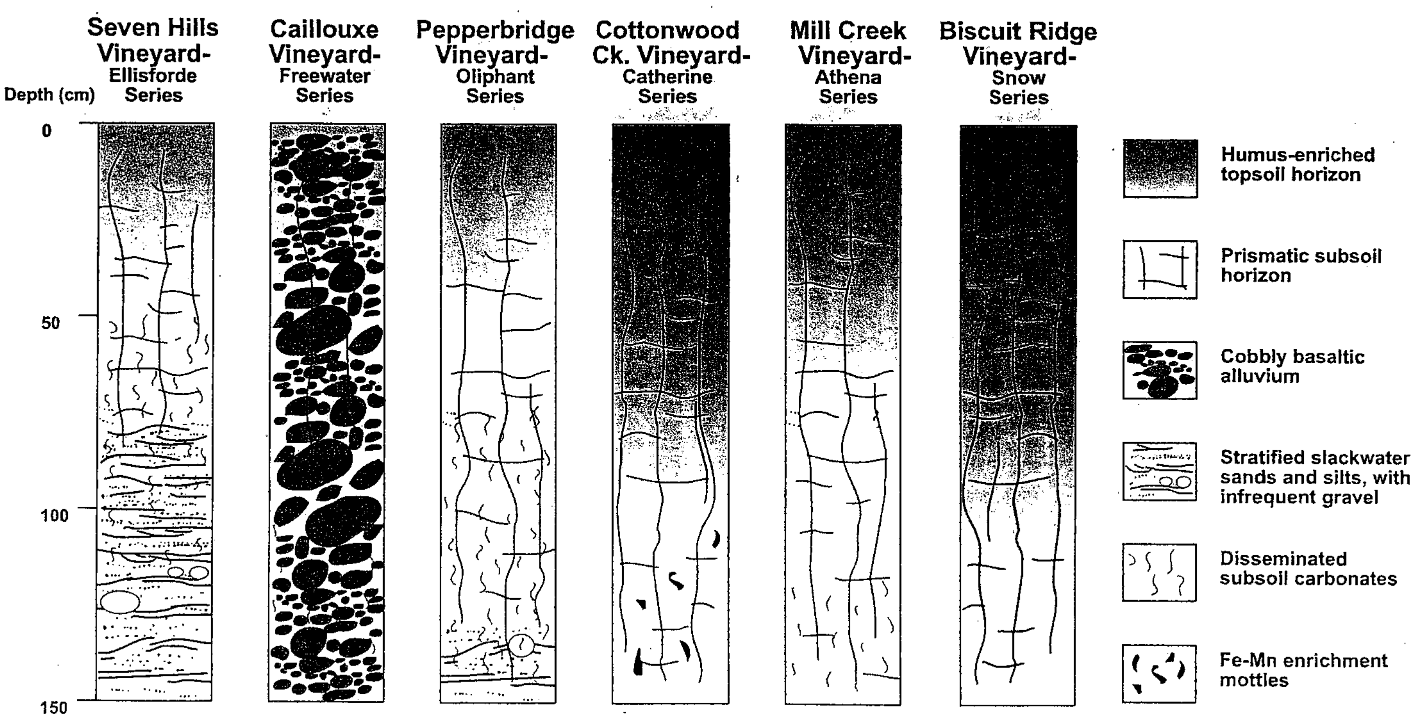

Figure 10 Selected representative soil profiles of the Biscuit Ridge, Mill Creek, Cottonwood Creek, Pepperbridge, Caillouxe, and Seven Hills vineyards. Degree of shading of the topsoil horizons is proportional to the content of humified organic matter. The irregular lines in the prismatic subsoil pattern represent the pattern of cracks that develops in this soil horizon.

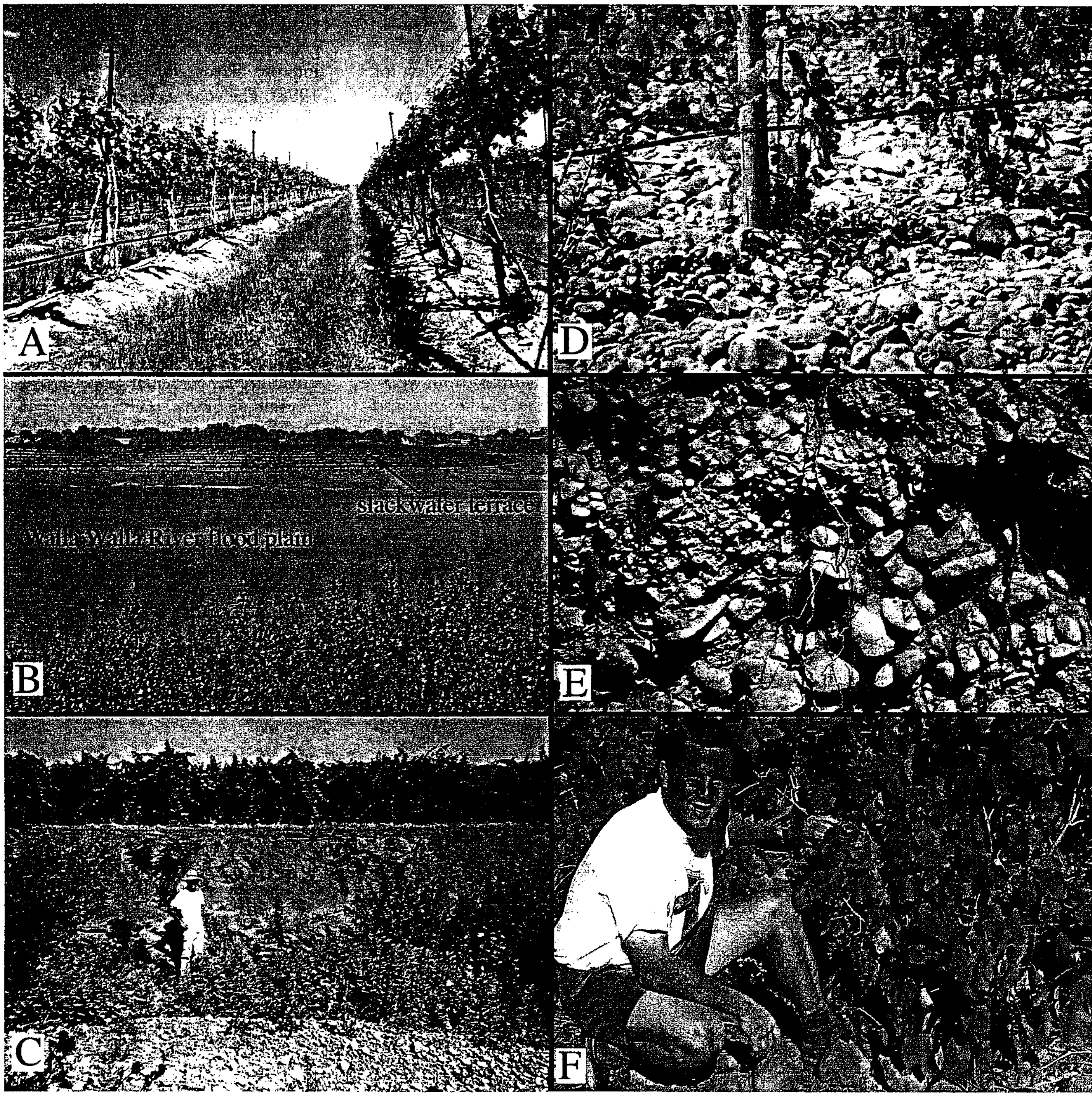

Figure 11 Photographs of vineyard features in the Walla Walla Valley area. (A) Smart-Dyson trellis system at the Pepperbridge Vineyard with Cabernet Sauvignon grape vines planted on a thin loess mantle over bedded slackwater terrace deposits. (B) Vineyard-covered "islands" of slackwater sediments separated by alluvial flood plains of the Walla Walla River. (C) Verdant growth of Chardonnay grapes on water-saturated flood plain silts at the Cottonwood Creek Vineyard. Grape grower Scott Byerly is standing at the edge of Cottonwood Creek with the dry gravel creekbed in the foreground. (D) Basalt cobbles from Walla Walla River alluvium pave the surface of the Caillouxe (formerly Cobblestone) Vineyard. Newly planted Syrah grapes are not yet trellised. (E) Trench near Caillouxe Vineyard exposes roots several meters below surface in the Walla Walla River alluvium. Longest root is approximately 1 m in length. (F) Vigneron Christophe Baron shows how Syrah grapes are trellised close to the ground to take advantage of the radiant heat of the basalt cobbles in the Caillouxe Vineyard.

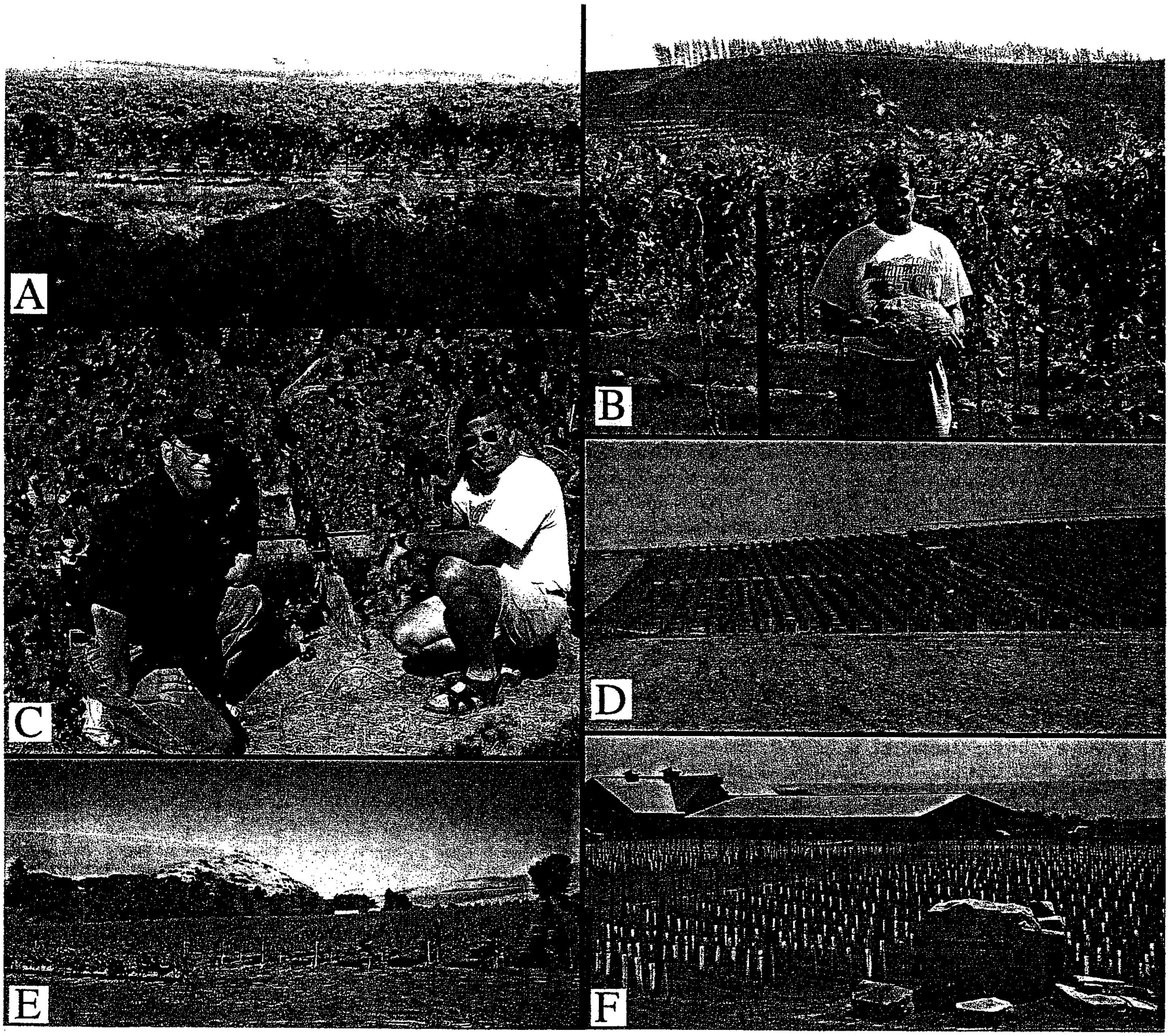

Figure 12 Photographs of vineyard features in the Walla Walla Valley area. (A) The Seven Hills vineyard is planted on ~2m of loess (in cliff exposure) overlying slackwater deposits (not visible here) similar to Figure 2c. (B) Further evidence of the glacial outburst flood activity that has shaped the *terroir* of the Walla Walla Valley are granitic erratics that were rafted in by floating glacial ice. Winemaker Gary Figgins is holding a 0.3 m granite boulder erratic that was found in the Seven Hills vineyard behind him. A chemical analysis of this rock is listed in Table 4. (C) The 20 year old vines, evidenced by the thick gnarled trunk, of this part of the Seven Hills vineyard have been the basis for some of the best wines produced by Casey McClellan (left), owner and winemaker at Seven Hills Winery, and Gary Figgins (right), owner and winemaker at Leonetti Cellars. (D) The Mill Creek Upland Vineyard is planted on thick loess soil on the eastern side of the Walla Walla Valley. Good air drainage off the moderate slopes prevents frost problems even though this vineyard at 500 m is higher than most in the valley. (E) Canyon-bottom flood plain soils are planted mainly with Gewürztraminer grapes at the Biscuit Ridge Vineyard. Cool air draining from the hillsides adds to the cool climate resulting from the 550 m elevation. (F) New grape vines (in grow tubes) were planted on flat flood plain soils surrounding the Three Rivers Winery in order to be close to the winery.

famous. Another negative example of *terroir* is the Cottonwood Creek Vineyard where poorly drained and overly fertile flood plain soils cause measurable sensory problems, including distinct vegetal characteristics.

Perhaps the purest illustration of *terroir* is the Syrah being produced from the Caillouxe Vineyard. Great Syrahs have been produced from several Walla Walla vineyards, but the Caillouxe Vineyard with its pavement of coarse basalt cobbles produces a wine distinct from neighbouring vineyards on loess or slackwater sediments. Although soils developed from loess, slackwater, flood plain, and river gravel sediments display considerable differences in mineralogy and chemistry (Table 4), the effect of each of these components on nutrient uptake and wine flavour is a subject of future research.

An appropriate place to end this discussion of Washington wine and *terroir* is with suggestions for future research. Much modern viticultural research has focussed on quantifiable aspects of plant physiology and the effects of *terroir* on wine composition and sensory attributes (*e.g.*, Reynolds *et al.*, 1995, 1996; Keller *et al.*, 1998). What remains to be done in a rigorous fashion is to examine the relationship between specific physical factors such as bedrock geology, hydrology, and pedology and the quality of wine produced from individual vineyards. One goal of this paper, and indeed of the *Geoscience Canada* series on Geology and Wine, is to explore the concept of *terroir* so that both producers and consumers of fine wine can continue the quest for quality. It is now time for the authors to get on with the latter part of this task. Truly indeed, it has been a pleasure conducting this research (Fig. 14).

ACKNOWLEDGMENTS

This study grew out of initial discussions with Rusty Figgins, owner and winemaker at Glen Fiona, about what factors were important in determining the quality of Walla Walla Valley wine. We are greatly indebted to all the vineyard owners and winemakers who so generously gave of their time and in many cases, their wine. In particular, Norm McKibben, Pepperbridge winery co-owner and past president of the Washington Association of Wine Grape Growers, was indispensable for his exhaustive knowledge of the Washington wine industry and viticultural practice. Chris Figgins, vineyard manager and assistant winemaker at Leonetti Cellars, deserves special mention for his energy and insight about connections between wine and the land. In particular, he inspired the authors to complete this study by coordinating several barrel tastings that showed not only how different vineyards contributed to a particular wine blend but also how a passion for quality at every stage of the winemaking process can result in wines of magnificence.

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Our motivation to prepare this paper was derived at least in part from a single vineyard, Seven Hills in the Walla Walla Valley *appellation* (Figs. 12a-c), and the wine made from that vineyard by a small group of vintners including L'Ecole No. 41, Leonetti Cellars, Seven Hills, and Woodward Canyon. A field examination of some of the old Seven Hills vines and

Table 6 Climate data for the Walla Walla Valley and Pepperbridge Vineyard. Data from Norm McKibben (written communication, 2000) and http://www.wrcc.dri.edu/climsum.html

Walla Walla Valley — Latitude 46° 02' Longitude 118° 20' Elevation 290 m Years of record: 40

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean max. temp.	4.1	8.4	12.6	17.1	21.8	26.4	31.4	30.3	25.0	17.7	9.5	5.4	17.5
Mean avg. temp.	0.9	4.6	7.9	11.5	15.7	19.9	24.0	23.3	18.4	12.3	5.9	2.3	12.2
Mean min. temp.	-2.3	0.9	3.2	5.8	9.7	13.3	16.7	16.3	11.8	6.8	2.3	-0.8	6.9
Precipitation (cm)	5.1	4.1	4.2	3.3	3.5	2.6	1.0	1.6	2.2	3.7	5.2	5.6	42.2
Snowfall (cm)	18.8	7.4	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	5.6	13.7	49.0
Degree days (50°F)	8	11	31	117	322	532	782	742	455	159	21	7	3187

Pepperbridge Vineyard — Latitude 46° 01' Longitude 118° 21' Elevation 250 m Year of record: 1999

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Max. temp. °C	12.8	11.7	17.8	25.6	30.0	34.4	40.0	37.2	32.8	26.1	27.2	14.4	40.0
Min. temp. °C	1.7	-1.7	-0.6	-0.6	1.7	3.3	7.2	11.1	-0.6	-1.7	-2.2	-3.3	-3.3
Mean 9:00 a.m. temp. °C	3.9	4.4	5.6	9.4	12.2	17.2	20.6	22.2	15.0	7.8	6.7	3.9	10.7
Mean 9:00 a.m. humidity (%)	77	71	71	62	61	57	50	58	55	73	83	83	67
Precipitation (cm)	3.2	6.9	11.4	2.6	3.6	7.3	0.8	0.0	1.0	3.9	4.1	4.3	49.1
Daylight hrs wind >24 kph	2	2	0	2	0	0	0	0	0	0	2	2	10
Solar radiation (W/m^2)	20	28	190	166	170	231	234	201	142	79	37	20	1518
Degree days (50°F)	0	0	0	196	147	440	1068	817	546	83	0	0	3297

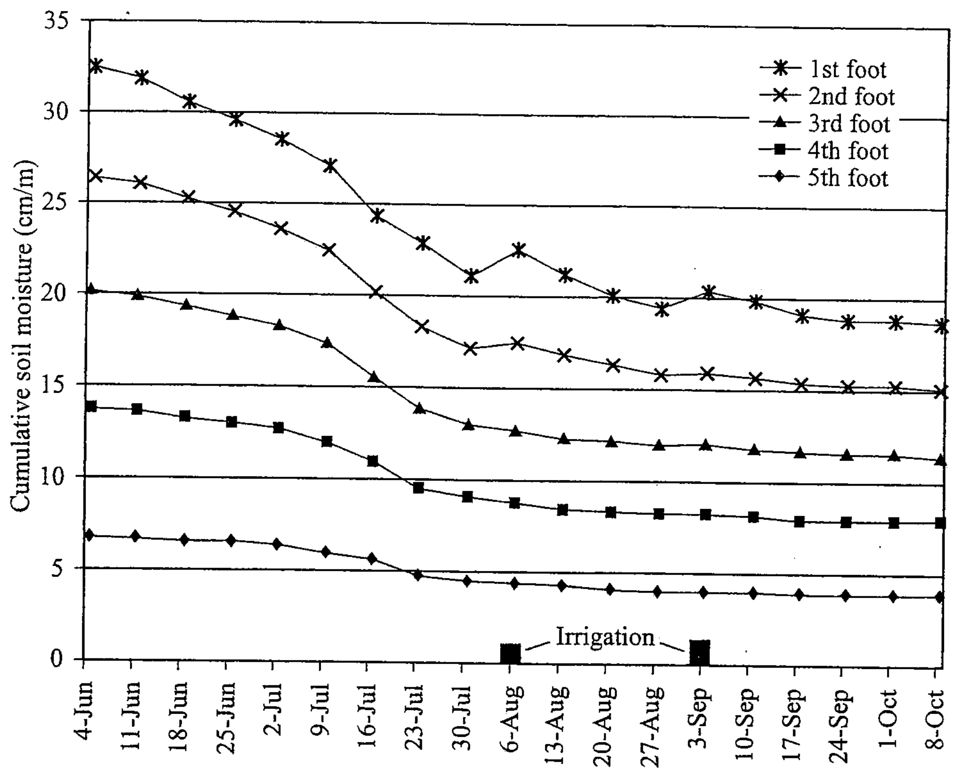

Figure 13 Neutron probe measurement of soil moisture for the Mill Creek Upland Vineyard (block 1, row 4) illustrating effects of irrigation and soil moisture retention properties. Drip irriation was applied on 6 August 1999 and 3 September 1999 (0.8 and 1.2 cm per acre, respectively) and affected the top metre of the soil profile. Data from Chris Figgins (written communication, 2000).

Figure 14 In order to fully understand the nuances of *terroir*, the authors, Larry Meinert (left) and Alan Busacca (right) tasted barrel samples of wine from many of the vineyards described in this paper. Some samples required repeated evaluation.

some of the wines made from them by Gary Figgins, winemaker at Leonetti, and Casey McClellan, winemaker at Seven Hills, provided further insight into the history of this vineyard and Walla Walla winemaking (Fig. 12c).

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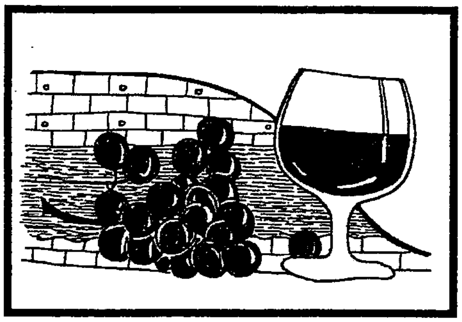

Geology and Wine 6. Terroir of the Red Mountain Appellation, Central Washington State, U.S.A.

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SUMMARY
Red Mountain is the newest of five appellations in Washington State and like the majority of Washington vineyards its terroir is influenced by 1) the rain shadow effect and volcanic tephra of the Cascade Mountain Range, 2) soils derived from Quaternary glacial sediments and wind-blown loess overlying Miocene basalt, and 3) a warm, dry climate with abundant sunshine and cool nights due to high latitude (N 46°) and topography. Variations of rooting depth, textures, calcium carbonate content, and other properties of vineyard soils are directly influenced by Quaternary glacial flood deposits in the back-eddy of Red Mountain and by the variable nature of the loess and dune cover on the flood deposits. This is the first demonstration of the effect of paleohydrology on vineyard site characteristics. In the past two years, wines made from Red Mountain grapes have received nine scores of ≥ 94 out of 100 in independent blind tastings and merlot wine made from Red Mountain grapes has been ranked as the best in the United States for each of the past two years by two different national wine magazines.

Red Mountain is one of the warmest and driest viticultural sites in Washington State, having heat summation (growing degree days) and total sunshine similar to Napa Valley, California which is 1000 km farther south. Other wine regions that have been influenced by the worldwide glacial processes that were so important in the development of Washington vineyards include the gravel mounds that underlie most of the first growth vineyards of Graves-Médoc, Bordeaux, France and some of the outwash gravel plains of New Zealand.

RÉSUMÉ
L'appellation Red Mountain est la plus récente des cinq appellations de l'État de Washington et, comme c'est le cas pour la plupart des vignobles de l'État de Washington, son terroir dépend 1) de l'effet parapluie de la chaîne des monts Cascade et de ses cendres volcaniques, 2) des sols dérivés des sédiments glaciaires quaternaires et des loess éoliens recouvrant le basalte miocène et, 3) d'un climat chaud et sec avec un fort ensoleillement, avec des nuits fraîches dues à la latitude (N 46°) et à la topographie. Les variations de la profondeur d'enracinement, de texture, de contenu en carbonate de calcium et d'autres propriétés pédologiques des vignobles varient selon le patron de dépôt des alluvions glaciaires quaternaires par écoulement tourbillonnaire de Red Mountain et de la variation de composition du loess et de la couverture des dunes des dépôts alluvionnaires. Cela constitue la première démonstration des effets paléohydrologiques sur les propriétés des sites vinicoles. Au cours des deux dernières années, les vins des raisins de Red Mountain ont reçu neuf cotes de plus de 94% lors de dégustation anonyme, et les vins merlots provenant de raisins de Red Mountain ont été jugés les meilleurs aux USA pour chacune des deux dernières années, par deux revues spécialisées d'envergure nationale.

La région de Red Mountain constitue l'un des sites viticoles les plus chauds et les plus secs de l'État de Washington, possédant un bilan thermique (degré-jour de croissance) et un ensoleillement comparable à ceux de la vallée de Napa en Californie, laquelle est située à 1 000 km plus au sud. Parmi d'autres régions ayant subi l'influence de processus glaciairemondiaux et qui se sont avérés si déterminant dans le développement des vignobles de l'État de Washington, on retrouve celle des collines graveleuses constituant le lieux de croissance de la plupart des vignobles de première génération de Graves-Médoc de la région de Bordeaux en France, et d'autres sur des plaines d'alluvions en Nouvelle-Zélande.

INTRODUCTION
As described in other articles in this Geoscience Canada series (*e.g.*, Wilson, 2001), *terroir* involves the complex interplay of climate, soil, geology, and culture that influences the character and quality of wine. These factors are in addition to, or perhaps underlie, the substantial contribution of good viticultural practice and expert winemaking. One common illustration of the importance of terroir is the occurrence of adjacent or nearby vineyards that produce strikingly different wines, even where many of the measurable aspects of climate, viticulture, and winemaking technique are very similar. It is also common, although usually incorrect, to point to a single factor as the explanation: "It's the soil." "It's the water." "It's the limestone." Terroir is the integration of individual factors that contribute to wine quality, and to make matters even more complicated there is the variable of time. What may be good terroir in one year may be less so in another. For

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example, in years that are relatively warm and dry, vineyard "X" with a particular slope, elevation, sun angle, and soil type may produce better wine than vineyard "Y", whereas the reverse may be true in years that are cooler and wetter. Similarly, no matter how good the site, poor vineyard management or winemaking practices can result in bad wine.

Although the term originated in France, terroir increasingly is being used in other parts of the world to explore differences at the scale of appellations to individual vineyards to within-vineyard domains (Halliday, 1993, 1999; Wilson, 1998; Haynes, 1999, 2000). The goal of the present paper is to document the terroir of Washington's newest appellation, Red Mountain (Fig. 1) and to contrast it with other Washington appellations such as Walla Walla (Meinert and Busacca, 2000). At least one aspect of the terroir of the Red Mountain appellation is similar to that previously documented for Walla Walla, 75 km to the east: the strong control on soil materials and landforms exerted by cataclysmic glacial outburst floods. However, there are other factors that vary to different degrees, such as topographic patterns that control air drainage, soil texture, depth to bedrock, growing degree days, solar radiation, rainfall, and frost hazards.

Washington State has some of the world's largest and most spectacular flood basalts and glacial outburst flood deposits as well as widespread dune and loess fields. All of these contribute to the terroirs of Washington State wines. In addition, recent volcanic activity such as the well-known 1980 eruption of Mt. St. Helens continues to shape the oenological and geological landscape. Many Washington vineyard soils have a component of ash erupted from Mt. St. Helens and other Cascade volcanoes such as the much larger Mt. Mazama eruption (6,850 ^{14}C yr. BP), which formed present-day Crater Lake in Oregon (Busacca *et al.*, 2001).

Washington State is second only to California in terms of the volume of wine produced in the United States (www.nass.usda.gov/wa/grape02.pdf). Most Washington State vineyards are located between latitudes 45° and 48° N, well to the north of the more widely known California vineyards but parallel to the great French wine regions of Burgundy and Bordeaux. This northerly latitude provides up to two hours more summer sunlight than

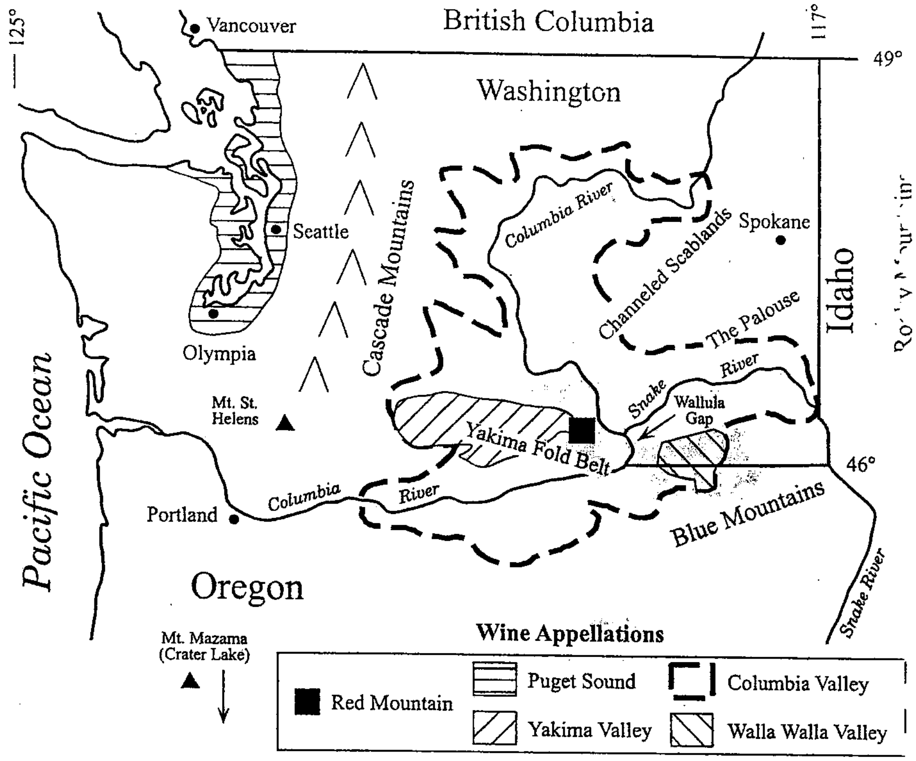

Figure 1 Location map of the Pacific Northwest showing wine appellations and major geological features described in the text.

occurs in California wine regions, somewhat offsetting the generally shorter growing season (Gladstones, 1992). Arid conditions created by the large rain shadow of the Cascade Mountains allow vineyardists a high degree of control of soil moisture. Almost all commercial vineyards lie east of the Cascade Mountain Range (Fig. 1).

Although there is considerable local variability, most Washington vineyards are sited on soils formed from Quaternary sediments that overlie Miocene basaltic rocks of the Columbia River flood basalt province. Many of the Quaternary sediments were deposited during cataclysmic glacial outburst floods that formed the spectacular geomorphic features of the Channeled Scabland (Fig. 2). In fact, comparison of Figures 1 and 2 demonstrates that more than 90% of Washington vineyards are located in areas affected by the glacial outburst floods. This element of terroir, combined with the rain shadow effect of the Cascade Mountains, distinguishes Washington vineyards from other grape growing areas of the world and suggests that Washington wines may develop flavour and quality characteristics that are equally distinct.

OVERVIEW OF WASHINGTON STATE WINE GRAPE PRODUCTION

Washington State has five wine appellations called American Viticultural Areas (AVAs) by the Bureau of Alcohol, Tobacco, and Firearms (BATF), the chief regulatory agency of the wine industry in the United States. The current Washington State appellations (AVAs) are Columbia Valley, Puget Sound, Red Mountain, Walla Walla, and Yakima Valley (Fig. 1). Sub-appellations, that may someday become AVAs, include Alder Ridge, Canoe Ridge, Cold Creek, Columbia River Gorge, Horse Heaven Hills, Wahluke Slope, and Zephyr Ridge (Peterson-Nedry, 2000). Other areas, such as the north bank of the Columbia River near the small town of Paterson, also are becoming known for growth of premium grapes owing to their south-facing slopes and the mitigation of temperature extremes by proximity to Lake Wallula on the Columbia River.

As with most other wine growing regions, Washington AVAs can be nested such that the Columbia Valley appellation, which produces more than 90% of the state's wine grapes, includes the Yakima Valley, Walla Walla Valley, and Red

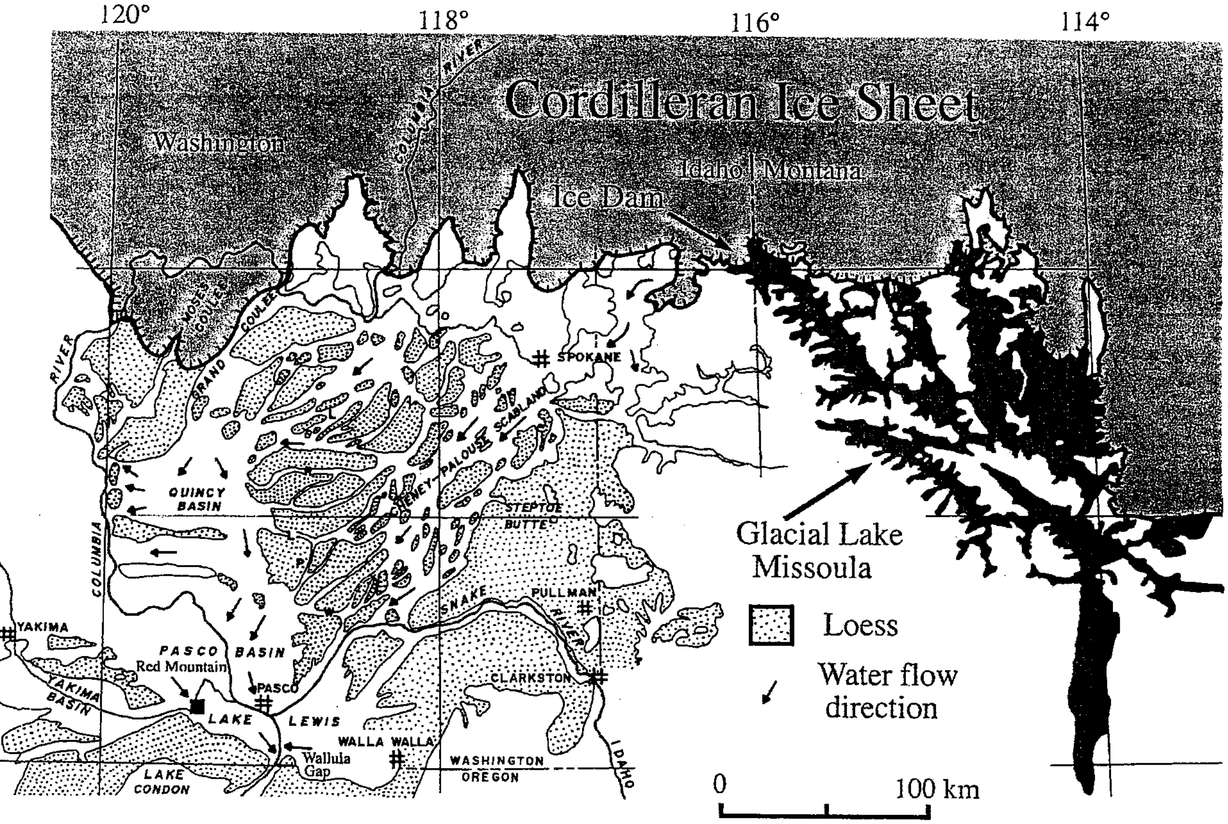

Figure 2 The Channeled Scabland of the Pacific Northwest showing the Cordilleran ice sheet in its approximate position at 15,000 years before present, glacial outburst flood channels, and the distribution of loess. Modified from Baker and Nummedal (1978).

Mountain appellations. The area available for future plantings is very large. In the 10.7 million-acre Columbia Valley appellation only about 16,000 acres are planted to wine grapes. Even the smallest appellation, Red Mountain, has room for expansion with approximately 710 acres planted to vines out of the 4040 acres of the AVA. In many cases the availability of water for irrigation is a larger limitation than the suitability of land for growing high-quality grapes.

Only about 18% of Washington's wine grapes are from vineyards more than 20 years old and from these older vineyards, white grapes (73%) predominate over red grapes (27%) (www.nass.usda.gov/wa/wine02.pdf). For example, prior to 1982 Riesling was the most widely planted white wine grape. In 1982, 54% of the current (2002) acreage was planted with Riesling grapes. In contrast, Cabernet Sauvignon, Merlot, and Syrah were the three most widely planted red grapes in 2002 and had only 12%, 5%, and 0%, respectively, of their current acreage planted prior to 1982.

In the summer of 2002, there were 212 wineries in Washington State. Total wine grape production in 2001 was 100,000 tons from 24,000 acres of bearing vineyards (Table 1). Wine grape production will continue to increase since there are an additional 6,000 acres of wine grapes planted that were not yet bearing fruit in 2001. Most grape vines start producing commercial yields in the third year. Of the wine produced in Washington State in 2001, there was an equal split between white and red wine, down from a 62% white wine majority in 1998. For example, the production of Semillon and Chenin Blanc in this three-year time period decreased 35% whereas the production of Cabernet Sauvignon, Merlot, and Syrah increased 200%. This trend towards a predominance of red wine production in Washington State likely will continue in the future because of the increased plantings of red varietals and the higher prices realized from red grapes in general (Table 1).

REGIONAL GEOLOGIC HISTORY

Red Mountain is located in the geographic center of the Columbia Plateau, which is bordered on the north and east by the Rocky Mountains, on the south by the Basin and Range Province, and on the west by the Cascade Mountains (Fig. 1). Red Mountain is part of a northwest-southeast-trending series of anticlinal ridges called the Olympic-Wallowa Lineament (OWL) that can be traced on topographic and geological maps for hundreds of kilometres (Fig. 3). The ridges result from the north-south-oriented compressional stress regime of south-central Washington State that has existed from the Miocene to the present day. Some anticlines in the Yakima fold belt have developed as much as 100 m of structural relief in the past 10 m.y. (Reidel *et al.*, 1992), and the Red Mountain area experienced an intensity VII (approximate Richter magnitude 6) earthquake on July 15, 1936 (Brown, 1937), most likely caused by movement on the Wallula fault zone (Mann and Meyer, 1993), which is subparallel to the Yakima Fold Belt (Fig. 1).

Erosion of some of the anticlinal ridgetops exposes bedrock of the Columbia River Basalt Group, which covers an area of about 165,000 km^2. The Columbia River Basalt Group was erupted mostly between

Table 1 Washington vinifera wine grape production 1997–2001 (data from http://www.nass.usda.gov/wa/wine02.pdf)

Variety	Tons Utilized					Acres planted	Acres bearing	Yield tons/acres	Average Price (US$/ton)				
	1997	1998	1999	2000	2001	2001	2001	2001	1997	1998	1999	2000	2001
Chardonnay	17,700	20,500	22,900	27,800	29,200	6,640	6,290	4.6	$1,055	$971	$882	$818	$788
White Riesling	10,100	11,500	9,800	10,100	10,600	2,200	1,940	5.5	$489	$533	$547	$590	$603
Sauvignon Blanc	3,300	3,900	3,400	3,400	3,300	710	680	4.9	$729	$750	$746	$728	$719
Gewurztraminer	1,700	1,600	1,300	1,600	2,200	670	540	4.1	$552	$629	$706	$684	$662
Semillon	2,800	3,100	2,600	2,700	2,100	550	540	3.9	$661	$625	$598	$571	$576
Chenin Blanc	1,800	2,300	1,700	1,500	1,400	450	450	3.1	$499	$488	$473	$494	$439
Other (*)	600	600	800	900	1,200	780	460	2.6	$789	$952	$777	$866	$834
Total White	38,000	43,500	42,500	48,000	50,000	12,000	10,900	4.6	$794	$772	$753	$736	$721
Merlot	12,800	14,100	14,300	21,400	23,400	5,980	5,630	4.2	$1,360	$1,197	$1,149	$1,060	$1,034
Cabernet Sauvign	7,800	8,300	8,400	13,000	16,700	6,050	5,130	3.3	$1,195	$1,204	$1,236	$1,144	$1,122
Syrah	#	#	800	2,200	4,400	2,100	1,610	2.7	#	#	$1,398	$1,343	$1,221
Cabernet Franc	1,100	1,700	2,000	3,300	3,300	750	720	4.6	$1,120	$1,102	$1,066	$994	$1,012
Pinot Noir	1,000	1,100	1,000	1,000	900	290	260	3.5	$653	$661	$647	$642	$689
Lemberger	500	500	500	500	500	230	180	2.8	$757	$760	$785	$790	$748
Other (+)	800	800	500	600	800	600	370	2.2	$1,400	$1,386	$1,152	$1,232	$1,286
Total Red	24,000	26,500	27,500	42,000	50,000	16,000	13,900	3.6	$1,255	$1,168	$1,152	$1,085	$1,073
Washington total	62,000	70,000	70,000	90,000	100,000	28,000	24,800	4.0	$972	$922	$910	$899	$897

* Includes muscat canelli, pinot gris, and viognier
\+ Includes gamay beaujolais, grenache, nebbiolo, sangiovese, and zinfandel
\# Included in "Other" Red Varieties for 1997-1998

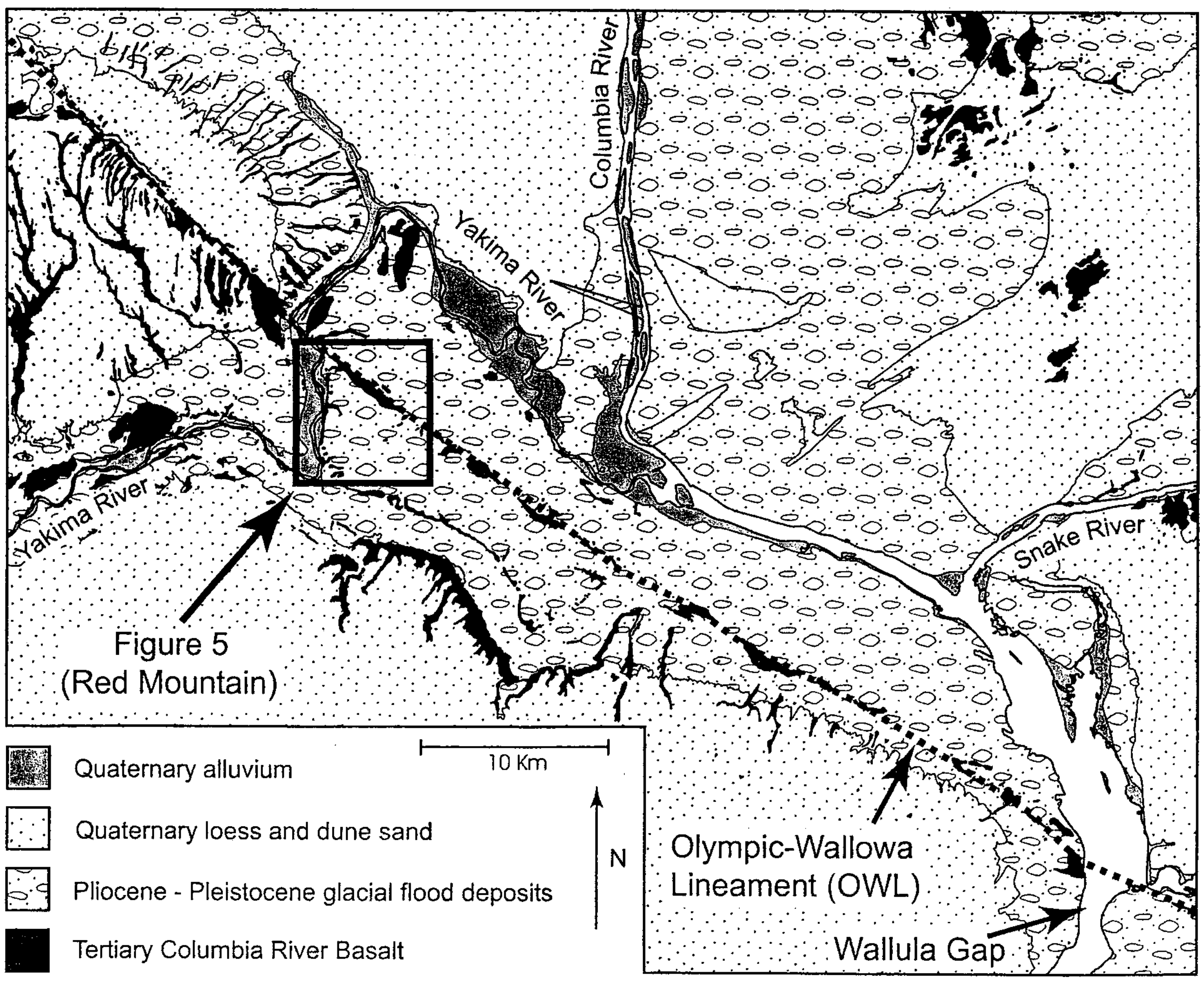

Figure 3 Regional geology of the Pasco Basin showing alignment of ridges along the Olympic-Wallowa Lineament (modified from Reidel and Fecht, 1994).

17 and 11 Ma (early Miocene) from north-south fissures roughly paralleling the present-day Washington-Idaho border. The Columbia River Basalt Group has individual flows with estimated eruptive volumes of at least 3,000 km^3, making them the largest documented lava flows on earth (Baksi, 1989; Landon and Long, 1989; Tolan *et al.*, 1989). This dwarfs the erupted volumes of typical Cascade volcanoes: even the explosive eruption of Mt. St. Helens in 1980 yielded only about 1 km^3 of volcanic material (Pringle, 1993). The basalt bedrock bedrock is overlain by unconsolidated sediments deposited by glacial outburst floods and eolian processes described in some detail in Meinert and Busacca (2000).

To briefly summarize: A lobe of the Cordilleran Ice Sheet blocked the Clark Fork River near the Canadian border in northern Idaho most recently about 18,000 Ka and created glacial Lake Missoula (Fig. 2), which covered 7800 km^2 of western Montana (Pardee, 1910). At the ice dam the water was approximately 600 m deep (Weis and Newman, 1989). The ice dam failed repeatedly, releasing the largest floods documented on earth (Baker and Nummedal, 1978). These floods overwhelmed the Columbia River drainage system and sent up to 2500 km^3 of water across the Columbia Plateau with each outburst (called jökulhlaups in Iceland where similar events occur). The floods eroded a spectacular complex of anastomosing channels, locally called 'coulees', into southwest-dipping basalt surfaces. They also eroded huge cataracts in the basalt now seen as dry falls and "loess islands" that 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 these features make up the Channeled Scabland as detailed in the early work by Bretz (1923, 1925, 1928a,b, c, 1932).

In south-central Washington State, the many paths of the onrushing floods converged on the Pasco Basin where floodwaters were slowed by the hydrological constriction of Wallula Gap before draining out through the Columbia River Gorge to the Pacific Ocean (Figs. 1, 2). This constriction caused backflooding of local river valleys and basins that resulted in deposition of relatively fine-grained slackwater sediments characterized by rhythmically graded bedding; these graded rhythmites locally are called Touchet beds, and multiple sets, indicative of multiple floods, have been recognized (Flint, 1938; Waitt, 1980, 1985).

In the last stages of the Pleistocene (roughly from 15,000 to 10,000 yr. ago) and continuing through the Holocene (the last 10,000 yr., a time when climates worldwide were essentially similar to those of today), prevailing southwesterly winds eroded slackwater and other glacial sediments and redeposited them into the present thick blanket of loess that covers much of the Columbia Plateau (45°30' to 48°N and 116°30' to 120°W). These windblown soils form the backbone of agriculture in all of eastern Washington (Boling *et al.*, 1998). The loess is thickest in a 10,000 km^2 area northeast of Red Mountain called the Palouse (Busacca, 1991) (Fig. 1).

RED MOUNTAIN AVA

The Red Mountain American Viticultural Area (AVA) is defined by a combination of topographic contour lines and geographic markers (Fig. 4) and encompasses approximately 4,040 acres. Of this 4,040 acres there is potential for up to 2,700 bearing acres, of which 710 are currently planted. Red Mountain is home to Hedges Cellars, Kiona and several smaller wineries, including Blackwood Canyon, Sand Hill, Seth Ryan, and Terra Blanca. There are 16 vineyards in the AVA (Table 2) and 37 different Washington wineries currently use Red Mountain wine grapes, including Arc-en-Ciel, Andrake, Andrew Will Cellars, Apex Cellars, Barnard Griffin, Betz Family Winery, Bookwalter, Cadence, Camaraderie Cellars, Canoe Ridge, DeLille Cellars, Gibbons Lane, Foris Vineyards, Hedges Cellars, Hightower Cellars, JM Cellars, Januik, Kiona, Kestrel vintners, L'Ecole No 41, Matthew Cellars, McCrea Cellars, Mount Baker Vineyards, Owen-Sullivan, Quilceda Creek, Randall Harris, Ryan Cray, Sandhill, Seth Ryan, Seven Hills, Soos Creek, Terra Blanca, Three Rivers, Waterbrook, Wilridge, Woodward Canyon, and Yakima River Winery.

Compared to the rest of Washington state, Red Mountain has a much higher proportion of red (80%) versus white wine grapes (20%). Currently, there are 570 acres of red wine grapes (480 bearing) and 140 acres of white wine grapes (120 bearing). Most of these are relatively young plantings, with only 4% of the Red Mountain vineyards planted prior to 1982, comprising 10 acres each of Gewürztraminer, Riesling, and Merlot (www.nass.usda.gov/wa/wine02.pdf). Currently, the three most abundant grape varieties planted within the Red Mountain AVA are Cabernet Sauvignon (35%), Merlot (21%), and Syrah (10%).

RED MOUNTAIN GEOLOGY

Columbia River Basalt Group

In general, the vineyards of Red Mountain all share the same basic geology in that they are rooted in a stratigraphic package consisting of a thin but variable mantle of Pleistocene to Holocene loess and dune sands on top of Quaternary glacial flood sediments. These in turn overlie Tertiary Columbia River Basalt basement. In the Red Mountain area the Columbia River Basalt Group consists of the Saddle Mountains Formation, about 8.5 to 12 million years old, which can be subdivided into three members: the Ice Harbor (8.5 Ma), Elephant Mountain (10.5 Ma), and Pomona (12 Ma) members (Reidel and Fecht, 1994). Locally, these members can be subdivided further into individual flow units that are exposed along the ridgetop of Red Mountain and by incisions of the Yakima River on the west side of the Red Mountain AVA (Fig. 5). Compositions of representative rock units are illustrated in Table 3. As shown in Figure 6, subdivisions among individual flow units can be made on a compositional basis using a variety of major and trace elements (Hooper, 2000).

In drill intercepts, it is also possible to distinguish between individual basalt flows by the presence of locally persistent but regionally discontinuous shaly interbeds (Fig. 7) that developed during the 1 to 2 million year intervals between eruption of major basalt units. These interbeds, along with relatively porous flow tops and basal flow breccias, form the main aquifers in the Columbia River Basalt Group. Static water level is about 100 m below the surface in most of these wells, coincident with the upper shaly interbed. Because of this hydrological regime, the rooting zone of all Red Mountain vineyards is well above the water table.

Structure

The basalt bedrock in Central Washington has been folded into a series of NW-SE-trending anticlines and synclines. On a regional scale (Fig. 3) the anticlines are exposed in ridges that form elongate

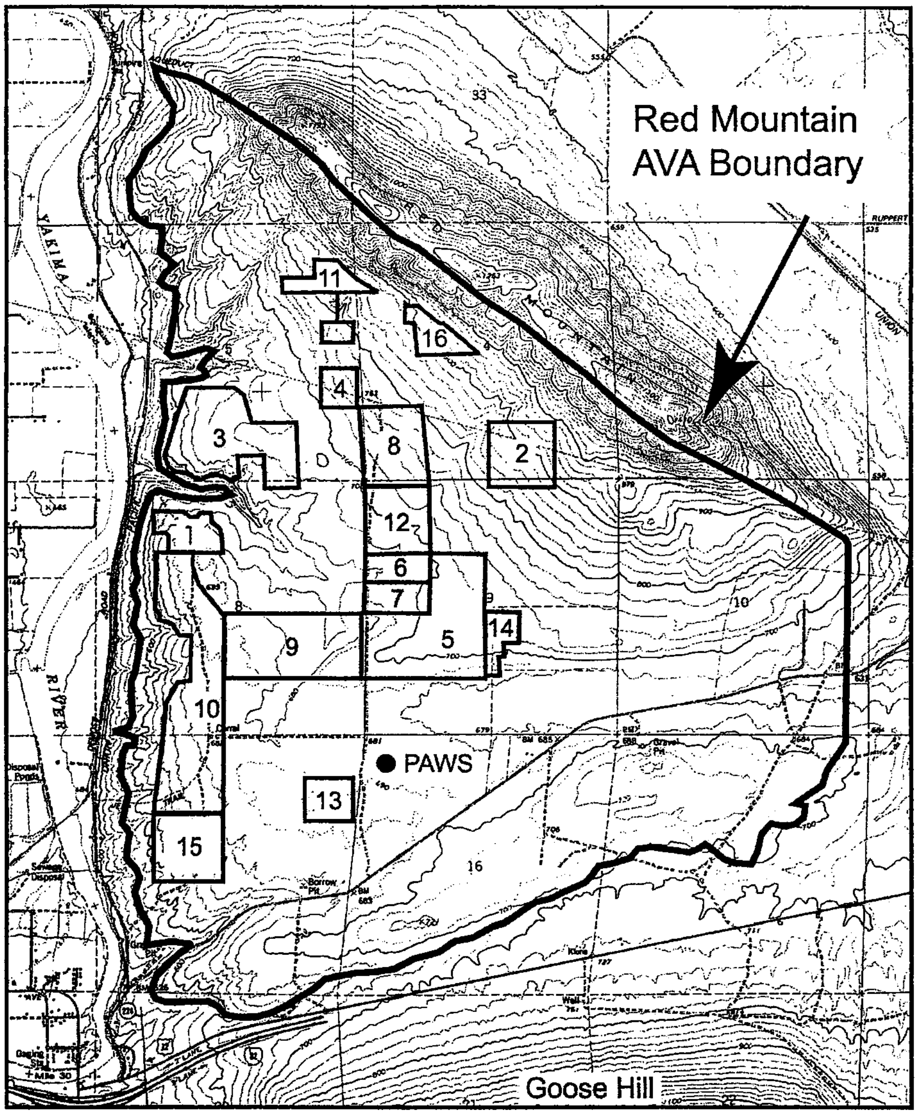

Figure 4 Location of vineyards and topography of the Red Mountain AVA. Base map is the 1:24,000 scale U.S.G.S. Benton City topographic map. Also shown is the location of the Washington State University Public Agricultural Weather System (PAWS) station that collected the data in Table 5. Information about numbered vineyards is presented in Table 2.

topographic features such as the Olympic-Wallowa lineament whereas the synclines generally form basins that are covered by younger sediments (Fig. 7). The Red Mountain and Goose Hill anticlines form the northern and southern geological boundaries of the Red Mountain AVA. Most of the vineyards are underlain by the intervening syncline, which has been called both the Goose Gap syncline and the Benton City syncline (Reidel and Fecht, 1994). According to Reidel and Fecht (1994) the southern limb of the Red Mountain anticline is steeper than the northern limb and like many such structures in the Yakima Fold Belt, may have local reverse faults (West *et al.*, 1996). Such faulting, as illustrated in the upper part of Figure 7, may explain the great differences in yield between otherwise similar water wells in the Red Mountain area.

Glacial Sediments

Except on ridgetops above about 400 m in elevation and where incised by modern drainage, the basalt in the Red Mountain area is everywhere overlain by unconsolidated sediments (labeled as Qht in Fig. 5) that were deposited by the series of glacial outburst floods related to the drainage of glacial Lake Missoula, described above. As the peak of Red Mountain is 430 m and the mean slackwater elevation of Lake Lewis, which temporarily filled the Pasco Basin (Fig. 2), is estimated at about 390 m, it is likely that the floodwater torrent surrounded Red Mountain, forming a very strong back-eddy behind (to the south of) Red Mountain as illustrated in Figure 8. The paleohydrology of this back-eddy resulted in extreme heterogeneity of the sediments that were deposited to the south of Red Mountain and that make up the deeper soil levels of the vineyards within the Red Mountain AVA.

Perhaps the most noticeable sedimentary features are the glacial erratics, large boulders that were carried by icebergs from the broken ice dam. These icebergs must have ranged up to 10s and perhaps 100s of metres in size, as the boulders that were dropped when these icebergs grounded, melted and deposited their entrained load, range up to several metres in size (Fig. 9A, B). Erratics are particularly prevalent along the high water strand of the slackwaters (Fig. 9A), but also are distributed throughout the Red Mountain AVA as illustrated in Figure 8D and evidenced by the rows, walls, and boxes of boulders (Fig. 9C) removed from the vineyards during initial planting and subsequent ploughing. Most of the boulders are granitic and metamorphic rock types that are not found within several hundred kilometres of Red Mountain, but which are abundant in the Rocky Mountain source region of the flood waters and the impounding glaciers. Figure 9B shows one such boulder that is about 3 m in diameter and consists of gleaming white marble with layers of brown garnet skarn, rock types that do not occur in outcrop anywhere in Central Washington.

Although the largest boulders could not have been carried directly by the flood waters, the peak velocity and discharge of the floods, estimated at 200 m/sec and 2 x 10^7 m^3/sec, respectively, (O'Connor and Baker, 1992) were sufficient to carry large amounts of relatively coarse sediment that was subsequently deposited when the water slowed near obstructions, as would be the case in the eddies behind Red Mountain (illustrated in Fig. 8D). This resulted in lenses of coarse gravels (Fig. 9D, F) in the generally finer grained silt and sand deposited by the ponded slackwater of Lake Lewis (Fig. 2).

In addition to the multiple pulses of floodwater that resulted in complex interbeds of gravel, sand, and silt, periodic eruption of Cascade volcanoes to the West

Table 2 Vineyards in the Red Mountain appellation[1]

Map no.	Name	Acres	Grapes	First Planted	Owner
1	Artz Vinneyard	20	8 cs, 5 m, 4 sb, 1 cf, 1 s, 1 c	1995	Fred Artz
2	Belle Ville	31	15 cs, 5 sy, 3 cf	1997	Pete Hedges
3	Blackwood Canyon	80	25 cs, 20 c, 15 m, 10 s, 5 sy, 2 n, 1 ca, 1 t, 1 cf	1984	Mike Moore
4	Cadence Vineyards	11	4 cf, 3 cs, 1 pv	2003	Ben Smith & Gaye L. McNutt
5	Ciel du Cheval	95	25 cs, 15 m, 14 sy, 9 cf, 7 sg, 5 ri, 5 ro, 4 v, 4 pv, 3 cb, 2 g, 2n, 1 co	1976	Jim Holmes
6	Grand Ciel Vineyard	9	7 cs, 2 sy	2001	Jim Holmes, Delille LLC
7	Golitzen Vineyard	17	17 cs	2001	Jim Holmes, Alex & Jeanette Golitzen
8	Hedges Cellars	36	18 m, 16 cs, 1 cf, 1 pv, 1 so	1990	Pete Hedges
9	Kiona Vineyards	70	28 cs, 15 l, 8 m, 5 cb, 4 c, 3 cf, 3 sg, 3 ri	1975	John and Ann Williams
10	Klipsun Vineyard	120	60 cs, 30 m, 13 sb, 9 s, 6 sy, 1 n	1984	Patricia & David Gelles
11	Tapteil	25	16 cs, 8 m, 2 cf	1985	Larry Pearson
12	Sand Hill (RMV)	40	24 cs, 13 m, 2 cf, 1 pg	1989	John Dingethal
13	Seth Ryan	7	2 cs, 2 m, 2 cf, 1 c	1996	Ron and Jo Brodzinski
14	Shaw Vineyard	12	7 cs, 4 m, 1 cf	1998	Ed and Eve Shaw
15	Terra Blanca	80	20 cs, 20 sy, 15 m, 5 c, 1 ma, 1 pv	1993	Keith Pilgrim
16	Williams	21	12 sy, 5 g, 3 sg	1978	Scott Williams

Grape abbreviations: ca = Carmenere, cf = Cabernet Franc, cs = Cabernet Sauvignon, c = Chardonnay, cb = Chenin Blanc, co = Counoise, g = Gewurztraminer, l = lemberger, ma = malbec, m = Merlot, n = Nebbiolo, pg = Pinot Gris, pn = Pinot Noir, pv = Petite Verdot, ri = Riesling, ro = Roussane s = Semillon, sb = Sauvignon Blanc, sg = Sangiovese, so = Souzao, sy = Syrah, t = Tannat, v = Viognier

[1]Data from Jim Holmes and individual vineyard owners, written communication, 2002. Vineyard locations are shown in Figure 4.

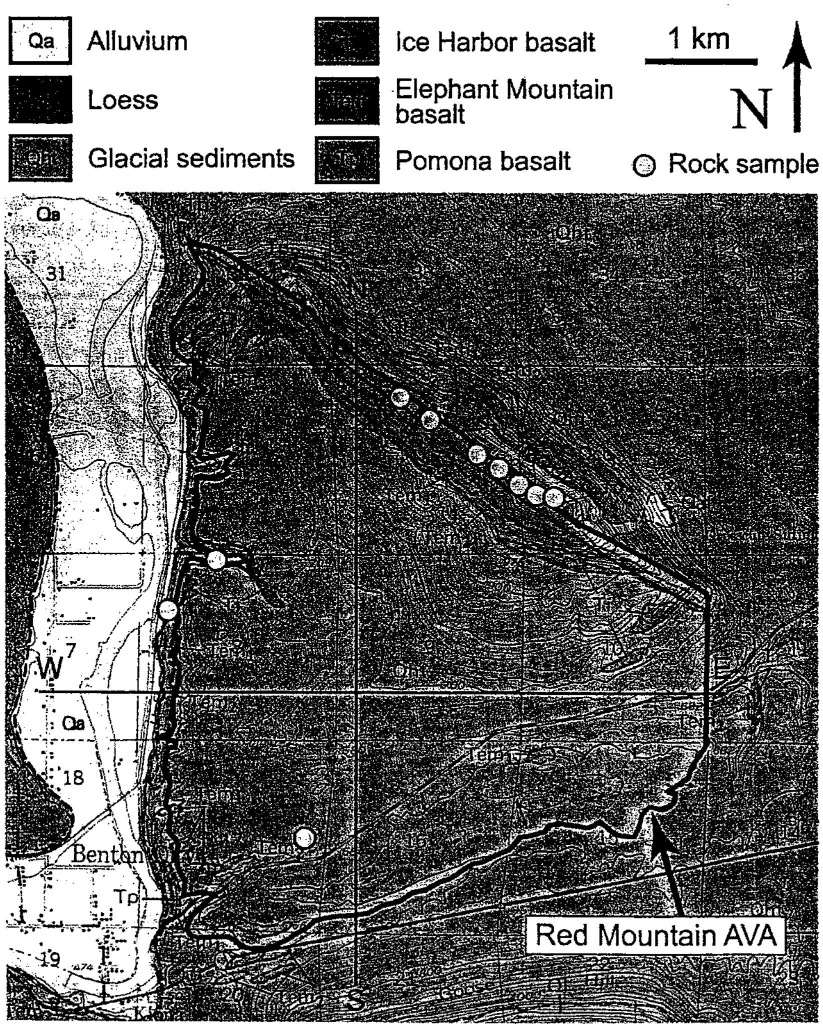

Figure 5 Geology of the Red Mountain AVA showing location of analyzed rocks (Table 3) and location of N–S and E–W cross-sections of Figure 7 (modified from Reidel and Fecht, 1994).

added a component of volcanic ash to the sediment mixture. Ash layers, such as Mt. St. Helens ash "S" (13,000 ^{14}C yr.; Mullineaux, 1996) are preserved in some roadcut and vineyard exposures (Fig. 9E). Although volumetrically minor, such ash layers provide evidence of periods of quiescence between flood pulses, necessary for the preservation of the delicate ash horizon.

WIND-BLOWN SEDIMENTS

Even though it is not shown generally on the geological map of the Red Mountain AVA (Fig. 5), loess or dune sand is everywhere present as a thin mantle ranging in thickness from decimetres to several metres on top of the slackwater sediments. As described above, the loess and the dunes were created by southwesterly winds that eroded slackwater and other glacial sediments and redeposited them into the present blanket of loess that covers much of the Columbia Plateau (Busacca, 1991). Buried soils in older loess at nearby sites not inundated by the floods indicate that deposition was intermittent during the Quaternary. The generally arid climatic conditions that continue to the present day resulted in limited chemical weathering and leaching, causing formation of calcic and petrocalcic soil horizons (Busacca, 1991; Soil Survey Staff, 1999).

CALCIUM CARBONATE CONTENT

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Although as much as 90% of incoming precipitation is returned to the atmosphere

Table 3 Chemical composition of representative Red Mountain rocks[1]

Sample no.	RM-1	RM-9	RM-11	RM-2	RM-3	RM-4	RM-5
Unit	Elephant Mtn	Elephant Mtn	Elephant Mtn	Pomona	Pomona	Pomona	Pomona
Type	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt
Location	RM top	Artz-BC gully	Demoss Rd.	50m W RM	100m W RM	150m W RM	200m W RM
SiO_2	51.47	51.17	51.50	52.48	52.29	52.53	52.78
Al_2O_3	13.23	13.00	12.89	15.34	14.98	15.22	15.27
TiO_2	3.69	3.62	3.55	1.65	1.68	1.72	1.72
FeO(t)	14.13	14.53	14.79	9.32	10.37	9.90	9.94
MnO	0.20	0.21	0.20	0.17	0.18	0.17	0.17
CaO	8.71	8.96	8.64	11.31	11.01	11.28	11.12
MgO	4.06	4.36	4.26	6.55	6.22	5.91	5.68
K_2O	1.42	1.30	1.16	0.59	0.66	0.59	0.66
Na_2O	2.51	2.32	2.47	2.36	2.38	2.44	2.43
P_2O_5	0.58	0.53	0.54	0.24	0.24	0.24	0.24
Ni	11	13	14	37	47	60	47
Cr	33	36	33	118	102	109	107
Sc	46	33	37	35	37	39	37
V	426	426	432	264	279	293	273
Ba	531	480	476	941	568	828	339
Rb	29	26	28	10	11	9	9
Sr	238	242	230	262	254	253	246
Zr	256	244	253	127	135	140	140
Y	50	49	51	29	29	30	31
Nb	26	24	24	12	13	14	13
Ga	26	25	22	20	18	20	17
Cu	7	7	5	28	36	43	40
Zn	147	142	142	81	82	88	93
Pb	12	3	11	6	5	4	0
La	39	31	31	41	3	9	13
Ce	73	61	82	28	23	40	47
Th	8	0	4	3	2	2	0

Sample no.	RM-6	RM-7	RM-8	Average	Average	Average	RM-10
Unit	Pomona	Pomona	Pomona	Ice	Elephant		Scooteney
Type	Basalt	Basalt	Basalt	Harbor	Mtn	Pomona	Caliche
Location	300m W RM	400m W RM	500m W RM	Basalt[2]	Basalt[2]	Basalt[2]	Quarry
SiO_2	52.29	52.29	52.81	47.98	51.68	52.19	38.48
Al_2O_3	14.81	14.89	15.05	11.70	13.16	14.76	4.82
TiO_2	1.70	1.60	1.67	3.78	3.54	1.64	0.41
FeO(t)	10.50	10.42	9.80	17.24	14.17	10.38	2.27
MnO	0.17	0.17	0.17	0.28	0.21	0.18	0.03
CaO	10.99	10.97	10.97	8.91	8.79	10.78	49.19
MgO	6.34	6.46	6.31	4.23	4.08	6.88	3.25
K_2O	0.68	0.69	0.58	1.31	1.24	0.57	0.56
Na_2O	2.29	2.30	2.40	2.71	2.58	2.39	0.73
P_2O_5	0.24	0.22	0.24	1.85	0.55	0.23	0.24
							28.29*
Ni	45	44	36	7	10	43	0
Cr	107	107	105	33	30	106	23
Sc	39	33	33	41	35	37	0
V	284	265	276	214	408	272	56
Ba	368	264	430	838	552	191	297
Rb	11	11	13	25	31	13	19
Sr	239	234	237	240	243	231	427
Zr	138	131	143	467	242	130	166
Y	31	30	30	108	50	31	15
Nb	13	12	12	55	28	13	7
Ga	23	20	20	26	23	19	9
Cu	38	32	30	6	18	50	10
Zn	87	87	88	223	154	88	20
Pb	0	0	1	9	6	7	4
La	37	17	26	72	26	9	21
Ce	7	47	28	160	72	43	27
Th	0	0	0	5	6	2	0

* Loss on Ignition

[1]Analyses by XRF and ICPMS in the Geoanalytical Lab at Washington State University.

[2]Averages for Ice Harbor, Elephant Mountain, and Pomona members from Hooper (2000).

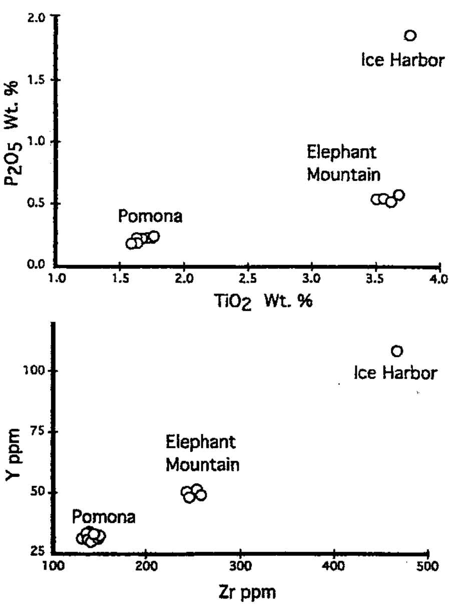

Figure 6 Compositional discrimination diagrams for Columbia River basalts using a) P_2O_5 versus TiO_2 and b) Y versus Zr. Data from Table 3 and Hooper (2000).

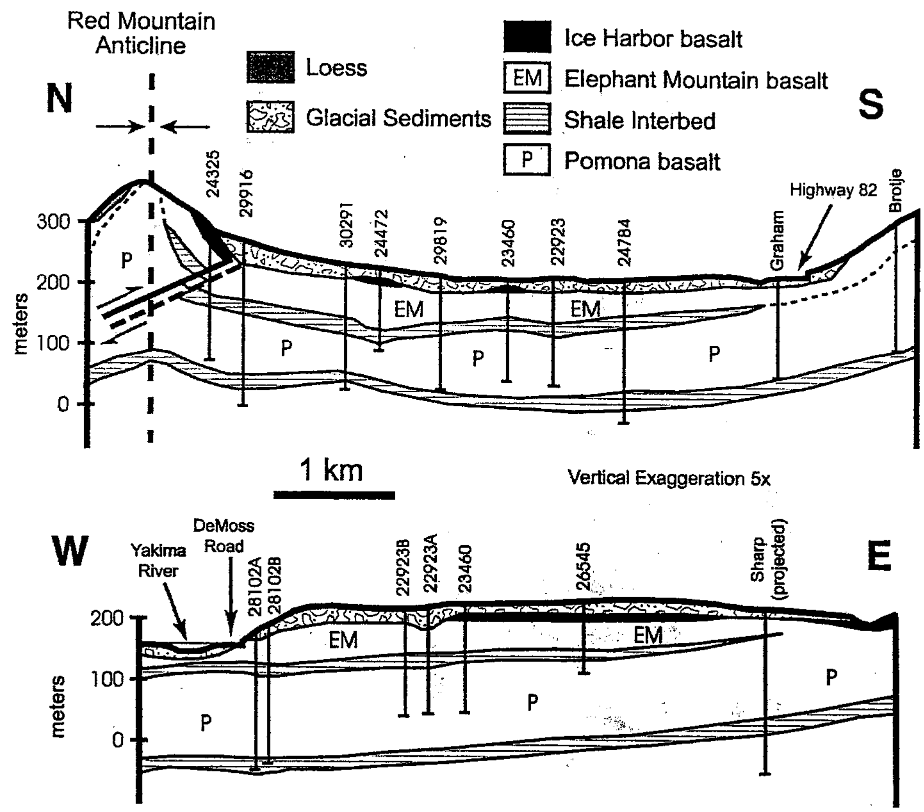

Figure 7 Geological cross-sections through the Red Mountain area (vertical exaggeration 5:1). Well log data courtesy of Lorne Jacobsen, written communication, 2001. Location of cross-sections is illustrated in Figure 5.

as evapotranspiration, the coarse gravel lenses intercept and channel the infiltration of precipitation descending through overlying loess and dune materials. Thus, shallow gravel lenses can contain significant calcium carbonate. An analysis of one such petrocalcic horizon (RM-10, Table 3) shows that it contains up to 50% CaO, an order of magnitude more calcium than average soil and rock values (Tables 3, 4). Although limestone is absent in the Red Mountain AVA, other than as erratic boulders, the calcite-cemented gravel lenses form significant reservoirs of calcium carbonate that can affect vineyard performance. For example, calcium is known to inhibit vine uptake of such essential nutrients as nitrogen and potassium (Winkler *et al.*, 1974; Ribéreau-Gayon *et al.*, 2000). Also, Fe is particularly affected if water pools on calcic layers in the root zone (Sara Spayd, written communication, 2002). Some Red Mountain wineries such as Terra Blanca, Spanish for white earth, point to these calcic layers as an important and sometimes negative part of the local terroir.

RED MOUNTAIN SOILS

The layered stratigraphy of bedrock basalt and overlying glacial floodwater and eolian sediments forms the substrate for soil development in the Red Mountain AVA. Given the heterogeneity of these sediments, it is not surprising that there are a number of different soils in the Red Mountain AVA (Fig. 10), and that these soils perform very differently under grape production.

A common theme to the soils of the benched area of Red Mountain is that they formed in eolian materials (loess or dune) over slackwater sediments from giant glacial outburst floods (Meinert and Busacca, 2000). Yet within this landscape, no fewer than eight different soil series have been mapped, and these can have very different textures (Table 4) and profile morphology (Fig. 11): Hezel (Xeric Torriorthents), Quincy (Xeric Torripsamments), and Finley, Scooteney, Prosser, Starbuck, Kiona, and Warden (all Xeric Haplocambids; Soil Survey Staff, 1999). Vineyards are planted on most of these, with development planned for the remainder.

All but two of the principal soils are classified as Aridisols in soil taxonomy (formative word Arid; Soil Survey Staff, 1999) based primarily on an aridic soil moisture regime. The two soils that formed in dune materials (Hezel and Quincy) are Entisols (formative word Recent) because the shifting sands lack most soil profile features. In sharp contrast to the Aridisols and Entisols of the appellation, soils on the floodplain of the Yakima River less than one kilometre outside the appellation and planted to *Vinifera* are Mollisols of the Pasco series (Fig. 11; Cumulic Endoaquolls), which are wet soils with very dark, thick, humus-enriched topsoils. These soils have a permanent water table whose height in the soil profile fluctuates seasonally with stages of the Yakima River. The generally high water table results in carbonates to the surface and uncontrolled access to water during the growing season.

Large areas of the benchlands of the Red Mountain appellation are underlain by the Warden series soils, formed in about 50 cm of loess or mixed loess and eolian sand over stratified flood sediments (Fig. 11), whereas adjacent areas, even within the same vineyard, are underlain by the Hezel series soils (Fig. 14b), which formed in a cover of about 50 cm of dune sand over sandy stratified flood sediments. In contrast, areas of Scooteney soils grade downward from an eolian sandy loam or loam at the surface to a fluvial unit of very cobbly sandy loam at

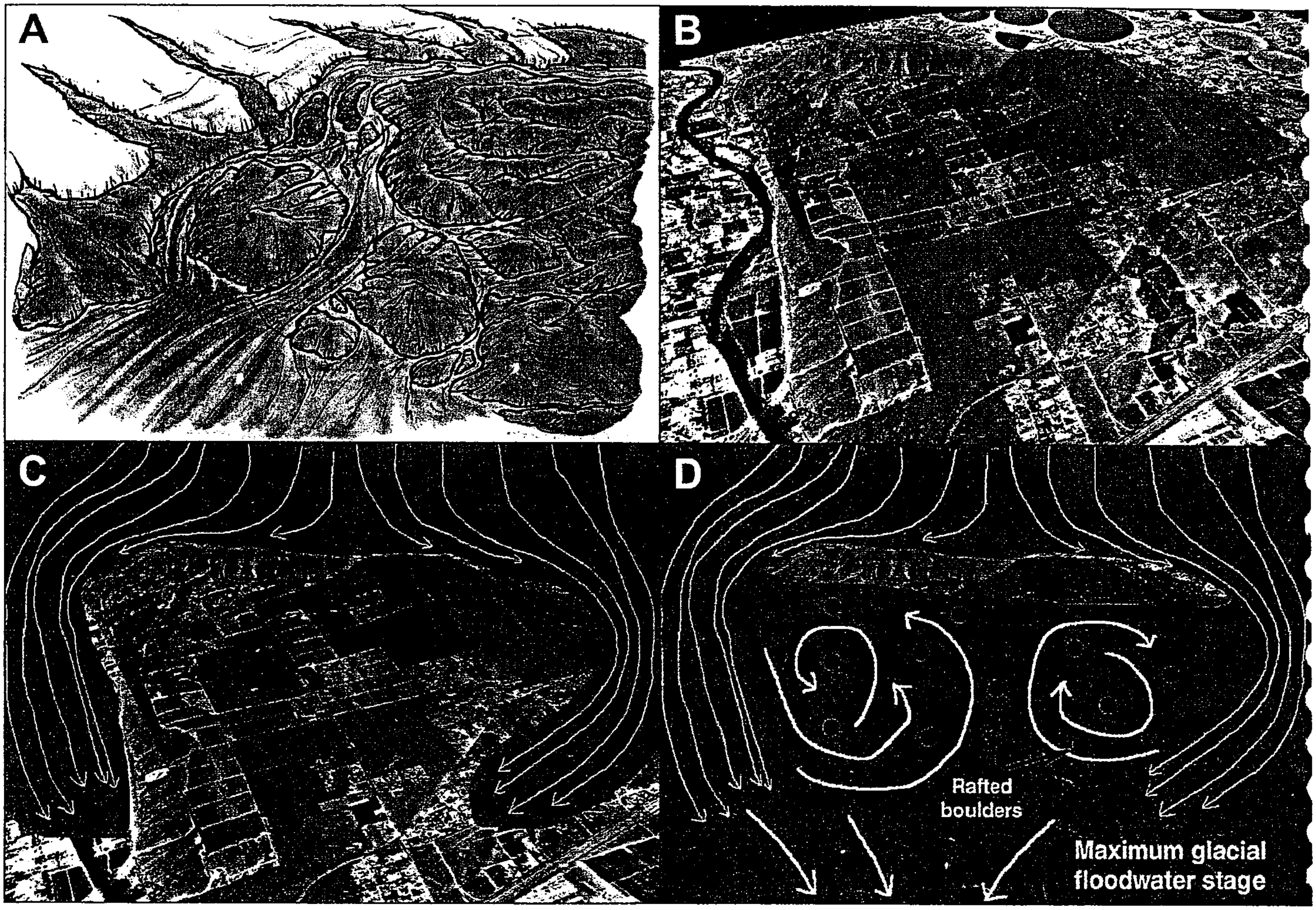

Figure 8 Cartoon illustrating the sequence of events during flooding caused by the catastrophic draining of glacial Lake Missoula. A) Artist's rendition of outburst flooding caused by failure of a glacial ice dam. Note torrent of water rushing around isolated hills analogous to Red Mountain. Modified from Molenaar (1988). B) 3-D perspective view of Red Mountain area with color infrared imagery draped over black and white ortho aerial photograph. Note that in infrared images, green vegetation such as leafy vineyards are red whereas arid range lands are dark green. Images courtesy of Francis Pierce, Center for Precision Agricultural Systems, WSU-IAREC. C) Approach of floodwaters with flowlines around Red Mountain. Even though standing water, as evidenced by the strandline of ice-deposited erratics, did not cover Red Mountain, it is possible that the initial flood surge may have overtopped the peak creating a temporary but rather large standing wave. D) Maximum flood stage as evidenced by the strandline of ice-deposited erratics, and schematic location of boulders deposited by melting of rafts of ice. See Figure 9A, B, C for examples of such ice-rafted boulders.

150 cm. All three of these soils can be tens of metres thick above hard basalt bedrock. A variant of Scooteney series soils, which was not recognized in the previous soil survey (Rasmussen, 1971), was found in our field reconnaissance to have a strongly lime-silica cemented duripan in flood gravel at depths of 50 cm to 100 cm. Thus vineyards in the Red Mountain AVA have soils that range from loess to dune sand to gravel to slackwater sediments in the lower part of the vine rooting zone.

Still other areas in this same landscape are underlain by Prosser and Starbuck series soils (Fig. 11), with bedrock at less than 40 cm to 80 cm depth. Small areas have Quincy soils that formed in dune sand more than 150 cm deep. Soils of the Kiona series (Fig. 11) that occupy the steep south face of Red Mountain (with slopes up to 60 percent) have formed in slope colluvium of fractured basalt mixed with loess and are cobbly loams to more than 150 cm. It appears that no vineyards have yet been planted on areas of Kiona soils.

The majority of the soils in the Red Mountain appellation are thicker than several metres (Fig. 7). The most important vineyard soils formed as the result of two end-member eolian processes, dune saltation and loess suspension. Dominantly sandy dune materials accumulated over either flood gravels or stratified flood slackwater sediments (*e.g.*, Hezel series, Fig. 11) in some places on Red Mountain, whereas dominantly silty loess materials have accumulated over flood materials in other places (*e.g.*, Warden series, Fig. 11). This is evident in the high total sand content of a Hezel sample (75.9%, CC-3, Table 4) versus the lower total sand content of a Warden sample (19.6%, BV-3, Table 4). However, mixing of variable amounts of saltated sand and suspended silt occurred in most of the sampled soils, leading to highly variable soil textures. In general, the soils are more sandy in the surface layer and more silty at 1 m depth (Table 4), suggesting that loess deposition dominated early in the post-flood history of Red Mountain and that dune sands have more recently covered or

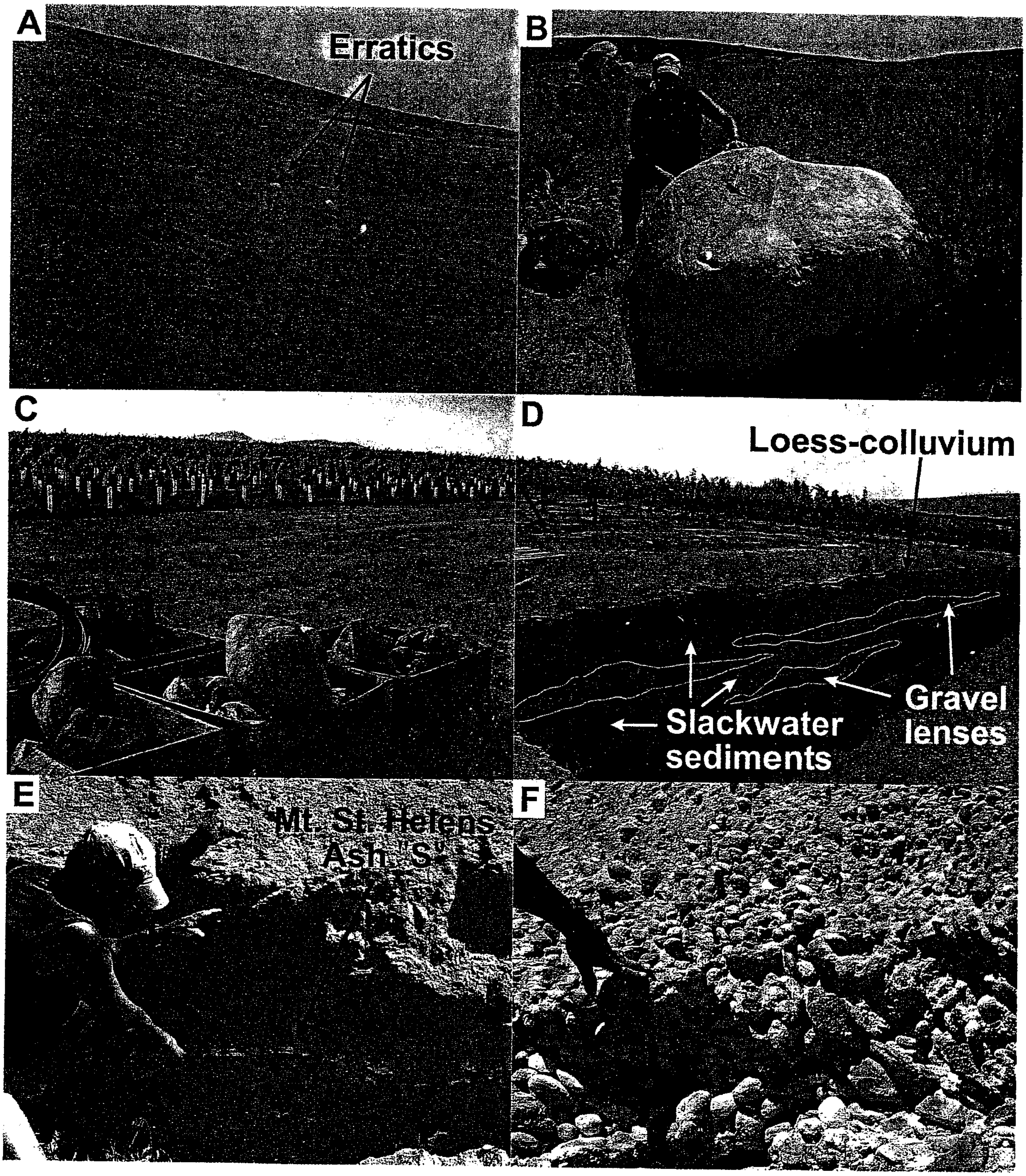

Figure 9 Photographs of vineyard features in the Red Mountain area. A) South side of Red Mountain about 100 m below the peak showing location of ice-rafted boulders. For scale, sagebrush is about 1 m high. B) Example of an ice-rafted boulder. The polished and rounded stone is gleaming white marble with layers of brown garnet skarn. C) Glacial erratic boulders gleaned from the Kiona vineyard are collected in wooden boxes (grape picking bins). D) Cut bank in Tapteil vineyard exposing 3–4 m cross-section of Quaternary loess, slackwater deposits, gravel lenses, and loess-colluvium. Gravel in lenses is similar in size to that in photo F. E) 2–4 cm white band of Mt. St. Helens "S" ash in Quaternary slackwater and channel deposits exposed in roadcut on south side of Red Mountain AVA. F) Lime-cemented gravels of the Scooteney soil association.

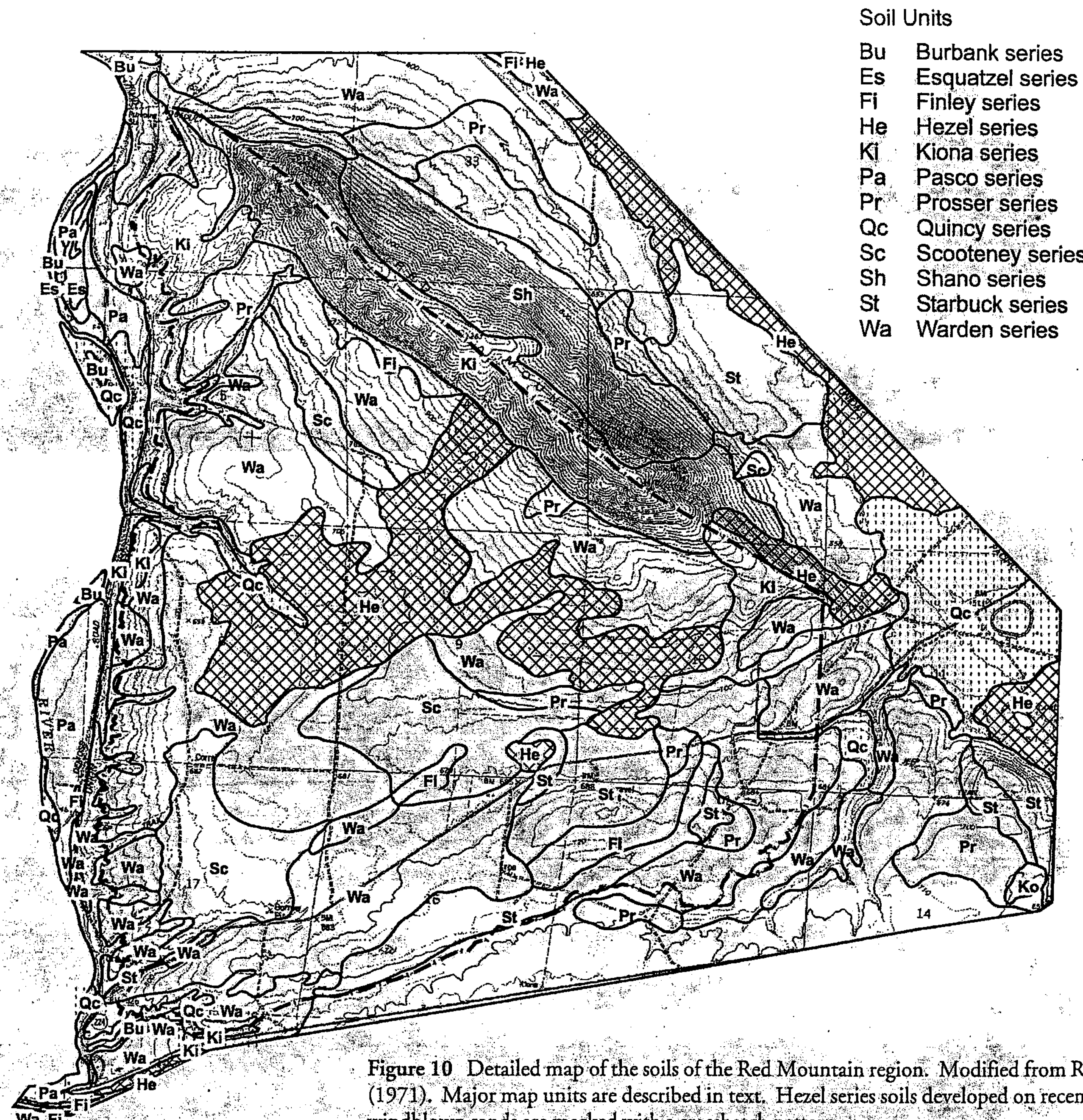

Figure 10 Detailed map of the soils of the Red Mountain region. Modified from Rasmussen (1971). Major map units are described in text. Hezel series soils developed on recent windblown sands are marked with a crosshatch pattern.

influenced most of the soils. With such marked variation in texture within and among soil profiles at Red Mountain, the volumetric water content at field capacity ranges from 7% for soils like the Hezel at the Ciel du Cheval vineyard to as high as 24% for soils like the Warden at the Belle Ville vineyard.

X-ray fluorescence and inductively coupled plasma mass spectrometry (ICPMS) total elemental analyses of selected soil samples from Red Mountain (Table 4) show that these soils have a remarkably uniform composition, ranging from 61 to 67% SiO_2, 12 to 14% Al_2O_3, and 6 to 8% FeO. The most variable element is calcium, ranging from about 4 to 8%. This is explained by the presence of variable amounts of pedogenic lime coatings in the samples. The major-element composition of the soils appears to be partly related to clay content; that is, soils with higher clay contents tend to have higher SiO_2 contents.

Soil profiles like the Scooteney hardpan variant strongly restrict rooting depth, whereas Scooteney, Warden, and Hezel pose only moderate restrictions on rooting depth. We have observed a vineyard just outside the appellation that is partly planted on the Starbuck soil (Fig. 11) that is less than 50 cm to bedrock. Vines in this soil show stunted development and severe late-season water stress compared to vines on deeper soils in the same vineyard.

Virtually all of the soils have free lime both at the surface and at one-metre depth (Table 4), which is a reflection both of the very low rainfall for leaching and the continual addition of carbonate-bearing dust to these soils. All of the soils have pH values of about 8 at the surface, reflecting a pH control by free calcium carbonate. Interestingly, all of the samples from a depth

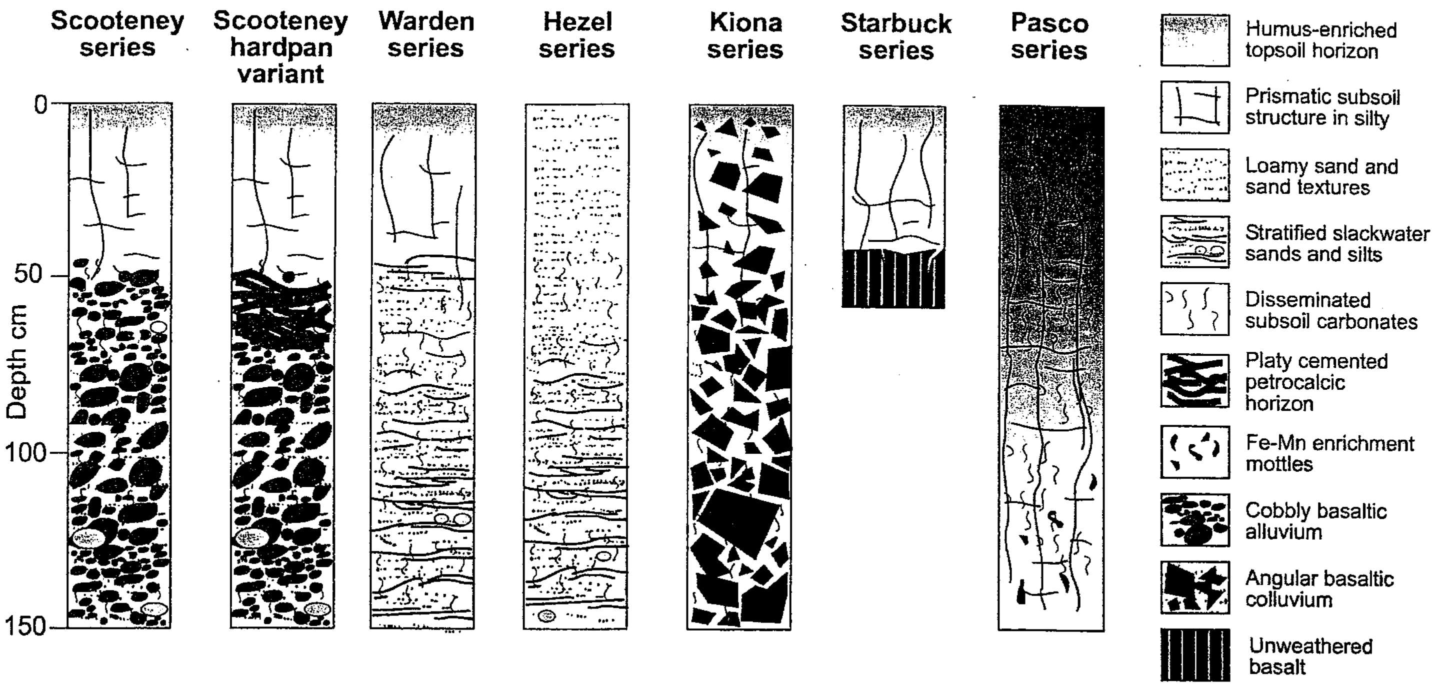

Figure 11 Representative soil profiles of the main soil series in the Red Mountain area. Degree of shading of the topsoil horizons is proportional to the content of humified organic matter. The irregular lines in the prismatic subsoil pattern represent the pattern of soil structure that develops in these silty soil horizons.

of one metre have pH values from 8.5 to 8.8, suggesting that these soils contain moderate amounts of exchangeable sodium. No evidence for a true sodic soil condition has been observed in the vineyards, however.

Vineyards planted on the wide range of soils that occur within the bounds of the AVA have large differences in water-holding capacity, infiltration, and potentially runoff. All of the soils share a strong soil-moisture deficit during the growing season, which allows growers to control water uptake by the grape vines and thus, one determinant of vine vigour. Some of the Scooteney hardpan variant soils may have a risk of shallow saturation and waterlogging under irrigation whereas others nearby are susceptible to drought.

RED MOUNTAIN CLIMATE

Red Mountain is one of the warmer vineyard sites in Washington State with 3409 degree days (50°F) recorded in 1998 and an average of 3016 degree days for the years of record (Table 5). For comparison, the Napa Valley in California and the Barossa Valley in Australia average 3280 and 3090 degree days, respectively [see the broader discussion by Meinert and Busacca (2000) of climatic measures in Washington and by Gladstones (1992, 2001) of general climatic measures relative to viticulture]. Red Mountain also may be the driest viticultural area in Washington State, with an average annual precipitation of 17.8 cm and a low in 1999 of 8.4 cm (Table 5). Comparison of monthly temperatures and precipitation (Fig. 12) shows that the lowest precipitation coincides with the highest temperatures, and because of the low water-holding capacity of the soil and low water table, this creates a moisture deficit that requires irrigation in all vineyards. With the high evapotranspiration rates in such conditions, drip irrigation is the dominant method of supplying supplemental water.

Red Mountain, at the eastern end of the Yakima Valley, is exposed to fairly steady westerly winds, averaging 6.8 km/hr, with relatively little monthly variation (5.5–7.9 km/hr). Strong winds (>24 km/hr) mostly occur in the spring, with only three months (March–May) having on average 10 or more daylight hours of winds >24 km/hr. During the prime ripening season of July–October there are only 4 daylight hours total with winds >24 km/hr (Table 5).

Another variable of critical importance in ripening of grapes is sunlight exposure (see Fig. 2 in Gladstones, 1992) which at Red Mountain averages 1229 kW/m^2 from April to October (Table 5). Both the heat summation (degree days) and the total sunlight exposure are nearly identical for vineyards in Red Mountain and Napa Valley, California even though Red Mountain is about 1000 km farther north (Gladstones, 1992). However, there are many other variables that distinguish between these regions, such as number of frost-free days and diurnal temperature range.

When standing in Red Mountain vineyards on a typical summer day, another aspect of the mesoclimate can be observed. Generally, because of regional air circulation patterns, there is a high pressure zone over Red Mountain that results in clear skies directly overhead even when partial cloud cover may obstruct areas only 10 km away (Fred Artz, personal communication, 2002). These clear skies over Red Mountain can have a negative aspect during the cooler months, as both frost damage and winter kill can be a problem in some years (Jim Holmes, personal communication, 2001). Winter temperatures drop below –10°C in most years and –27.6°C was recorded in 1996 (Table 5), a year of devastating winter kill in many Pacific Northwest vineyards.

VINEYARDS AND WINES OF THE RED MOUNTAIN AVA

The Red Mountain AVA is not only Washington's newest AVA (approved in 2001), but many of the plantings are

Table 4 Composition and grain size of representative Red Mountain soils[1]

Sample #	CC-3	CC-4	CC-5	CC-6	CC-8	CC-9	CC-10	CC-1	CC-2	CC-7
Vineyard	Ciel Cheval	Ciel Cheval	Ciel Cheval	Ciel Cheval	Ciel Cheval	Ciel Cheval	Ciel Cheval	Ciel Cheval	Ciel Cheval	Ciel Cheval
Soil type	Hezel	Hezel	Hezel	Hezel	Warden	Warden	Warden	Scooteney	Scooteney	Scooteney
Depth	Surface	1 m	Surface	1 m	Surface	1 m	Surface	Surface	1 m	Surface
Grape type	Cab Sauv	Cab Sauv	Cab Sauv	Cab Sauv	Cab Sauv	Cab Sauv	Syrah	Merlot	Merlot	Cab Sauv
SiO_2	66.40	64.40	66.65	65.53	66.68	64.98	66.23	66.10	64.98	66.28
Al_2O_3	13.22	13.44	13.49	13.22	13.83	13.52	13.89	13.17	13.19	13.87
TiO_2	1.37	1.49	1.36	1.35	1.25	1.21	1.33	1.36	1.42	1.35
FeO(t)	6.98	7.09	6.77	6.69	6.84	6.81	7.16	6.93	7.34	6.95
MnO	0.12	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.12
CaO	4.62	6.03	4.31	5.72	4.00	6.16	4.00	5.00	5.61	4.12
MgO	2.35	2.71	2.29	2.51	2.23	2.54	2.30	2.54	2.55	2.28
K_2O	1.99	1.83	1.95	1.80	2.09	1.99	2.06	2.00	1.80	2.07
Na_2O	2.51	2.42	2.61	2.63	2.55	2.24	2.47	2.32	2.52	2.51
P_2O_5	0.26	0.28	0.25	0.25	0.24	0.24	0.25	0.27	0.27	0.25
LOI	3.58	3.88	3.17	3.91	3.89	5.44	4.82	4.01	3.19	4.22
Ni	18	24	22	22	20	23	21	19	19	22
Cr	47	55	51	51	41	40	48	47	45	53
Sc	17	19	23	19	22	15	18	16	16	20
V	183	210	184	190	156	161	155	182	199	172
Ba	647	651	653	677	651	659	659	627	655	657
Rb	63	62	61	58	69	74	70	68	60	67
Sr	355	354	359	393	330	317	319	337	390	336
Zr	245	262	245	250	252	223	271	262	250	263
Y	31	33	32	32	35	34	35	32	31	35
Nb	15	17	16	16	16	16	16	13	14	17
Ga	14	16	20	14	16	17	17	17	15	15
Cu	6	9	4	4	6	7	7	10	8	9
Zn	84	84	73	73	86	80	83	82	84	80
Pb	14	13	17	17	21	19	25	19	14	19
La	29	22	55	32	32	27	31	26	45	28
Ce	55	70	62	81	63	52	56	66	51	86
Th	10	13	12	11	11	9	7	8	12	11
very coarse sand	1.0	2.4	1.2	1.3	0.6	0.2	1.7	n.d.	0.9	n.d.
coarse sand	2.5	1.8	2.4	2.2	1.3	0.5	2.1	n.d.	1.5	n.d.
medium sand	3.9	2.6	3.7	3.3	2.0	0.5	2.8	n.d.	2.0	n.d.
fine sand	1.3	0.1	0.1	1.4	7.0	0.1	0.4	n.d.	0.1	n.d.
very fine sand	67.2	43.9	65.0	69.2	46.2	30.3	56.2	n.d.	68.5	n.d.
% total sand	75.9	50.9	72.4	77.4	57.1	31.7	63.2	n.d.	73.0	n.d.
coarse silt	8.7	36.0	8.5	15.6	17.9	47.2	16.5	n.d.	20.8	n.d.
fine silt	4.1	11.4	5.1	4.5	10.1	18.4	7.7	n.d.	5.1	n.d.
% total silt	12.8	47.4	13.7	20.0	28.0	65.6	24.2	n.d.	25.9	n.d.
% total clay	11.3	1.8	13.9	2.6	14.9	2.7	12.6	n.d.	1.1	n.d.
total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	n.d.	100.0	n.d.
pH 1:1	8.2	8.5	8.0	8.7	8.2	8.5	8.2	8.4	8.8	8.1
$CaCO_3$	0.7	3.0	2.7	3.3	0.4	4.8	0.4	1.1	2.2	0.4
$MgCO_3$	0.38	0.21	0.12	0.22	0.15	0.21	0.59	0.19	0.20	0.13

[1]All samples sieved to exclude >2mm fraction. Major and trace elements analyses by XRF and ICPMS in the Geoanalytical Lab at Washington State University. Grain size, pH, carbonate, and nirtogen analyses by Department of Crop and Soil Sciences at Washinton State University

relatively young, making up only about 30% of the AVA's potential acreage in cultivation. Irrigated vineyards form a striking contrast to the natural xerophytic (drought tolerant) vegetation, including species of *Artemisia, Purshia,* and *Crysothamnus* (Fig. 13A). While most of the older vineyards are planted in N–S rows, some of the younger plantings have a N10°E orientation (Fig. 13B) to maximize sun exposure (60% morning, 40% afternoon) at this latitude (46°20') and provide greater shading of fruit on the west side of the canopy in the later afternoon (Jim Holmes, personal communication, 2001).

Although the Red Mountain AVA is bounded on the west by the Yakima River (Fig. 13C), none of this water is used directly for irrigation within the Red Mountain AVA. Rather, all irrigation water in the Red Mountain AVA comes from wells that typically are about 200 m deep in order to tap intraflow aquifers (Fig. 7). Static water level is about 100 m below the surface in most of these wells, except for those closest to the Yakima River on the western margin of the Red Mountain AVA. Because of this hydrological regime, the rooting zone of all Red Mountain vineyards is well above the water table and most available soil moisture comes from drip irrigation augmented by stored soil moisture from winter rainfall and by relatively rare rainshowers during the growing season (about 5 cm total from April to October; Table 5).

As previously described, the soils and bedrock geometry of the Red Mountain AVA are well suited for vineyard production and differ in several respects from those in areas immediately surrounding the AVA. For example, the soils in vineyards such as Klipsun (Fig. 13D) within the Red Mountain AVA are quite different from those in vineyards that are only a few hundred metres outside the AVA, such as on

Table 4 Continued

Sample #	CC-11	CC-12	CC-13	K-1	BV-1	BV-2	BV-3	O-1	O-2
Vineyard	Ciel Cheval	Ciel Cheval	Ciel Cheval	Klipsun	Belle Ville	Belle Ville	Belle Ville	Oakwood	Oakwood
Soil type	Scooteney	Scooteney	Scooteney	Scooteney	Warden	Warden	Warden	Pasco	Pasco
Depth	1 m	Surface	1 m	Surface	Surface	Surface	1 m	Surface	1 m
Grape type	Syrah	Syrah	Syrah	Cab Sauv	Sagebrush	Syrah	Syrah	Riesling	Riesling
SiO_2	65.20	66.91	63.67	67.31	66.94	64.05	65.72	66.39	67.02
Al_2O_3	13.40	13.60	12.88	14.12	13.71	13.18	13.52	13.91	14.39
TiO_2	1.43	1.26	1.31	1.15	1.29	1.36	1.23	1.37	1.13
FeO(t)	7.73	6.74	7.14	6.38	6.69	7.21	6.87	6.65	5.93
MnO	0.13	0.12	0.12	0.11	0.12	0.12	0.12	0.12	0.11
CaO	4.99	4.10	7.80	3.84	4.07	7.06	5.39	4.16	4.05
MgO	2.59	2.31	2.60	2.04	2.15	2.46	2.57	2.25	2.17
K_2O	1.82	2.06	1.84	2.00	1.95	1.90	1.93	1.88	1.94
Na_2O	2.29	2.48	2.21	2.64	2.67	2.20	2.23	2.81	2.85
P_2O_5	0.25	0.24	0.24	0.21	0.22	0.26	0.22	0.26	0.23
LOI	4.18	3.79	6.12	3.72	2.78	5.79	4.79	4.10	2.93
Ni	25	22	20	29	21	20	23	29	32
Cr	45	50	46	61	44	43	49	97	81
Sc	24	19	17	18	21	16	19	16	18
V	173	152	170	134	170	171	168	161	136
Ba	635	623	626	643	639	645	682	619	643
Rb	68	68	65	67	63	69	72	59	62
Sr	314	335	333	331	354	321	308	341	330
Zr	288	272	286	285	256	283	321	262	216
Y	37	34	36	31	32	36	37	32	29
Nb	18	16	16	16	16	18	18	15	13
Ga	17	17	18	17	13	15	18	18	19
Cu	11	8	11	9	3	11	9	7	10
Zn	79	78	76	82	74	81	77	84	75
Pb	23	21	26	23	20	22	23	22	20
La	29	29	48	35	55	24	32	55	19
Ce	63	61	72	99	64	69	69	82	47
Th	9	10	14	11	11	11	13	10	8
very coarse sand	2.4	0.5	1.2	2.5	3.8	1.8	0.2	1.8	2.2
coarse sand	2.2	1.2	1.4	3.1	4.6	2.2	0.3	2.8	2.7
medium sand	0.9	2.4	1.9	3.2	4.6	1.9	0.2	4.0	3.5
fine sand	0.1	1.0	0.1	6.8	0.1	0.1	0.0	12.4	0.3
very fine sand	29.9	51.0	34.6	34.8	61.2	34.9	18.8	41.3	53.5
% total sand	35.5	56.1	39.1	50.4	69.9	40.9	19.6	66.6	62.2
coarse silt	48.2	20.9	39.6	23.2	18.7	40.8	64.9	18.1	22.2
fine silt	15.2	9.2	17.0	10.5	5.9	15.2	13.8	8.1	9.3
% total silt	63.4	30.1	56.6	33.7	24.6	56.0	78.7	26.2	31.5
% total clay	1.1	13.8	4.2	15.9	5.5	3.1	1.7	7.2	6.3
total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
pH 1:1	8.7	8.4	8.6	8.7	7.9	8.7	8.8	7.8	8.6
$CaCO_3$	2.0	0.5	7.8	0.6	0.3	6.5	3.9	0.3	0.4
$MgCO_3$	0.14	0.10	0.18	0.11	0.09	0.23	0.27	0.08	0.12

a high basalt knob to the Southwest (Fig. 13E) or on the Yakima River floodplain to the West (Fig. 13F).

The pictured vineyard (Fig. 13F) on the Yakima River flood plain is about 100 m west of the Red Mountain AVA boundary and about 200 m from the Klipsun vineyard (Fig. 13D). The rich Mollisol soils (Table 4, Fig. 11) and abundant water (even without supplemental irrigation) in the flood plain of the Yakima River result in more vigourous vegetative growth of both grape vines and ground cover relative to the nearby Red Mountain vineyards, as illustrated in photos taken on the same day of the growing season (compare Fig. 13D and 13F).

About 700 m southwest of the Red Mountain AVA there is a vineyard planted on a basalt hill that has less than a metre of loess and Quaternary glacial sediments on top of the basalt to form soils. The vine roots have penetrated into the basalt and the free drainage of the fractured basalt and thin sediment cover results in a rapid loss of soil moisture. In contrast to the vineyards on the Yakima River floodplain that have perhaps an overabundance of moisture and plant vigour, the shallow soils on this basalt knob hold little water, even after irrigation, and the resulting moisture deficit can result in reduced plant vigour (Fig. 13E).

Although the above examples illustrate differences between Red Mountain and surrounding areas, there also are important differences within the Red Mountain AVA. As previously discussed, there are variations in soil types, thickness and homogeneity of Quaternary glacial sediments, and depth to bedrock among Red Mountain vineyards (Figs. 5, 7, 10, 11, 14).

For example, Ciel du Cheval (Fig. 14B) lies in the geographic center of the Red Mountain AVA (Fig. 4) and is one

Table 5 Red Mountain 1995–2001 climate data (Red Mountain PAWS*, Lat. 46°20', Long. 119°40', Elev. 194 m)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean max. temp. °C	5.3	8.8	14.2	18.8	23.3	27.5	32.9	32.5	27.1	18.0	10.2	4.4	18.6
Mean avg. temp. °C	1.5	3.7	7.8	11.6	15.9	19.8	24.2	23.4	18.3	10.7	5.5	1.0	11.9
Mean min. temp. °C	-2.1	-1.0	1.3	3.6	7.4	10.7	14.3	13.8	9.8	3.6	1.0	-2.3	5.0
Precipitation (cm)	2.4	2.1	1.8	0.8	1.2	0.7	0.8	0.1	0.7	1.8	3.4	2.0	17.8
Snowfall (cm)	10.9	4.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	6.4	23.1
Mean wind speed (kph)	7.6	7.9	7.5	7.2	7.4	7.2	6.1	5.7	5.5	5.7	6.9	7.2	6.8
Daylight hrs wind >24 kph	2	8	11	12	10	5	1	3	0	0	0	2	54
Solar radiation (kW/m^2)	38	63	112	161	195	222	216	201	142	93	44	28	1514
Mean 9 am temp. °C	0.4	2.5	6.9	11.6	16.3	20.1	24.0	23.2	18.1	10.4	4.6	0.3	11.5
Mean 9 am relative humidity	86	81	69	55	49	45	41	44	53	67	85	86	63
Mean 2 pm temp. °C	4.2	7.6	12.8	17.3	21.6	25.8	30.8	30.7	25.7	16.9	9.0	3.2	17.1
Mean 2 pm relative humidity	71	60	45	36	33	28	24	24	31	42	68	75	45
Degree days (50°F)	2	8	26	161	320	529	772	700	389	91	16	2	3016

	1995	1996	1997	1998	1999	2000	2001	Mean
Maximum air temperature °C	40.1	41.5	39.4	42.7	39.5	39.8	40.2	40.4
Minimum air temperature °C	-17.0	-27.6	-13.3	-16.8	-8.2	-10.5	-6.6	-14.3
Precipitation (cm)		24.8	19.4	22.9	8.4	19.3	11.8	17.8
Degree days (50°F)		2836	3039	3409	2786	2920	3106	3016

* Data from Washington State University Public Agricultural Weather System (PAWS) http://frost.prosser.wsu.edu/ Courtesy of Francis Pierce, Center for Precision Agricultural Systems, WSU-IAREC

of the older vineyards, first planted in 1976. The Ciel du Cheval vineyard has a relatively low slope (Fig. 4), with homogeneous air drainage and mesoclimate. Thus, most climatic variables are approximately constant throughout the vineyard. In contrast, there are three different soil units present in the vineyard (Fig. 14B) that cut across the N–S rows of vines. The three soil units are Hezel, Scooteney, and Warden. As previously discussed, these differ in texture and composition. The Ciel du Cheval vineyard has been owned and managed by a single person, Jim Holmes, for nine years and thus has a consistency of management style that should allow for examination of viticultural and enological variations as a reflection of soil type. Initial results of grape analyses suggest that there are differences that may correlate with soil types and an ongoing study of wine sensory analysis over a three-year period has been designed to test whether different soil types can be correlated with statistically significant wine flavor profiles (Sara Spayd, written communication, 2002). This will be reported in a future publication. Such sensory differences have been correlated previously with a number of terroir variables (*e.g.,* Douglas *et al.,* 2001).

In contrast to Ciel du Cheval, the Belle Ville vineyard is relatively young, first planted in 1997. It is the northeasternmost vineyard in the Red Mountain AVA (Fig. 4), is underlain entirely by Warden series soils, and lies on a moderate slope that was extensively graded to smooth the original topography (Steve Lessard, personal communication, 2001). Expressions of topography and drainage are readily visible in Figure 14C, an orthogonal infrared image taken in August, 2001. The variations visible in the image correspond to zones of vine stress that cut across rows of a single cultivar and management regime and therefore are unlikely to result from differences in canopy management, irrigation, or other viticultural practice (Steve Lessard, personal communication, 2001). It is hypothesized that grading of the Warden series soils may have disrupted the natural drainage patterns, grain size distribution, or lime content that vary systematically with depth in the other non-graded vineyards (Table 4). All of these factors may be interrelated, making it difficult to pinpoint a single variable that may be most responsible for differences in vineyard vigour. Previous studies have correlated the onset of black leaf and other problems in Washington State to within vineyard variations of soil moisture, drainage, and grading (Ahmedullah and Dow, 1982; Silbernagel *et al.,* 1998). Whatever the cause of the observed vine stress in the Belle Ville vineyard, the apparent correlation with topography and drainage patterns suggests that environmental variation can have at least as significant an effect as can viticultural practices in vineyard performance.

DISCUSSION

The vineyards in the Red Mountain AVA share a common history of soils developed on eolian materials (loess or dune) over variable sediments that derive from giant glacial outburst floods, which in turn overlie basalts of the Columbia River Group. Variations in soil type within the appellation or even within individual vineyards, such as Ciel du Cheval, are significant but pale in comparison to that of vineyards just outside of the appellation such as on adjacent basalt knobs (Fig. 14E) or on the Yakima River floodplain (Fig. 14F). This illustrates the importance of terroir in defining a sense of place, that with appropriate vinification can lead to a distinct wine style. The Red

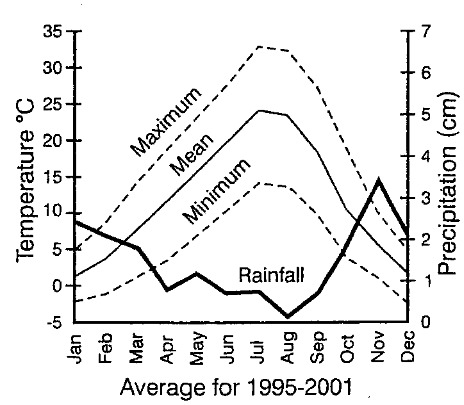

Figure 12 Graph of monthly maximum, mean, and minimum temperatures in contrast to precipitation for the Red Mountain area. Data from Table 5.

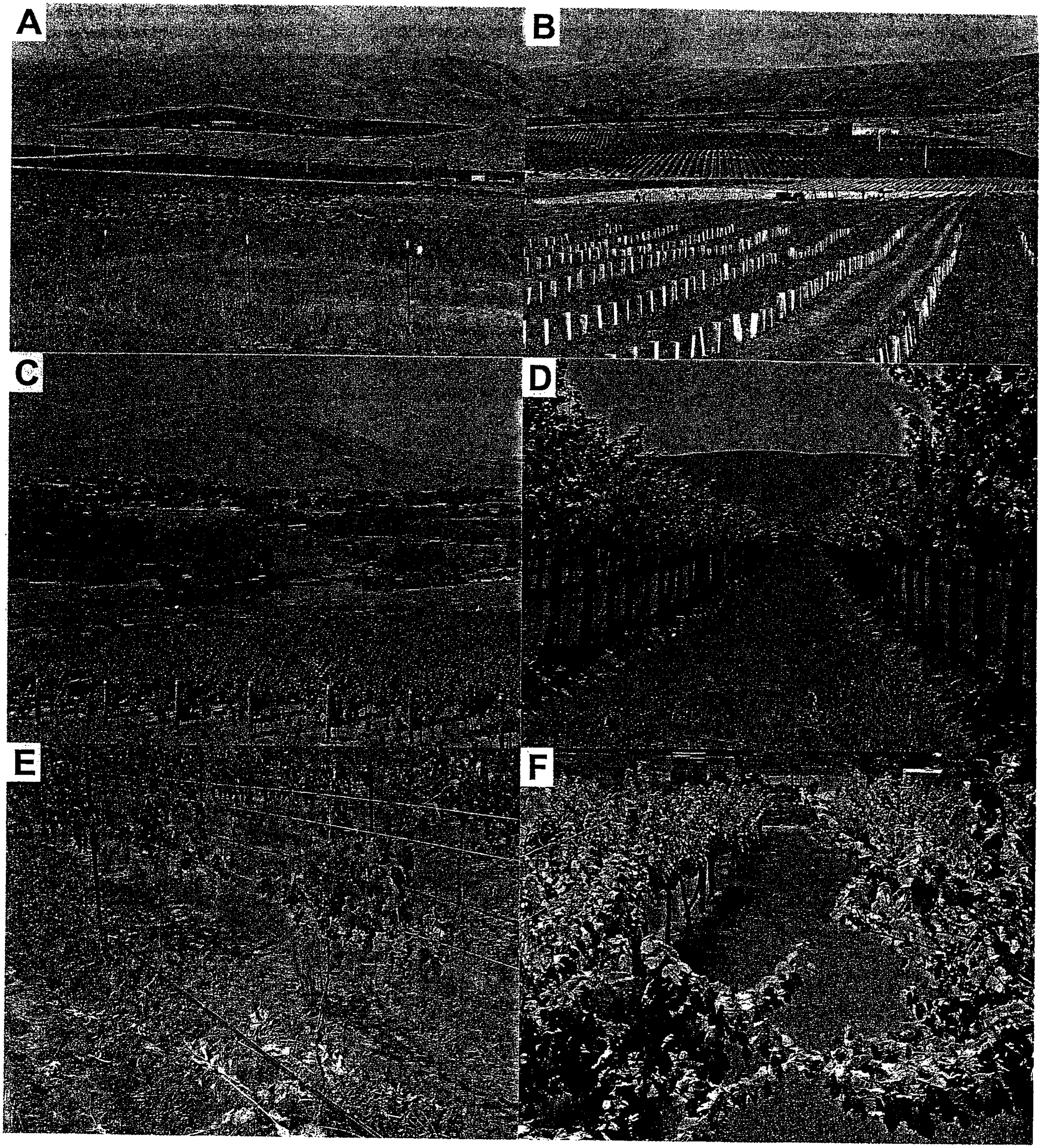

Figure 13 Photographs of vineyard features in the Red Mountain area. A) View looking northeast from the Klipsun vineyard (#10) across the Hedges Cellars (#8) and Bell Ville (#2) vineyards towards Red Mountain. B) Newly planted vines of the Golitzen vineyard (#7) have a northeasterly trend relative to the older N–S plantings of the Sand Hill (#12) and Hedges Cellars (#8) vineyards. C) View from Artz Vineyard (#1) northwest across the Yakima River towards Rattlesnake Mountain. D) View from Klipsun vineyard (#10) south towards Goose Hill. E) Vineyard planted on very shallow (<1 m, locally <10 cm) soils on top of basalt knob approximately 700 m southwest of Red Mountain AVA illustrating difference in plant vigour relative to Klipsun vineyard (#10). F) Vineyard planted on Yakima River floodplain approximately 100 m west of Red Mountain AVA illustrating difference in vine and ground cover vigour relative to Klipsun vineyard (#10). Photos D and F taken on the same day.

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Mountain wine style has been described by wine critics as powerful and intense (Antrim, 2002). Some terroir elements that contribute to this wine style include high heat summation, intense growing-season solar energy from nearly cloud-free skies, very low annual precipitation, and large growing-season soil-moisture deficits.

The numerous awards won by wines made from the Red Mountain appellation suggest that this grape-growing region is indeed becoming recognized. For example, in the past two years wines made from Red Mountain grapes have received nine scores of 94 or above out of 100 in independent blind tastings by national wine publications (Jim Holmes, written communication, 2002). In addition, the Andrew Will Merlot made from grapes from the Ciel Du Cheval Vineyard was named the best merlot in the United States by Food and Wine Magazine in 2000 (Anon., 2000) and by Wine & Spirits Magazine in 2002 (Teague, 2002). Finally, the Klipsun vineyard of Red Mountain was recognized in 2002 as one of the top 25 vineyards in the world by Wine & Spirits Magazine (Antrim, 2002).

Comparisons with other appellations in Washington State (*e.g.*, Meinert and Busacca, 2000), North America, and other wine regions in the world show some common threads and also some important differences. As noted at the onset of this paper, more than 90% of Washington vineyards are located in areas affected by glacial outburst floods. In the Red Mountain area, these flood sediments were mostly deposited from the swirling back-eddies behind Red Mountain and include numerous lenses of relatively coarse gravel. In the Walla Walla area, the flood sediments are generally finer grained as a result of their deposition from ponded floodwaters behind Wallula Gap, although there are some zones of coarse gravels in modern river channels (Fig. 9C, D, E; Meinert and Busacca, 2000). Even with these differences in grain size, however, both Red Mountain and Walla Walla have in common a mantle of loess and more recent wind-blown sands over the glacial flood sediments.

The common glacial history of most Washington vineyards is offset by differences in a variety of climate measures. Red Mountain is near the extremes for Washington State in terms of high heat summation (growing-degree days) and low precipitation. For example, most of the Yakima Valley has 200 to 400 fewer growing-degree days than Red Mountain, and Walla Walla has more than twice the precipitation on average (Meinert and Busacca, 2000). Like many Washington appellations, Red Mountain is susceptible to both spring frosts and winter kill. According to the optimum climatic criteria for winegrape growing identified by Gladstones (1992, 2001), Red Mountain is near the top in growing-degree days, growing-season solar radiation, mean temperature, and rainfall. However, Red Mountain is outside of the optimum ranges identified by Gladstones for relative humidity, high maximum temperature, and temperature variability index (roughly the daily variation between highest and lowest temperatures), although the very high-quality wines that have been produced from Red Mountain grapes suggest that the subtle interactions of climatic factors are not completely understood.

With the clear evidence of glacial influence on Washington state vineyards, it seems appropriate to examine how other viticultural regions have been affected by glaciation. Although the complex sedimentary patterns caused by the glacial outburst flooding in the back-eddy of Red Mountain may be unique among world vineyards, many other wine-producing areas of the world also have links to Pleistocene glaciation. This is primarily due to two factors: worldwide lowering of sea level during maximum glaciation, and the locally abundant clastic sediments produced by alpine and continental glaciers.

At the glacial maximum, sea level was lowered by about 130 m relative to today, exposing many coastal areas to increased erosion and changing sedimentation patterns, such as wind-blown loess and sand dunes from the newly exposed coastal shelves. Many viticultural areas within 100 km of the ocean have been so affected. Concurrent with this sea level drawdown was an increased sediment load in both rivers and valley glaciers fed by mountain ranges that intercepted moisture-laden maritime air and consequently built up extensive icefields.

A prime example of this is the Graves-Médoc region of Bordeaux, France (Wilson, 1998). Outwash gravels from alpine glaciation in the Pyrenees along the French-Spanish border and the Massif Central in central France overloaded the Garonne and Dordogne rivers leading to the Gironde Estuary, which itself had been enlarged and deepened in response to the lowering of sea level. Each period of

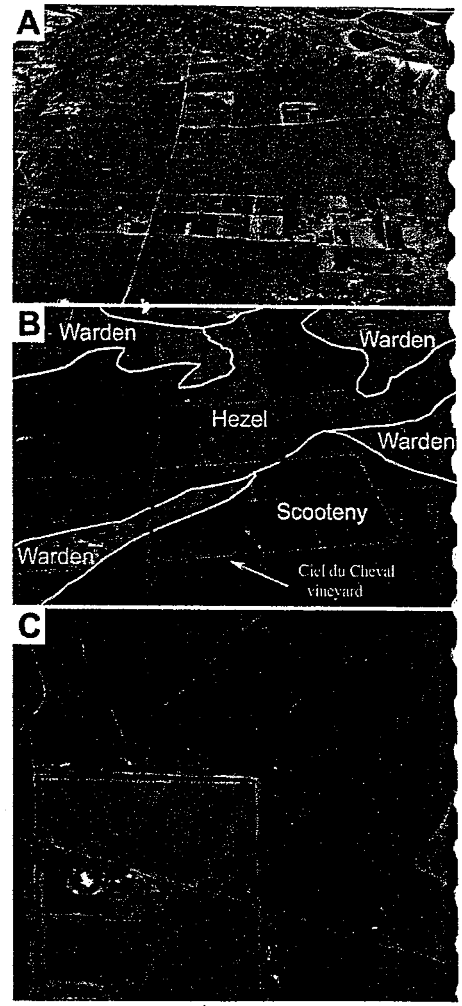

Figure 14 Soil and vegetation patterns for vineyards in the Red Mountain AVA. A) 3-D perspective view of Red Mountain area with soil series draped over black and white ortho aerial photograph. Data from Rasmussen (1971). B) Close-up of 14A showing soil series patterns within individual vineyards. In the Ciel du Cheval vineyard (#5) some vine rows cross three different soil types, providing an opportunity to study the effect of different soil characteristics on grape vine performance with little or no change in climate or viticultural practice. C) Aerial color infrared imagery showing differences in plant vigour relative to topography and soil distribution in the Belle Ville vineyard (#2). Note that in infrared images, green vegetation such as leafy vineyards is red whereas arid range lands are dark green. Images courtesy of Francis Pierce, Center for Precision Agricultural Systems, WSU-IAREC.

glaciation produced its own series of gravel outwash floodplains along the rivers. Of the four glacial stages identified by Wilson (1998), the Günz stage produced the gravel mounds that are synonymous with the best (First Growth) vineyards (Wilson, 1998). Wineries such as Chateaux Lafite-Rothschild, Haut-Brion, Latour, and Mouton-Rothschild are well known to wine-lovers throughout the world, and each of these wineries and their estate vineyards are located on gravel mounds (the geographical name 'Graves' means gravel in French) formed during a Pleistocene glacial maximum. Wilson (1998, his Table 5.1) provided an extended analysis of the various glacial and interglacial epochs of the Bordeaux region along with correlations to archeological timelines that predate settlement of North America by tens of thousands of years, such as the prehistoric cave art of Les Eyzies, Lascaux, and Pech Merle. Even without the common terroir connection to Washington State this makes for fascinating reading!

Less well known are the gravel outwash plains of the South Island of New Zealand. These were fed by the extensive alpine glaciation of the Southern Alps mountain range that transects the island. These gravels form the substrate for many of the vineyards in the Marlborough area of New Zealand, and some of the wineries of this region focus on the coarse gravels, such as the Rapaura Series, for their best vineyards (http://www.stoneleigh.co.nz/). Another area in New Zealand, Gimblett Gravels, is perhaps the first viticultural region in the world to specifically define itself on the basis of the gravel. Legally, wines from this appellation have to consist of at least 95% grapes grown on the Gimblett Gravels, specifically the Omahu Gravels (http://www.gimblettgravels.com/index.htm). These gravels are somewhat different from those in the Marlborough area in that they have been extensively reworked by present and paleoflows of the Ngaruroro River. Within the Gimblett Gravels are lenses of sand, silt, and clay at various depths. These lenses contain up to 20% silt and 9% clay. In general, the gravels are free draining with little water-holding capacity, mostly between 9 and 20% soil moisture (http://www.gimblettgravels.com/terroir.htm). These features are similar to those documented for the gravels of Bordeaux, France (Figure 6.3 of Wilson, 1998) and some of the soil and gravel lenses of Red Mountain, Washington (Table 4, Fig. 9D, F).

Even though some vineyards in Washington State, Bordeaux, and New Zealand share elements of a common Pleistocene glacial history, there still are large differences in climate, viticultural, and oenological practices that make these areas distinct. The present study does not aim to minimize these other factors or the importance of human ingenuity in making great wine from great vineyards (Moran, 2001), but seeks to illustrate the importance of understanding the physical environment as one essential element of terroir. From both an oenological and geological perspective, the terroir of Red Mountain is truly excellent.

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Wine and geology—The terroir of Washington State

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ABSTRACT

Washington State is second only to California in terms of wine produced in the United States, and some of its vineyards and wines are among the world's best. Most Washington vineyards are situated east of the Cascades on soils formed from Quaternary sediments that overlie Miocene basaltic rocks of the Columbia River Flood Basalt Province. Pleistocene fluvial sediments were deposited during cataclysmic glacial outburst floods that formed the spectacular Channeled Scabland. Late Pleistocene and Holocene sand sheets and loess form a variable mantle over outburst sediments. Rainfall for wine grape production ranges from ~6–18 in (150–450 mm) annually with a pronounced winter maximum and warm, dry summers. This field trip will examine the terroir of some of Washington's best vineyards. Terroir involves the complex interplay of climate, soil, geology, and other physical factors that influence the character and quality of wine. These factors underpin the substantial contribution of good viticultural practice and expert winemaking. We will travel by bus over the Cascade Mountains to the Yakima Valley appellation to see the effects of rain shadow, bedrock variation, sediment and soil characteristics, and air drainage on vineyard siting; we will visit the Red Mountain appellation to examine sites with warm mesoclimate and soils from back-eddy glacial flood and eolian sediments; the next stop will be the Walla Walla Valley appellation with excellent exposures of glacial slackwater sediments (which underlie the best vineyards) as well as the United States' largest wind energy facility. Finally, we will visit the very creatively sited Wallula Vineyard in the Columbia Valley appellation overlooking the Columbia River before returning to Seattle.

Keywords: wine, terroir, wine grapes, loess, soils, outburst floods.

INTRODUCTION

The purpose of this field trip is to examine the connection between wine and geology in Washington State, a connection that commonly is described by the word "terroir." Although the term originated in France, terroir increasingly is being used in other parts of the world to explore differences at the scale of appellations to individual vineyards to within-vineyard domains (Halliday, 1993, 1999; Wilson, 1998, 2001; Haynes, 1999, 2000). But the word "terroir" is mysterious to many people; there is confusion about what it is, how it is documented, and even how it is pronounced (tehr-wahr). Terroir involves the complex interplay of climate, soil, geology, and other physical factors that influence the character and quality of wine. These factors are in addition to, or perhaps underlie, the substantial contribution of good viticultural practice and expert winemaking. One common illustration of the importance of terroir is the occurrence of adjacent or nearby vineyards that produce strikingly different wines even though many of the measurable aspects of climate, viticulture, and winemaking technique are very similar. It is also common,

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although usually incorrect, to point to a single factor as the explanation: "it's the soil"; "it's the water"; "it's the limestone"; etc. Terroir is the integration of individual factors that contribute to wine quality, and to make matters even more complicated there is the complexity of year-to-year variation in climate. What may be good terroir in one year may be less so in another.

The 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 (from http://www.m-w.com/cgi-bin/dictionary?book=Dictionary&va=appellation; accessed on September 4, 2003). Washington State has five wine appellations called American Viticultural Areas (AVAs) by the Alcohol and Tobacco Tax and Trade Bureau (TTB; formerly Bureau of Alcohol, Tobacco, and Firearms), the chief regulatory agency of the wine industry in the United States. The current Washington State appellations (AVAs) are Columbia Valley, Puget Sound, Red Mountain, Walla Walla Valley, and Yakima Valley (Fig. 1). Sub-appellations that may someday become AVAs include Alder Ridge, Canoe Ridge, Cold Creek, Columbia River Gorge, Horse Heaven Hills, Wahluke Slope, Zephyr Ridge (Peterson-Nedry, 2000), and the Okanogan Valley-Lake Chelan area.

As with most other wine growing regions, Washington AVAs can be nested such that the Columbia Valley appellation, which produces more than 90% of the state's wine grapes, includes the Yakima Valley, Walla Walla Valley, and Red Mountain appellations (Fig. 1). The area available for future planting is very large. In the 10.7-million-acre Columbia Valley appellation, only ~16,000 acres are planted with wine grapes. Even the smallest appellation, Red Mountain, has room for expansion with ~710 acres out of the 4040 acres of the AVA planted with vines. In many cases the availability of water for irrigation is a larger limitation than the suitability of land for growing high-quality grapes.

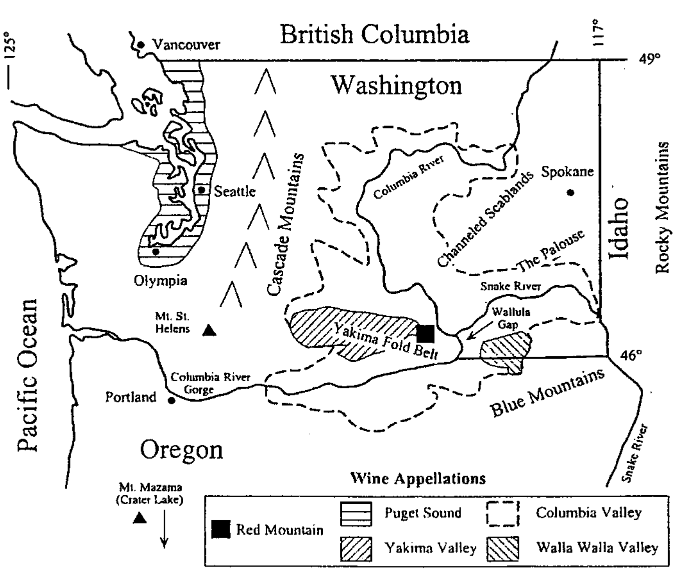

Figure 1. Location map of the Pacific Northwest showing wine appellations of Washington State and major geographical features described in the text.

Only ~18% of Washington's wine grapes are from vineyards more than 20 yr old, and of these older vineyards, white grapes (73%) predominate over red grapes (27%) (www.nass.usda.gov/wa/wine02.pdf). For example, Riesling was the most widely planted white wine grape prior to 1982 at 54% of its current (2002) acreage. In contrast, Cabernet Sauvignon, Merlot, and Syrah were the three most widely planted red grapes in 2002 and had only 12%, 5%, and 0%, respectively, of their current acreage planted prior to 1982.

Currently there are ~240 wineries in Washington State. Total wine grape production in 2001 was 100,000 tons from 24,000 acres of bearing vineyards. 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 2001. Most grape vines start producing commercial yields in their third year. Wine grape production in 2002 was 115,000 tons. Of the wine produced in Washington State in 2002, there was an equal split between white and red wine, down from a majority (62%) of white wine in 1998. For example, the production of Semillon and Chenin Blanc in this three-year period decreased 35%, whereas the production of Cabernet Sauvignon, Merlot, and Syrah increased 200%. This trend toward a predominance of red wine production in Washington State likely will continue in the future because of the increased plantings of red varietals and the higher prices realized from red grapes in general.

REGIONAL GEOLOGIC HISTORY

Most Washington vineyards lie in the geographic center of 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 Mountains (Fig. 1). The area is underlain by the Columbia River Basalt Group, which covers an area of ~165,000 km^2. The Columbia River Basalt Group was erupted mostly between 17 and 11 Ma (early Miocene) from north-south fissures roughly paralleling the present-day Washington-Idaho border. The Columbia River Basalt Group has individual flows with estimated eruptive volumes of at least 3000 km^3, making them the largest documented lava flows on Earth (Baksi, 1989; Landon and Long, 1989; Tolan et al., 1989). This dwarfs the erupted volumes of typical Cascade volcanoes: even the explosive eruption of Mount St. Helens in 1980 yielded only ~1 km^3 of volcanic material (Pringle, 1993). The basalts are interstratified with volcaniclastic rocks of the Ellensburg Formation, mainly in the western part, including the Yakima fold belt through which we will be traveling.

The basalt bedrock is overlain by unconsolidated sediments deposited by glacial outburst floods and eolian processes described in some detail in Meinert and Busacca (2000). To briefly summarize: a lobe of the Cordilleran Ice Sheet blocked the Clark Fork River near the Canadian border in northern Idaho most recently ca. 18,000 ka and created glacial Lake Missoula (Fig. 2), which covered 7800 km^2 of western Montana (Pardee, 1910). At the ice dam the water was ~600 m deep (Weis and Newman, 1989). The ice dam failed repeatedly, releasing the largest floods documented on Earth (Baker and Nummedal, 1978). These floods overwhelmed the Columbia River drainage system and sent up to 2500 km^3 of water across the Columbia Plateau with each outburst (called jökulhlaups in Iceland, where similar, though orders of magnitude smaller, events occur today). The floods eroded a spectacular complex of anastomosing channels, locally called "coulees," into southwest-dipping basalt surfaces. They also eroded huge cataracts in the basalt, now seen as dry falls, and "loess islands" that 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 these features make up the Channeled Scabland as detailed in the early work by Bretz (1923, 1925, 1928a, b, and c, 1932).

In south-central Washington State, the many paths of the onrushing floods converged on the Pasco Basin, where floodwaters were slowed by the hydrologic constriction of Wallula Gap (Fig. 2) before draining out through the Columbia River Gorge to the Pacific Ocean. This constriction caused back flooding of local river valleys and basins, which resulted in deposition of relatively fine-grained slackwater sediments characterized by rhythmically graded bedding; these graded rhythmites, locally called touchet beds and multiple sets, have been recognized and are indicative of multiple floods during the Last Glacial Maximum (Flint, 1938; Waitt, 1980, 1985).

Loess, sand dunes, and sand sheets have been accumulating on the Columbia Plateau throughout much or all of the Quaternary Period (Busacca, 1989). The loess is thickest, up to 75 m, in a 10,000 km^2 area northeast of the Columbia Valley appellation in an area called the Palouse (Fig. 2; Baker et al., 1991). A major source of sediment for the dunes and loess has been slackwater and other glacial sediments from older episodes of outburst flooding (McDonald and Busacca, 1988; Sweeney et al., 2002). Most recently during the last stages of the Pleistocene (from ca. 20 ka to 14 ka) and continuing through the Holocene, prevailing southwesterly winds eroded slackwater and other glacial sediments and redeposited them into the present sand dunes, sand sheets, and loess that mantle much of the Columbia Plateau. Soils formed from these windblown sediments are the backbone of agriculture in all of eastern Washington (Boling et al., 1998).

Two major units of loess that span approximately the past 70,000 yr have been informally named L1 and L2 (McDonald and Busacca, 1992). Many layers of distal tephra have been described and sampled from loess exposures and fingerprinted by electron microprobe (Busacca et al., 1992). Distal tephra layers in L1 loess have been correlated to Glacier Peak layers G and B (ca. 13,300 cal. yr B.P.) and to Mount St. Helens set S distal tephra (MSH S; ca. 15,300 cal. yr B.P.), and those in L2 loess to Mount St. Helens set C distal tephra (MSH C; ca. 50,000–55,000 thermoluminescence [TL] yr B.P.).

The L1 and L2 loess units thin and fine away from major slackwater sediment areas in the Umatilla and Pasco Basins (Busacca and McDonald, 1994) and Eureka Flat (Sweeney et al., 2003). The patterns are consistent with evidence that two major episodes of scabland flooding, one ca. 70,000–60,000 yr B.P. and the other the classic Spokane Floods ca. 20,000–15,000 TL yr B.P., triggered the last two major cycles of loess deposition on the Columbia Plateau and that they accumulated with only temporary slowing of deposition for much of the succeeding interglacial intervals.

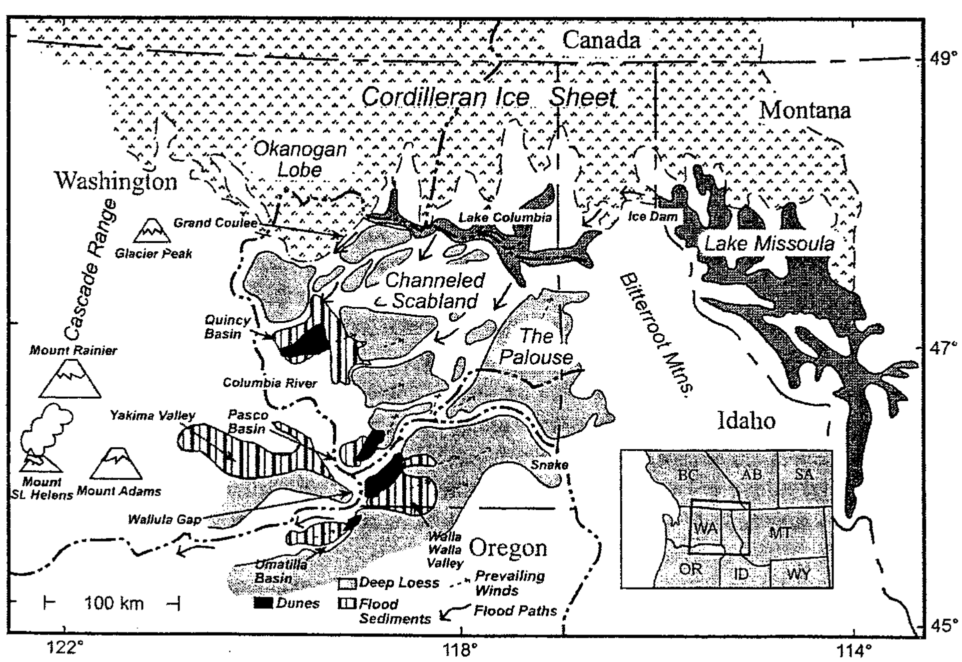

Figure 2. Schematic diagram showing the Pacific Northwest during the Last Glacial Maximum, the Lake Missoula–Channeled Scabland system, eolian sediments, and volcanoes of the Cascade Range.

SOILS, NATIVE VEGETATION, AND CLIMATE

Surface soils on the Columbia Plateau are dominantly Mollisols, Aridisols, and Entisols (Boling et al., 1998; Soil Survey Staff, 1999). In the central part of the Columbia Plateau where mean annual precipitation (MAP) is less than ~9 in (230 mm), soils developed in loess under sagebrush steppe are Aridisols, whereas soils developed in sand dunes under similar vegetation and precipitation are Entisols. Soils developed in loess under perennial bunchgrass vegetation where MAP is greater than or equal to ~9 in are Mollisols. Around the margins of the plateau loess soils formed under conifers are Alfisols. Some forest soils have a mantle of tephra-rich loess from Mount Mazama and are Andisols. Soils used for wine grapes commonly are Aridisols in which the upper horizons are formed in loess or sheet sands and lower horizons are formed in stratified silty to gravelly outburst flood sediments. Some have a lime-silica indurated pan at the interface between materials. Some wine grape soils are formed in loess or sand to 5 ft (1.5 m) or more. Thus, there are major differences in rooting depth, texture, and resulting water-holding capacity, which are key properties for inducing controlled water stress to improve grape quality.

Pre-agricultural vegetation in southeastern Washington ranged from sagebrush-steppe in the driest areas, to meadow steppe in areas of intermediate precipitation, to coniferous forest (Daubenmire, 1970). Xerophytic (drought tolerant) shrubs include several species of *Artemisia*, *Purshia*, and *Crysothamnus*. Perennial grasses include the major species bluebunch wheatgrass (*Agropyron spicatum*), Idaho fescue (*Festuca idahoensis*), and Sandberg bluegrass (*Poa sandbergii*) and a host of less common annual and perennial grasses and forbs. Mesophytic (moisture-loving) shrubs include *rosa* spp., Serviceberry (*Amelanchier alnifolia*), and Snowberry (*Symphoricarpos albus*). Several zones of conifer vegetation have been recognized with increasing effective moisture and decreasing temperature (Daubenmire and Daubenmire, 1984).

Climate is one of the more important components of terroir. In some ways it is the most difficult to evaluate because it varies in both space and time. There are many weather 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.

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 (http://frost.prosser.wsu.edu/). Such data can be used for regional and worldwide comparisons, e.g., the excellent analyses of Gladstones (1992, 2001).

The climate of the Columbia Plateau is influenced to a great extent by prevailing westerly winds and by the Cascade and Rocky Mountains. The Cascade Mountains create a rain shadow, and as a result the climate of the Columbia Plateau is arid to subhumid (15–100 cm of mean annual precipitation). The amount of precipitation is closely correlated with elevation, generally increasing from west to east and southeast. The Rocky Mountains protect this section of Washington from the coldest of the arctic storms that sweep down through Canada.

During the summer, high-pressure systems prevail, leading to dry, warm conditions and low relative humidity. Average afternoon temperatures in the summer range from 20 to over 35 °C. Most of the growing season is very dry and some vineyards experience no measurable precipitation during the summer months. The rainy season extends from October to late May or June, as frontal storms sweep across the area. In eastern Washington, most of the precipitation from mid-December to mid-February is in the form of snow.

As an example of climates of Washington appellations, Red Mountain is a warm vineyard site with 3409 degree days (50 °F) 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 (see the broader discussion by Meinert and Busacca [2000, 2002] of climatic measures in Washington and by Gladstones [1992, 2001] of general climatic measures relative to viticulture). Red Mountain also may be the driest viticultural area in Washington State, with an average annual precipitation of 17.8 cm and a low in 1999 of 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. With the high evapotranspiration rates in such conditions, drip irrigation is the dominant method of supplying supplemental water.

Regional comparisons are possible using the above geologic history and climatic data. For example, more than 90% of Washington vineyards are located in areas affected by glacial outburst floods. In the Red Mountain appellation, these flood sediments were mostly deposited from the swirling back-eddies behind Red Mountain and include numerous lenses of relatively coarse gravel. In the Walla Walla Valley appellation, the flood sediments are generally finer grained due to deposition from ponded floodwaters, although there are some zones of coarse gravels in modern river channels.

The goal of this field trip is to examine the terroir of specific Washington vineyards and to attempt to correlate the observed features of soils, geology, climate, and other physical factors with variations in grape and wine quality. The specific field stops will include:

Day 1	
Stop 1	Yakima Valley appellation—Red Willow Vineyard
Stop 2	Hogue—lunch and winery tour
Stop 3	Red Mountain appellation—Ciel du Cheval and Klipsun Vineyards
Stop 4	Webber Canyon slackwater deposits with Mount St. Helens "S" ash and post-flood (L1) loess
Stop 5	Wallula Gap overlook (optional)
Stop 6	Holiday Inn Express, check in before dinner
Stop 7	Gourmet wine and dinner at L'Ecole No. 41 Winery

Day 2	
Stop 1	Walla Walla Valley appellation—Cailloux Vineyard
Stop 2	Walla Walla Valley appellation—Pepperbridge Vineyard
Stop 3	Walla Walla Valley appellation—Loess Vineyard: Leonetti Cellars
Stop 4	Burlingame Canyon exposure of slackwater sediments and L1 loess
Stop 5	Lunch and tour at FPL Energy's Stateline Wind Energy Center
Stop 6	Columbia Valley appellation—Wallula Vineyards; taste Stimson Lane wines sourced from Wallula and Canoe Ridge Vineyard grapes
Stop 7	Dinner at Grant's Brewpub in Yakima, return to Seattle Convention Center

ROAD LOG

Day 1. Seattle to Walla Walla (Fig. 3A)

Cumulative Miles	*(km)*	
0.0	(0.0)	Check in for field trip at main entrance to the Washington State Convention and Trade Center at 7:00 am to enable 7:30 am departure. Start out going southwest on Union St. Go three blocks and turn left onto 5th Ave. Go three blocks and turn left onto Spring St. Take the I-5 south ramp toward Portland.
1.3	(2.1)	Junction of I-5 with I-90 east. Immediately merge onto I-90 east via the exit—on the left—toward Bellevue/Spokane.
50.3	(80.9)	Snoqualmie Pass, elevation 3022 ft, on I-90, is the lowest and most heavily traveled east-west highway crossing in Washington State. It is one of the state's two east-west highways with mountain passes open year-round. It is the drainage divide between generally cool, rainy lands west of the Cascades and warm, dry lands east of the Cascades.
109.3	(175.9)	Take offramp from I-90 east to I-82 east toward Yakima.
146.8	(236.2)	Take offramp from I-82 onto State Highway 97 south.
147.4	(237.2)	Here the Yakima River passes through Union Gap, a water gap in Ahtanum Ridge, part of the Yakima fold belt (see Reidel et al., 1984). The Yakima fold belt formed when basalt flows and their interstratified sediments were folded and faulted by north-south compression. The Yakima fold belt is composed of sharp anticlinal ridges separated by wide synclinal valleys. Most of the folding is younger than ca. 10.5 Ma (Reidel and Hooper, 1989), or after the end of the major outpourings of Columbia River basalt. The steep north sides of most anticline ridges are faults that consist of imbricated thrust zones (Reidel, 1984; West et al., 1996).
149.4	(240.4)	Exit from Highway 97 by turning right (south) onto Lateral A.
154.2	(248.1)	Turn right onto West Wapato Road and travel west. Here the road travels across the Holocene fan of the Yakima River created as flood-stage flows expanded into the upper Yakima Valley after passing through the constriction of Union Gap. The low-lying fan and floodplain soils are not well suited for vinifera grapes but support hops, field crops, concord grapes (Washington is the United States' largest producer of concord grapes for juice and jellies), and various fruit crops such as apples and cherries.
156.9	(252.4)	The road rises 5–8 m over a dissected remnant of glacial slackwater sediments deposited by outburst floods that backflooded more than 70 mi (112 km) up the Yakima Valley from the Columbia-Yakima Rivers' confluence. The Horse Heaven Hills, the largest anticline in the fold belt, are visible on the left (to the south).
164.8	(265.2)	Turn right onto Stephenson Road (at 164.2 mi) and continue to the end of the road at Mike Sauer's Red Willow Vineyard.

Stop 1. Red Willow Vineyard

Red Willow Vineyard is on the south slope of Ahtanum Ridge and is within the Yakama Indian Reservation. Unlike almost all other vineyards in Washington State, Red Willow is entirely above/outside the influence of the Missoula floods and thus occurs on much older soils developed on Miocene-age volcaniclastic sediments of the Ellensburg Formation (Waters, 1961; Bingham and Grolier, 1966; Smith, 1988). At this stop we will examine soils formed from loess over volcaniclastic sediments (Fig. 4A) and discuss vineyard siting by grape varietal with owner Mike Sauer.

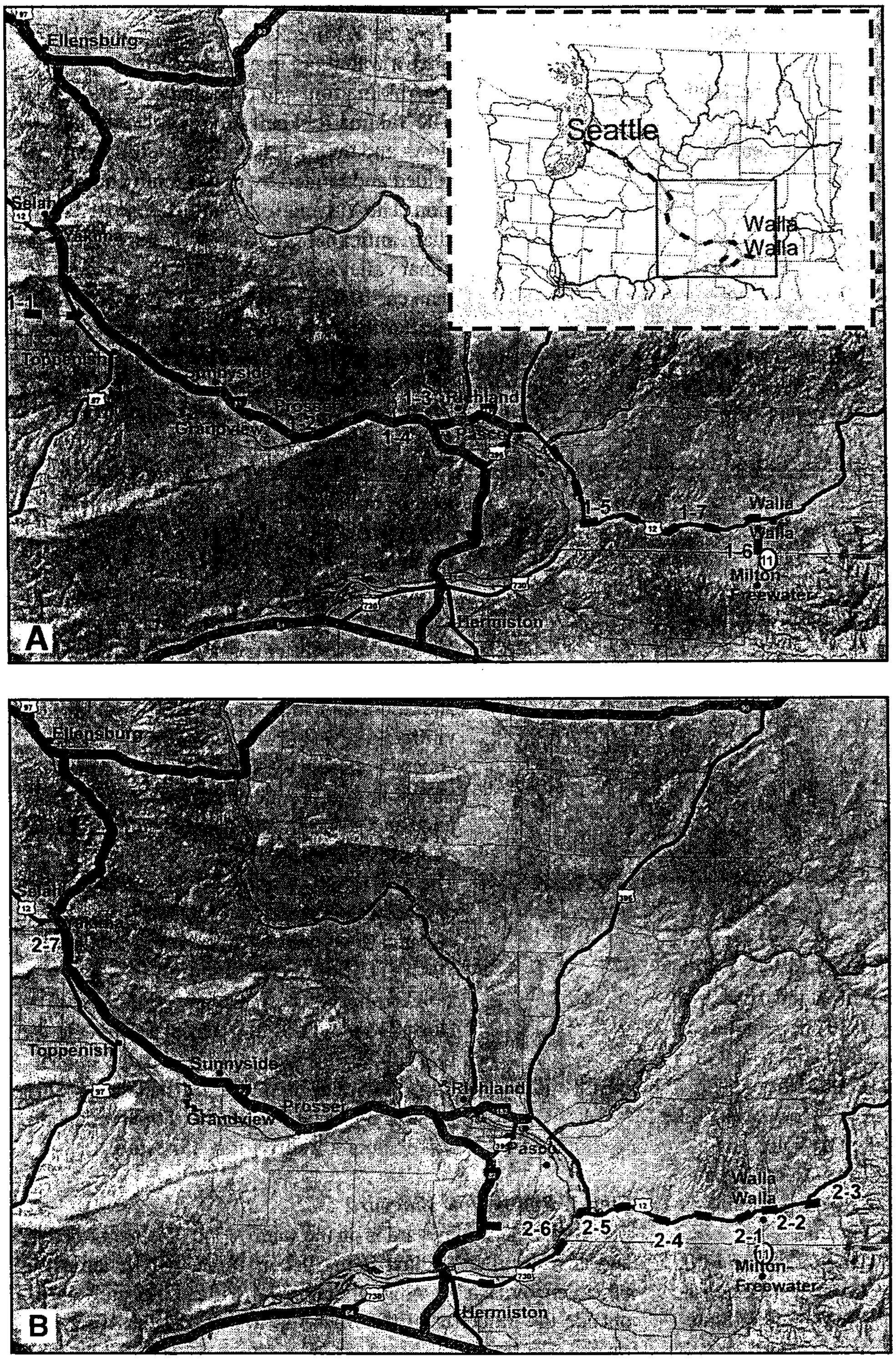

Figure 3. Maps of the routes and stops for Days 1 and 2 of the field trip.

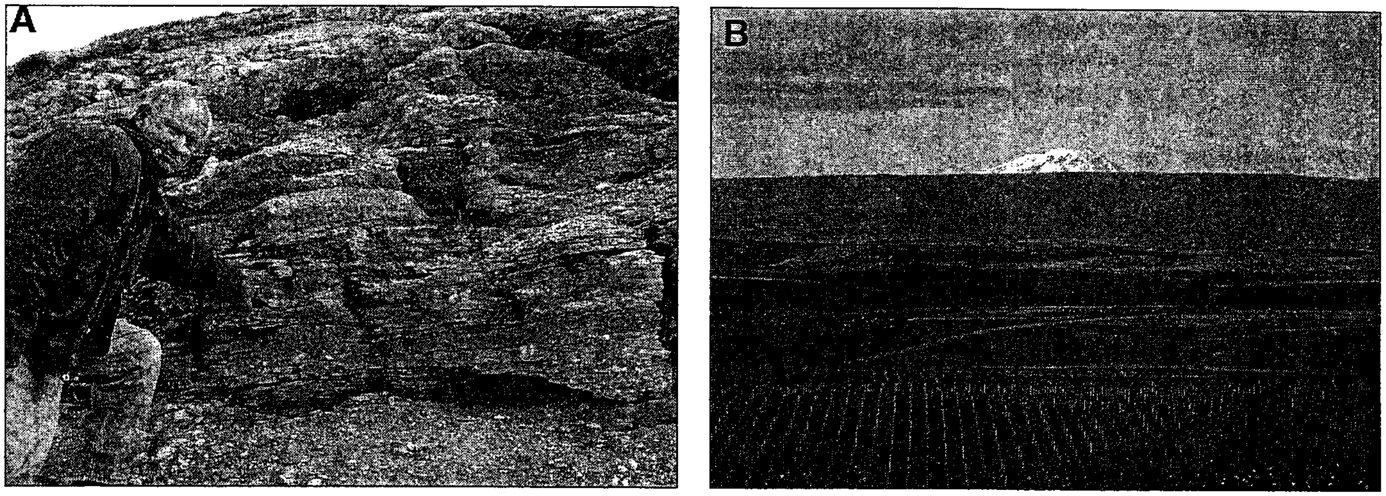

Figure 4. A: Outcrop of distinctive volcaniclastic sediments that form the soils at the Red Willow Vineyard in the Yakima Valley appellation. B: View to the south from Red Willow Vineyard showing Mount Adams (12276 ft/3472 m).

Known for being the inspiration for new varietals in the state, Red Willow has successfully pioneered varietals such as Syrah, Sangiovese, Malbec, Viognier and Cabernet Franc and has long produced award-winning Cabernet Sauvignon and Merlot.

At Red Willow Vineyard, the vines are planted on a peninsula of land jutting out from the south-facing Ahtanum Ridge. It is the only vinifera vineyard on the Ahtanum Ridge, and is the most westerly and the most northerly vineyard in the Yakima Valley appellation of Washington state. At 1300 feet above sea level, it is also the highest. To the west rise the foothills of the Cascades with Mt. Adams' snowcapped peak dominating the landscape.

While Red Willow itself is the highest vineyard in the Yakima Valley, it is also a relatively warm site—averaging 2700 degree days during the growing season. At 1300 feet above sea level, Red Willow stood above the cataclysmic Missoula floods at the end of the last ice age, floods that deposited silt and sand over the surrounding area. The ancient, well-drained, and nutritionally poor soil provides superb conditions for vinifera grapes.

Red Willow Vineyard first planted Cabernet Sauvignon in 1973 on the precipitous west-facing slope of the peninsula. In 1981, Columbia Winery released the first vineyard-designated wine from the vineyard with its Red Willow Cabernet Sauvignon. Cabernet Sauvignons from Red Willow are generally substantial, powerful wines with plum and blueberry fruit. Often the wine is blended with Cabernet Franc, which gives it an added finesse. Columbia Winery first produced Merlot from Red Willow grapes in 1987. This Merlot was the first in Washington to be blended with Cabernet Franc in the traditional Bordeaux manner.

With the release of Syrah from Red Willow Vineyard in 1988, Columbia Winery produced the first Syrah in the Pacific Northwest. In 1991, Columbia Winery released the first Red Willow Cabernet Franc and Columbia Winery's first vintage of Red Willow Sangiovese was 1995. (excerpted from http://www.columbiawinery.com/vineyards/redwillow.asp, accessed on August 5, 2003)

Cumulative Miles	*(km)*	
177.8	(286.1)	Retrace route on Stephenson Road, turning left and proceeding back to the east on West Wapato Road. Continue east on West Wapato Road across Lateral A to the intersection of State Highway 97. This is part of the Yakama Indian Nation. The reservation includes more than 1,300,000 acres, twice as large as Rhode Island. Its lands are used for agriculture, timber, range, and gathering of native plants.
178.3	(286.9)	Continue east across Highway 97 through the town of Wapato and angle left (NE) onto South Wapato (Donald Wapato) Road, crossing the railroad tracks.
179.3	(288.5)	Cross the Yakima River.
179.7	(289.1)	Enter onramp to I-82 east. There are good exposures of slackwater sediments on the left (north) side of the interstate.
186.7	(300.4)	On the left (north) side of the interstate are 10–20-m-high bluffs formed in slackwater sediments.
187.4	(301.5)	Slackwater sediment exposures on the left (north) side of the interstate have a distinctive white 2–5-cm-thick layer of 15 ka Mount St. Helens "S" ash near the top. This provides evidence for the timing of this emplacement of the slackwater sediments at the end of the Last Glacial Maximum.
198.3	(319.1)	On the right (south) side of the interstate is Snipes Mountain, a failed anticline.
217.6	(350.1)	Take exit 82 off of I-82 and turn right onto Wine Country Road.

218.5	(351.6)	Continue east for ~0.9 mi on Wine Country Road, following signs to Hogue Cellars parking lot for lunch and tour.

Stop 2. The Hogue Cellars

Our stop here will provide a catered lunch, wine tasting, and tour of this state-of-the-art winery. The Prosser-based Hogue Cellars is Washington State's third largest winery, behind Stimson Lane (Château Ste. Michelle/Columbia Crest) and Constellation Brands (Columbia Winery/Covey Run), producing 450,000 cases of wine per year.

Mike and Gary Hogue's parents, Wayne and Shyla Hogue, began farming in the Yakima Valley in the 1940s, and eventually turned management of the business over to Mike. In 1974, he planted Hogue's first wine grapes, and in 1982, the first wine (2000 cases of Johannisberg Riesling) was produced by Hogue Cellars. Approximately 650 acres of the Hogue's 1600 acre farm is used to grow nine varieties of wine grapes. The additional acres produce hops, table grapes, apples, and vegetables, some of which are pickled and sold under the Hogue Farms label. In 2001, Vincor International bought Hogue Cellars, which continues to be run by Mike Hogue. Wade Wolfe is general manager and David Forsythe is director of winemaking.

Cumulative Miles	*(km)*	
219.4	(353.0)	Return to onramp of I-82 and enter freeway heading east.
221.3	(356.1)	To the south on the steep slopes of the Horse Heaven Hills are numerous landslide scarps and zones of hummocky ground indicative of the numerous mass failures on these oversteepened slopes. Landslides may have been set off by relatively recent earthquakes.
224.8	(361.7)	To the left (north) is a spectacular scabland landscape with scoured basalt on the valley floor where flood waters rushing into the Yakima Valley were constricted by the narrow valley walls. Rattlesnake Mountain is visible on the skyline to the north.
228.8	(368.1)	To the north is a breached anticline on the north side of the Yakima River. The anticline was cut by the backflooding of Missoula floodwaters upvalley into the Yakima Valley. The valley narrows here to less than four miles wide between the Rattlesnake Hills to the north and the Horse Heaven Hills to the south, concentrating the floodwaters and their erosive power. Upstream (toward Prosser and Yakima), the valley widens to more than twenty miles.
230.0	(370.1)	Red Mountain is visible in the distance on the north side of the highway.
233.7	(376.0)	Take exit 96 off of I-82 to Benton City. At the bottom of the offramp, turn left and go under the freeway toward Benton City.
234.1	(376.7)	Turn right onto 224 east.
234.6	(377.5)	Turn left onto Sunset Road.
235.0	(378.1)	On the right (east) is the tower of the Public Agricultural Weather Station (PAWS). This is one of many automated data collection sites operated by Washington State University.
235.5	(378.9)	Turn right into the driveway of the Ciel du Cheval Vineyard.

Stop 3. Red Mountain AVA: Ciel du Cheval and Klipsun Vineyards

The Ciel du Cheval and Klipsun Vineyards are two of about fifteen vineyards located in Red Mountain, the newest appellation in Washington State. Growing conditions include ~3000 degree days, with a 210 day growing season, which are similar to other great wine growing areas. Our stops here will include discussions with Jim Holmes of Ciel and Fred Artz and the Gelles family of Klipsun regarding the pioneering spirit and good fortune that led them to plant wine grapes at Red Mountain, the challenges posed by soil variability, extreme temperatures during veraison (ripening), and drying winds on grape quality.

Our discussion of these topics will draw on information and figures presented in Meinert and Busacca (2002) on the terroir of Red Mountain. Copies of this paper will be handed out at the beginning of the field trip. Diverse soils such as the Scooteney, Warden, and Hezel form the backbone of wine production at Red Mountain (Fig. 5; also see Figs. 11 and 14 in Meinert and Busacca, 2002).

Wines made from Ciel grapes have been described in the wine press as being among the best in the world. No wine is made at the vineyard; however, Ciel supplies grapes to more than 20 wineries in Washington and Oregon, such as Andrew Will, Quilceda Creek, and McCrea Cellars. Plantings on the 120 acre ranch include most Bordeaux types (Cabernet Sauvignon, Cabernet Franc, Merlot), several Rhone varieties (Syrah, Grenache), and two Italian varieties. Recent plantings have emphasized use of clones selected for their exceptional wine quality in France and Italy.

Klipsun Vineyards was founded in 1982. In 2002, *Wine and Spirits* magazine acclaimed Red Mountain's Klipsun Vineyard as one of the world's top 25 vineyards. The first 40 acres was planted with Cabernet Sauvignon, Chardonnay, and Sauvignon Blanc in 1984 and has now been expanded to 120 acres, including Cabernet Sauvignon, Merlot, Syrah, Sauvignon Blanc, Semillon, and Nebbiolo. Klipsun sells to ~25 different wineries in the Pacific Northwest. Vineyard rows are numbered so each winery knows which rows will be theirs.

Cumulative Miles	*(km)*	
238.3	(383.4)	Retrace route to and under the I-82 underpass.
238.4	(383.6)	Continue straight south, cross the railroad tracks, and curve left on Webber Canyon Road.

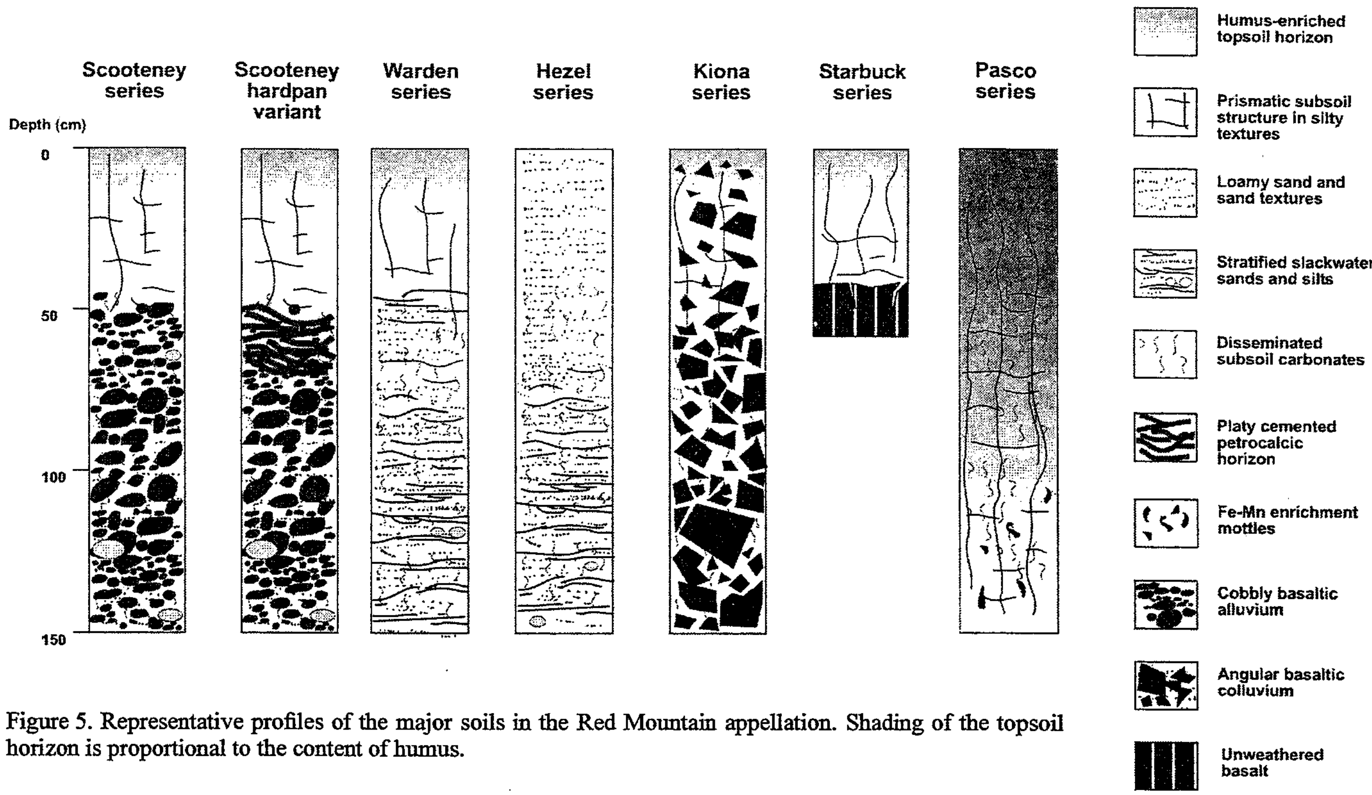

Figure 5. Representative profiles of the major soils in the Red Mountain appellation. Shading of the topsoil horizon is proportional to the content of humus.

239.0 (384.6) Drive past the road cut and park in the wide section of Webber Canyon Road.

Stop 4. Exposure of Loess, Slackwater Sediments, and Tephra

On the left (north side) is a road cut that exposes slackwater sediments that contain a "doublet" of Mount St. Helens "S" ash that was deposited from an eruption that occurred simultaneously with an outburst flood slackwater ponding event. 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). TL age dating of loess enclosing the same tephra (Busacca et al., 1992) yields a similar age estimate (Berger and Busacca, 1995). At this site, the slackwater sediments are covered by ~30 cm to 1 m of post-flood L1 loess (McDonald and Busacca, 1992).

Cumulative Miles	*(km)*	
239.7	(385.7)	Turn around and return to the onramp for I-82 and enter the interstate heading east.
244.7	(393.7)	Junction of I-82 and I-182. Take exit 12 on right onto I-182 toward Richland and Pasco.
257.6	(414.5)	At the intersection of State Highway 395 and State Highway 12, take Highway 12 east toward Walla Walla.
262.1	(421.7)	The Vaughan Hubbard Bridge crosses the Snake River, which flows in a channel cut into mega gravel bars deposited by outburst flood flows into the Pasco Basin. The force of the largest of these floods was great enough to travel more than 100 mi (160 km) upstream on the Snake River past Lewiston, Idaho.
272.7	(438.8)	Turn left at the town of Wallula, then left again on the frontage road, and park in front of the post office.

Stop 5. Wallula Gap Overlook (Optional)

Wallula Gap, the water gap where the Columbia River passes through the Horse Heaven Hills today, was one of the major flow constrictions along the lower Columbia River that was responsible for hydraulic damming and ponding of outburst floods that then backflooded axial valleys upstream from the constrictions. Elevations of high divide crossings eroded in basalt above Wallula Gap indicate that the maximum flood stage was at least 1150 ft (350 m). The floor of the original river channel beneath Lake Wallula was ~240 ft (80 m). Flood-cut scarps in the deep loess cover on the hills at the entrance to the constriction allow that the maximum stage could have been as high as 1200 ft (365 m; O'Connor and Baker, 1992). This is close to the highest elevations at which ice-rafted granitic erratic are found around the Pasco Basin.

Recent calculations of maximum flood discharges based on this high-water evidence suggest that ~10 million m^3s^{-1} passed through Wallula Gap (O'Connor and Baker, 1992). This is ~300 times the maximum flows of the 1993 Mississippi River flood! We are standing on a gravel bar deposited by giant floods; notice the mixed lithologies of the gravel. Today the Columbia River is dammed by a series of 10 dams from Bonneville Dam, 65 km (40 mi) east of Portland, Oregon, to Grand Coulee Dam in north-central Washington. The flat water in front of us is Lake Wallula ponded behind McNary Dam.

Cumulative Miles	*(km)*	
272.8	(438.9)	Rejoin Highway 12 toward Walla Walla. Nearby is a historical marker denoting former site of Fort Walla Walla (now underwater), originally a fur trading post of Hudson's Bay Company dating from 1818.
274.8	(442.2)	Intersection of Highways 12 and 730. At stop sign, turn left, continuing east on Highway 12 toward Walla Walla.
282.5	(454.5)	FPL Energy's Stateline Wind Energy Facility, which will be a stop on Day 2, is visible on the Horse Heaven Hills to the right (south).
283.8	(456.6)	Beginning of the Walla Walla appellation. The Blue Mountains form the skyline ridge straight ahead (east).
286.6	(461.1)	On right (south) are incised remnants of the very thick fill of bedded slackwater deposits that today form terrace remnants throughout the Walla Walla Valley.
287.7	(462.9)	The relatively flat Holocene flood plain of the Walla Walla River, which is bounded by terrace remnants, can be seen here.
291.8	(469.5)	On the left (north) are the Woodward Canyon and L'Ecole No. 41 Wineries. After checking in at the hotel in Walla Walla, we will return for dinner at L'Ecole Winery.
298.0	(479.5)	On the right (south) is the Three Rivers Winery.
302.5	(486.7)	Turn right onto West Pine Road.
302.7	(487.0)	Turn right into the Holiday Inn Express parking lot.

Stop 6. Holiday Inn Express

Check in, rest, and dress for dinner, then re-board the bus to drive to L'Ecole Winery for dinner. Retrace steps out of the Holiday Inn Express parking lot, left onto West Pine Road, and left again onto Highway 12 west.

Cumulative Miles	*(km)*	
313.6	(504.6)	Turn right into the L'Ecole No. 41 parking lot.

Stop 7. L'Ecole No. 41 Winery

Dinner will be provided through the hospitality of owner/winemaker Marty Clubb and executive chef Cristiana Fagioli, who will prepare an extraordinary dinner expertly pairing L'Ecole's new wine releases with five innovative courses.

L'Ecole No. 41 has been producing premium handcrafted varietal wines since 1983 in the historic Frenchtown School in Lowden, Washington. L'Ecole No. 41 is a family-owned business. Founded by Jean and Baker Ferguson, the winery is now owned and operated by their daughter and son-in-law, Megan and Marty Clubb. Marty has been the general manager and winemaker since 1989.

Built in 1915, the schoolhouse is located in historic Frenchtown, a small community just west of Walla Walla, Washington. Frenchtown derived its name from the many French-Canadians who settled the valley during the early 1800s. Legend has it, these men of French descent were raising grapes and producing wine. By the 1860s, nurseries, vineyards and winemaking had become a part of the region's growing economy. The name—L'Ecole No. 41, French for "the school" located in district number 41—was chosen to salute these pioneer viticulture efforts.

The winery currently produces ~20,000 cases annually. Semillon, Chardonnay, Merlot, and Cabernet Sauvignon at L'Ecole are all barrel aged, creating quite a demand for barrel storage. Today, L'Ecole has over 1,000 French and American oak barrels. In recent years, the winery has produced more single-vineyard and Walla Walla Valley appellation designated wines to take advantage of the exceptional fruit from the Walla Walla AVA. (excerpted from http://www.lecole.com/, accessed on August 5, 2003)

After dinner, drive east again to the Holiday Inn Express.

Cumulative Miles	*(km)*	
324.5	(522.1)	Turn right onto West Pine Road and into the parking lot of the Holiday Inn Express. End of Day 1.

Day 2. Walla Walla to Seattle (Fig. 3B)

Cumulative Miles	*(km)*	
0.0	(0.0)	From parking lot of Holiday Inn Express, turn right (east) onto West Pine St. and veer left to stay on West Pine to N 9th Ave. (Highway 125).
0.9	(1.4)	Turn right (south) onto N 9th Ave. (Highway 125) and continue on Highway 125 south.
6.6	(10.6)	Oregon-Washington state line. Washington Highway 125 becomes Oregon Highway 11 at the state line. The Walla Walla Valley appellation is one of the few to cross state lines and is, appropriately, bounded by natural rather than political features. Along the route the highway is alternately sited on higher elevation remnants of slackwater terraces and on

lower alluvial surfaces of the Holocene and modern Walla Walla River and its tributaries.

9.3 (15.0) Turn right (west) onto Sunnyside Rd. This area around Milton-Freewater, Oregon, has been a highly productive center of production of orchard crops (cherries, peaches, apples, etc.) for more than 100 yr.

10.8 (17.4) On the right (north) side of the road is the Cailloux Vineyard, planted by vigneron Christophe Baron of Cayuse Vineyard on the cobbly former riverbed of the Walla Walla River.

Stop 1. Cailloux Vineyard

Discussion at Stops 1–3 today will draw heavily on information and figures presented in Meinert and Busacca (2000) on the terroirs of the Walla Walla Valley appellation. Copies of this paper will be handed out at the beginning of the field trip.

The soils of the Walla Walla Valley appellation have formed from four different types of surficial sediments or bedrock. Various combinations of soil parent materials and a strong gradient of mean annual precipitation across the appellation are key to determining vineyard potential performance. Soils formed from young alluvium vary tremendously in their properties, such as texture (cobbly to clayey), salt effects, and presence or absence of a water table within the rooting zone of vines. Soils formed from loess more than 150 cm deep are found around the margins of the Walla Walla Valley appellation and have dominantly silty, uniform soil profiles. Mean annual rainfall varies widely depending on location in the appellation, and this, along with slope steepness and aspect, determines suitability or potential for development of dryland or irrigated vineyards. Soils formed from thin to moderately thick loess overlying slackwater sediments (Fig. 6) have been the main focus of vineyard development up to the present time in the appellation. Soils located on steep slopes of the Blue Mountains that have bedrock at shallow depth have not been fully evaluated to determine their potential for vineyard development.

The objective of Stop 1 is to examine the Cailloux Vineyard, which is sited on one of the most unique agricultural soils in the Northwest, and to discuss the viticultural practices that have been tailored specifically to the stony, hot, droughty Freewater series soils (Figs. 6 and 7).

Christophe Baron was the first to envision the potential of these stony soils to produce grapes for fine wines. He planted the ten acres of this vineyard in 1996. Ten acres of En Cerise (French for cherry), and ten acres of Coccinelle (French for ladybug) followed in 1997. The ten acres of En Chamberlin were planted in spring of 2000. The majority of the vineyards are planted with Syrah alongside a few acres of Cabernet Sauvignon, Cabernet Franc, Merlot, Roussanne, Tempranillo, and Yiognier. A fifth vineyard, Armada, planted in 2001, contains 3 acres of Grenache, 3 acres of Syrah, and 1 acre of Mourvedre. Yields average 2–2.5 tons per acre, resulting in rich, highly-concentrated fruit.

Spacing is four feet between vines and five feet between rows, 2178 vines per acre. This is nearly double the standard vine quantity and easily marks it as the highest density vineyard in the Walla Walla Valley. The vines in all of the vineyards are trained

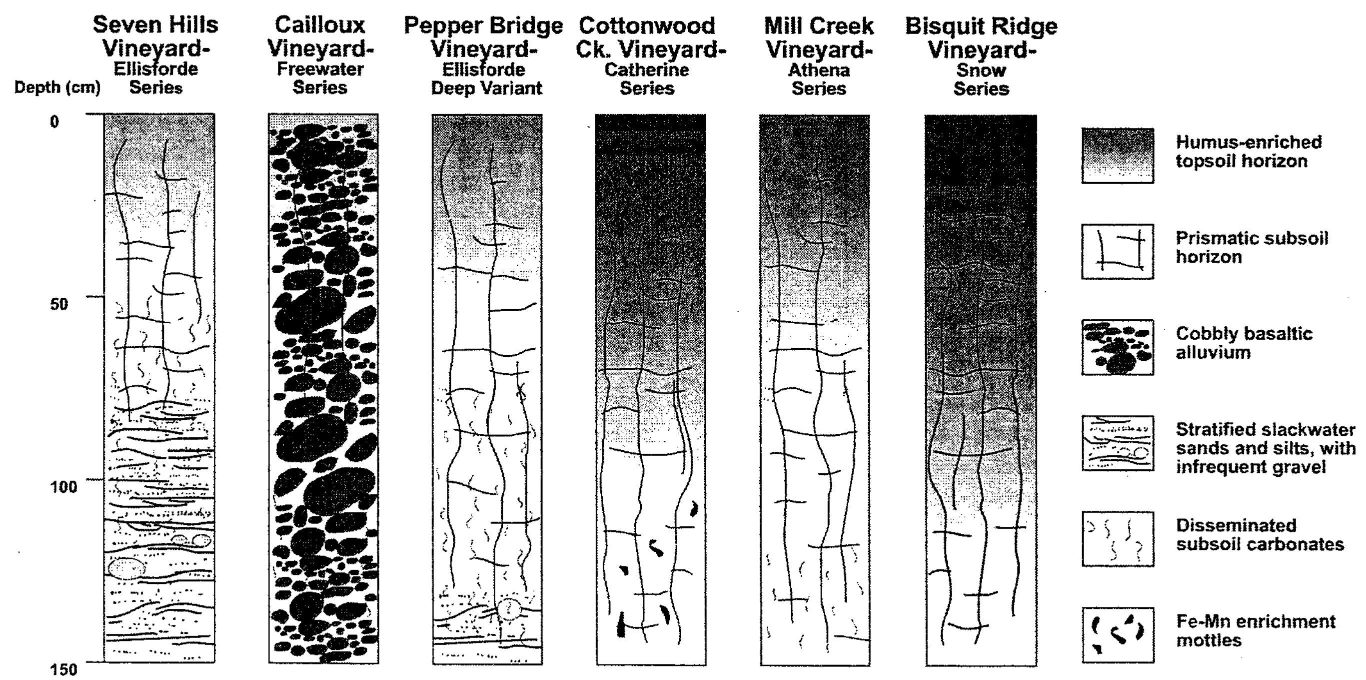

Figure 6. Representative profiles of the major soils in the Walla Walla Valley appellation. Shading of the topsoil horizons is proportional to the content of humus.

Figure 7. Cobbly surface horizon of the Freewater series soil in the Cailloux Vineyard.

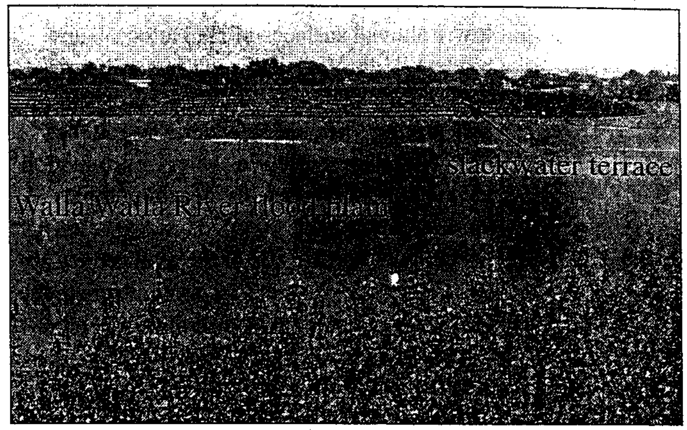

Figure 8. View across a part of the floodplain of the Walla Walla River showing dissected remnants of outburst flood slackwater terraces that make excellent vineyard sites.

low to the ground in the belief that re-radiation of heat at night from the exposed cobbly surface aids in the development of the fruit. An extra cane is maintained on the trunk close to the ground and is buried in the fall to provide a new starter trunk for each vine against a killing freeze in this low-lying valley site. Irrigation includes the application of scant quantities of water by drip irrigation, inducing water stress that concentrates fruit flavors, and the vines are organic.

Cumulative *Miles*	*(km)*	
12.3	(19.8)	Turn around and go back to Highway 11. Turn left (north) toward Walla Walla.
15.0	(24.1)	Turn right onto Stateline Road.
15.2	(24.4)	Turn left onto Pepper Road.
15.6	(25.1)	Turn right onto J.B. George Road.
16.3	(26.2)	Turn left onto Larson Road.
16.7	(26.9)	Pepper Bridge Winery is on the left and the Northstar Winery is on the right.

Stop 2. Pepper Bridge Vineyard

This stop will highlight the concept of terroir or optimal vineyard siting to produce fine wines. The best vineyards in the Walla Walla Valley occupy the tops of flood slackwater terraces (Fig. 8) with optimal soil characteristics and air drainage. Soils at Pepper Bridge Vineyard are dominantly a deep variant of the Ellisforde series with ~100–120 cm of loess over stratified slackwater sediments (Fig. 6). At this stop, there will be discussion about viticultural practices for wine grape production and we will relate these practices to the Pleistocene and Holocene geology.

The original 10 acres were planted in 1991 and have expanded to a total of 180 acres of wine grapes. Pepper Bridge Vineyard has gained an outstanding reputation with winemakers throughout the state of Washington, and especially the Walla Walla Valley. Tom Waliser has been the vineyard manager at Pepper Bridge Vineyard since its inception in 1991. All grapes are grown on split canopy trellises, in which the vines are trained both up and down off the cordon, or grape-bearing wire. With the exception of 5 acres of Merlot, which is on the Scott-Henry trellis system, all grapes are on the Smart-Dyson trellis system.

The vineyard uses cutting edge technology in its irrigation and weather systems. Weather data, temperature, humidity, wind, and sun energy units are recorded around the clock and the data are downloaded to computer by phone line. Over sixty moisture-measuring points are spread throughout the farm and moisture is data logged once an hour, 24 hours per day.

Cumulative *Miles*	*(km)*	
18.4	(29.6)	Return to the Pepper Road/J.B. George Road intersection, then turn left onto Pepper Road, right onto Stateline Road, and proceed to stoplight at Highway 125. Turn right onto Highway 125 and proceed toward Walla Walla (north).
23.6	(38.0)	Turn right onto W Poplar St.
24.1	(38.8)	Turn left onto S 2nd Ave.
24.7	(39.7)	Merge onto Highway12 east via the ramp on the left.
27.9	(44.9)	Take the offramp for Airport Road.
28.2	(45.4)	Turn right onto Airport Road, heading south, then left onto Isaacs Ave.
30.4	(48.9)	Isaacs Ave. becomes Mill Creek Road. Turn left at Walla Walla Vintners sign and drive up to Mill Creek Upland Vineyard of Leonetti Cellars and park opposite the vineyard.

Stop 3. Mill Creek Upland Vineyard of Leonetti Cellars

The purpose of this stop is to examine a state-of-the-art vineyard installation at Leonetti Cellars, one of the premier wineries in the Pacific Northwest. Chris Figgins, vineyard manager and assistant winemaker, will explain the use of the latest drip irrigation systems, virus-free rootstocks, new clones and varietals, and environmental monitors to take grape and wine quality to the next level. This vineyard receives ~16–18″ (400–460 mm) of annual precipitation, making it perhaps the vineyard with highest precipitation in eastern Washington. This and the very deep, organic matter–rich Athena soils in loess (Fig. 6) provide a new challenge for Leonetti Cellars to develop management strategies for this vineyard, which perhaps could be dry farmed because of the high rainfall and high water holding capacity of the silt-loam textured soils. This and the steep south-facing slope provide excellent sun exposure and air drainage.

Leonetti Cellars' owner and winemaker, Gary Figgins, honed his craft as a home winemaker and released his first commercial wine in 1978. Leonetti Cellars produces limited quantities of the highest quality Cabernet Sauvignon, Merlot, and Sangiovese.

Leonetti Cellars manages their vineyards very intensively, using a combination of the latest in technology, proven traditions, and sustainable agriculture. They draw their fruit increasingly only from vineyards in the Walla Walla Valley AVA. Yields are moderately low to very low, ranging from 1.5–4 tons per acre, depending on the vineyard and variety. Most vineyards are trellised to a vertically divided canopy, a method known as Smart-Dyson or Scott Henry. Deficit irrigation, monitored by neutron probes and a system called "enviroscan," is practiced in all of Leonetti's vineyards to control vegetative growth, reduce berry size, and intensify flavors in the berries. All grapes for Leonetti wines are handpicked at physiological maturity after a season of intensive hand pruning, hand leaf-plucking, shoot positioning, and cluster thinning.

Cumulative *Miles*	*(km)*	
32.9	(52.9)	Retrace route to Highway 12, enter Highway 12 west.
49.0	(78.8)	Continue on Highway 12 west through Walla Walla to the town of Lowden.

Stop 4. Burlingame Canyon, the "Little Grand Canyon"

The spectacular exposure of slackwater or touchet sediments from cataclysmic outburst flooding, which can be seen stopping at this site (Fig. 9), was created by a break in the irrigation canal a number of years ago. The purpose in stopping at this site is to discuss paleoflood dynamics, the "40-floods" hypothesis, and to show what underlies the terrace remnants in valleys like the Walla Walla and Yakima, forming the landscapes of some of the better vineyard sites in the Northwest.

Note: This exposure is on private property of the Gardena Farms Irrigation District and we are allowed to visit during this field trip only by special permission. Please do not return to this site at a later time on your own. Take any photos during this visit only. Please note the dangerous banks and stay clear of the edge. Our thanks to Stuart Durfee, manager.

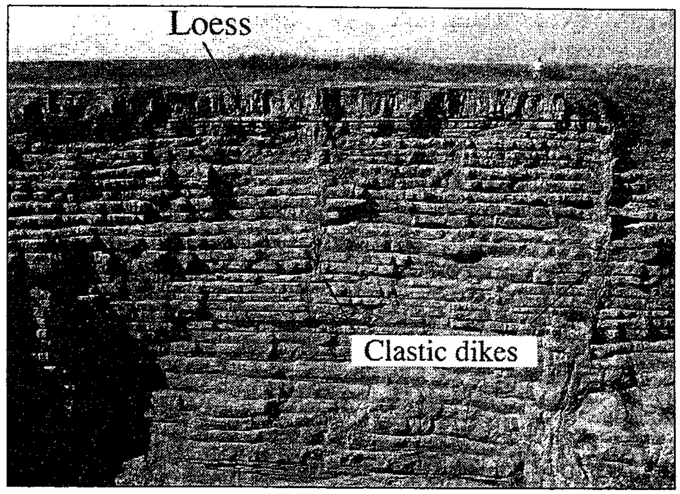

Figure 9. Exposure of a loess-covered terrace formed of rhythmically bedded outburst flood sediments.

The following are guidelines set by the land owner for our safety during our visit:

1. If a representative of Gardena Farms Irrigation District No. 13 accompanies you during your visit, you will abide by all instruction or be asked to leave immediately.
2. You will park along the main irrigation canal at the top of the hill near the house and walk down the west side of the channel leading south to the Little Grand Canyon.
3. You will not travel outside of the fenced area on the east side of the canyon or travel down the west side of the canyon unless instructed to do so.
4. There will be no ascent into the canyon past the first ascending down slope at the northern entrance to the canyon.
5. Visitors to the canyon must act in an orderly fashion so as not to endanger any of the participants.
6. The visitation privileges for your organization or any organization associated with the visit will be revoked for future visits if you fail to follow directions or if there are unauthorized repeat visits by persons in attendance on this site visit.

Exposures of fine sand-, silt-, and clay-dominated slackwater rhythmites at sites such as Burlingame Canyon formed the inspiration for Richard Waitt's hypothesis for multiple outburst floods during the last glaciation (Waitt, 1980, 1984, 1985). It also has been argued that some rhythmites, rather than signaling individual outburst floods separated by decades-long intervals of subaerial exposure, instead reflect multiple flood surge events during a few floods (Baker, 1973; Bjornstad, 1982; Bunker, 1982; Baker and Bunker, 1985). This alternate argument is supported by the scarcity of definitive sedimentary evidence for subaerial exposure of rhythmites, an impression one gets while viewing the parallel, amalgamated nature of the multiple, stacked rhythmites exposed in the canyon. However, the paleoaridity and attendant sparse vegetation of this region both during and after slackwater flood accumulation, the isolation of broad reaches of slackwater deposits from flanking valleys (and hence colluvial deposits), as well as compelling ecologic and sedimentary evidence elsewhere on the plateau (e.g., Smith, 1993) tend to support Waitt's (1985) contention for multiple floods. Regardless of the explanation you prefer, sites such as Burlingame Canyon provide clear evidence that the glacial outburst floods provided an abundance of raw sedimentary material from which winds have created sand sheets, sand dunes, and loess-covered landscapes.

Cumulative Miles	*(km)*	
65.9	(106.0)	From Lowden, continue west on Highway 12 to Hatch Grade Road. Rendezvous with representative of FPL Energy at Hatch Grade Road turnoff. Follow representative to FLP Energy's Stateline Wind Energy Center.

Stop 5. Stateline Wind Energy Center

The purpose of this stop is to recognize the incredible wind energy that has partnered with the incredible energy of the cataclysmic floods to redistribute huge amounts of fluvial sediment into the eolian mantle of soils, which provide the basis for the agricultural wealth of the inland Pacific Northwest. In addition, this impressive facility is the largest wind energy facility in the United States.

Developed, owned, and operated by FPL Energy, the 300 megawatt Stateline Wind Energy Center provides clean, renewable energy to PacificCorp Power Marketing (PPM) for customers throughout the Pacific Northwest.

The Stateline Energy Center was fully operational in December 2001, just nine months after construction of the facility began. The first power from Stateline reached consumers in July 2001. The facility has the capacity to provide enough electricity to power ~60,000 homes and businesses. The Stateline Energy Center provides electricity for PPM customers including Bonneville Power Administration, Seattle City Light, the Eugene Water and Electric Board, and Avista Utilities.

FPL completed a 37 megawatt expansion of the Stateline Wind Energy Center in early December of 2002, making it the largest wind energy facility in the United States at 300 megawatts.

The Stateline Wind Project is the Northwest's largest commercial facility to generate electricity using wind. The project is located on Vansycle Ridge, an anticline ridge straddling the Washington-Oregon border, near Touchet, Washington. The ridge catches winds from the Columbia Gorge, which average 16–18 mph; this is considered excellent for wind farm development. The area around the project is used mostly for private farming, and this has continued beneath the completed wind project. The site is also close to preexisting transmission lines, reducing the need for new cables and minimizing the amount of power lost during transmission.

The Stateline Wind Project uses 660 kw Vestas wind turbines (Fig. 10), producing a maximum output of 300 megawatts (MW) of electricity. On average the project receives enough wind to deliver 30%–35% of its peak capacity year round: enough power for more than 21,600 Northwest homes. Electronic control systems point each turbine into the wind and adjust the pitch of the blades to make the best use of wind at any speed. The turbines can generate power at wind speeds of 7–56 mph. At higher speeds the turbines automatically shut down, a feature which allows them to withstand hurricane-force winds.

The Stateline Wind Project was planned carefully and underwent extensive review to minimize its environmental impact. Early biological studies indicated that the site receives little use by birds or other vulnerable species. The project uses tubular towers and buried cables in order to avoid adding new perching places for birds. Slower-moving blades and an upwind design further minimize any potential for avian fatality. As a clean power source, the project also eliminates some of the need for fossil fuel electric plants in the region. If natural gas or coal were used to generate the same amount of power, they would emit at least 310,000 tons of carbon dioxide per year, as well as air pollutants and acid rain precursors. Wind power produces no air emissions.

Return from the wind energy center to Highway 12. Turn left (south) onto Highway 730-395 south.

Cumulative Miles	*(km)*	
67.4	(108.4)	The highway and the Columbia River pass through Wallula Gap. Scabland topography can be seen up to ~1200 ft (366 m).
91.1	(146.6)	Take the exit onto Interstate 82 west, crossing the Columbia River from Oregon into Washington. Continue north, rising onto the Horse Heaven Hills. An application to the Bureau of Alcohol, Tobacco, and Firearms has recently been submitted to create a Horse Heaven Hills appellation.

Figure 10. Wind turbines seen during a dust storm at the Stateline Wind Energy facility near Walla Walla, Washington.

100.1	(161.1)	Get off of I-82 at exit 122, Coffin Road. At the stop sign at the bottom of the offramp, turn right and drive east on Coffin Road.
104.9	(168.9)	Turn right (south) onto 9 Canyon Road.
105.8	(170.2)	Turn left (east) onto Easterday Ranch private road.
110.3	(177.5)	Turn right (south) onto Finley Road.
112.3	(180.7)	Entrance to Wallula Vineyards.

Stop 6. Wallula Vineyards

The purpose of this stop is to view the Columbia River and Wallula Gap from the downstream side and to see and discuss a very interesting and potentially outstanding new vineyard with a diverse array of vineyard sites ranging from gentle, south-facing sites on deep loess soils to steeply sloping terraced sites, to microvineyards on shallow soils on small scabland buttes (Fig. 11A).

The family farm, which has expanded steadily to include Wallula Vineyards LLC today, was started by Andrew denHoed in 1954. Andy started out raising traditional row crops such as sugar beets, mint, potatoes, and dry edible beans. The original "home place" included 15 acres of concord grapes. Today his sons, Andy denHoed Jr. and Bill denHoed, are partners with Andy Sr. Today's operation includes 980 acres of vinifera, 125 acres of juice grapes, and 85 acres of orchard. The denHoeds first planted vinifera in 1979 at the Desert Hills Vineyards near Grandview in the Yakima Valley. Planting started at Wallula Vineyards in 1998. Desert Hills Vineyards includes 560 acres of wine grapes; Wallula Vineyards has 420 acres of wine grapes. The majority of the denHoed's grapes are delivered to the Stimson Lane group: Chateau Ste. Michelle, Columbia Crest, and Snoqualmie Wineries. A small portion go to the Hogue Cellars in Prosser, Washington.

Wallula Vineyards totals 1550 acres. Approximately 950 of that is plantable. Development has been divided into three phases. Phase I is currently in production. Phases II and III are in the planning stages. Before the irrigation system was installed and the first vines were planted, multiple earth-moving machines worked 5 days a week, 45–50 weeks a year, for 3 years to prepare the site. Unique aspects of this vineyard include plantings of vines that range in elevation from 350 ft (107 m) to 1200 ft (366 m), a difference which provides a greater range of mesoclimates than any other vineyard in the state. Soil temperature is monitored in each vineyard with temperature probes to develop a database for management decisions and to inform future plantings. At the lower elevation sites, Lake Wallula provides a lake effect that moderates high temperatures in summer and low temperatures in winter.

Soils in deep loess at the upper elevations are classic Mollisols of the Ritzville series; those in deep loess below ~1000 ft elevation (305 m) actually receive enough less precipitation to be classed as Aridisols of the Shano series. Soils on margins of the scabland portion of the vineyard are formed in loess over stratified gravelly flood sediments (Fig. 11B) and are soils such as the Scooteney series (Fig. 5). Soils on the scabland buttes and benches are highly variable but include shallow and stony soils such as the Starbuck and Kiona series (Fig. 5).

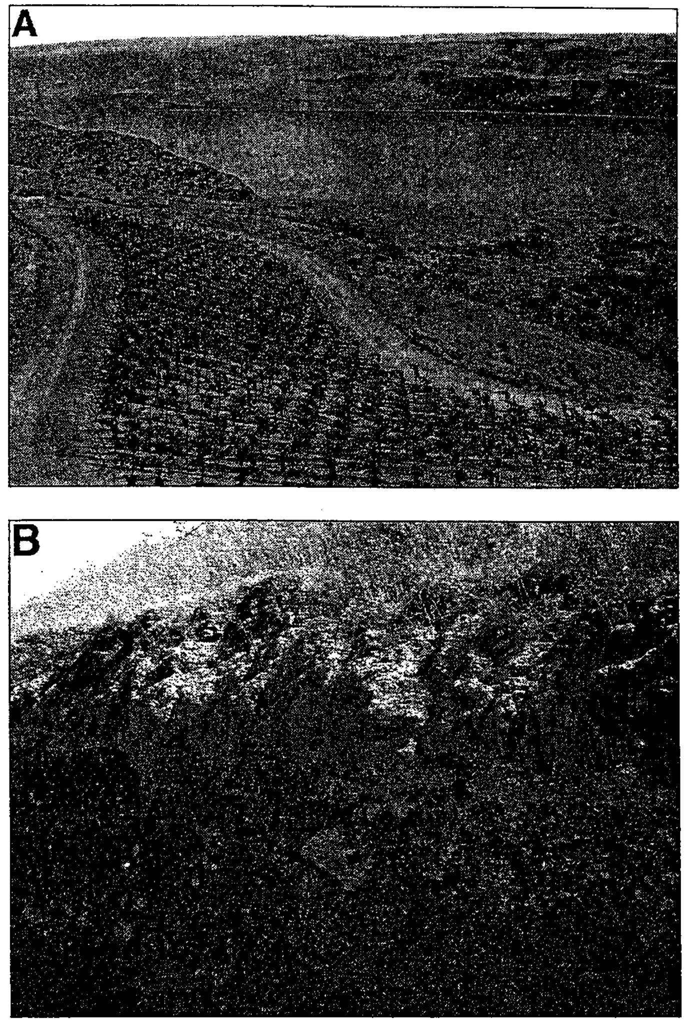

Figure 11. A: Vineyard terraces and scabland topography at the Wallula Vineyard in Columbia Valley appellation. B: Scooteney-type soil formed of loess over outburst flood slackwater sediments at the Wallula Vineyard. The loess mantle is ~75 cm thick.

The Phase I vineyard produces Cabernet Sauvignon, with clones 4, 6, 8, and 15. Clone 8 is the predominant clone, and is widespread throughout the state. Clones 6 and 15 of Merlot are also planted, as are the Piccolo and Grosso clones of Sangiovese. Other red wine grapes include Syrah, Mourvedre, Barbera, Cinsault and Dolcetto. White varieties include Chardonnay, Viognier, and Pinot Gris.

All of the water comes from the Columbia River, is pumped from the river to a settling pond, and is distributed from there through a drip irrigation system. Because of soil variability, the irrigation system is divided into many zones and subzones to provide the flexibility to tailor water delivery to the vines to maintain uniformity throughout the vineyard for crop and canopy.

Crop load ranges from 2.5 tons/yr (0.6 Mg/hectare) to 7 tons/yr (15.7 Mg/hectare) and is specified by the winery that takes each block of grapes.

124.5	(200.3)	Retrace steps to the intersection of Coffin Road and Interstate 82. Enter onramp for I-82 toward Yakima (west).
213.4	(343.4)	Continue on I-82 to Yakima. Take exit 33 (Yakima Ave., toward Terrace Hts.) to E Yakima Ave.
214.8	(345.6)	Drive west on E Yakima to N 1st St. Turn right and immediately look for the train station that houses Grant's Brew Pub. Dinner at Grant's Brewpub, 2 N Front St., 509-575-2922.
216.2	(347.9)	Retrace steps to I-82. Take onramp and enter I-82 west toward Seattle.
246.8	(397.1)	Take I-82 west toward Ellensburg to junction with I-90 west.
355.6	(572.2)	Take interchange from I-90 west to I-5 north.
356.4	(573.4)	Take the I-5 north exit, number 2C, toward Madison St./Convention Place.
357.7	(573.9)	Take the exit toward Madison St./Convention Place. Stay straight onto 7th Ave. Turn left onto Madison St.
357.9	(575.9)	Turn right onto 6th Ave.
358.0	(576.0)	Turn right onto 7th Ave.
358.1	(576.1)	Turn right onto Union St., then onto Convention Place. Stop in front of Seattle Convention and Trade Center. End of trip.

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The Wine Project

WASHINGTON STATE'S WINEMAKING HISTORY

Dr. Walter J. Clore

RONALD IRVINE
WITH WALTER J. CLORE

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been in high school then. Herrmann told us that they have lost about two-thirds of the Chardonnay.

Walt, George, and I headed out into the vineyard. It is 660 acres, a vast sea of green, yellow, and brown. The Grenache vineyard was noticeably browner, lots of dead wood. While we were looking at the vines, Jesse Sandoval, the production supervisor, drove up in his all-terrain buggy. With temperatures in the mid-'70s and a beautiful clear blue sky, he appeared overdressed to me. Under his jean jacket was a dark blue hooded sweatshirt, capped by his round white helmet. I assumed that he had probably been out here since early morning. It was about ten o'clock and plenty warm for me. Jesse nodded and said, "Grenache is crazy." They plan on tearing it out and replanting to Syrah.

He gave us directions to the Chardonnay blocks, Blocks E10 and E12, and pointed out how the two blocks, each about 20 acres planted at the same time, are contiguous to each other, the one block below the other and divided by a twenty-foot roadway. He said that last year the blocks had different growth patterns. The northerly and upper block seemed more vigorous and productive. The lower vineyard seemed weaker. This year they have reversed themselves. The upper block, Block E10, was devastated by the cold air, while the lower block was almost unaffected.

Jesse shook his round brown face and said, "It doesn't make any sense."

Walt chuckled and said, "Maybe we are not supposed to understand it."

This struck me as an odd thing for Walt to say. It didn't sound like the scientist, but the Methodist, speaking.

—*WAHLUKE SLOPE*—

From Cold Creek we got back on the highway and headed north to the Wahluke Slope. Driving along the river, now on Highway 243, we could see Sentinel Gap, a gap in the Saddle Mountains that allows the Columbia River to flow south. Past the tiny hamlet of Desert Aire we turned up into the 300-acre Indian Wells Vineyard. It is a broad vineyard that slopes southwesterly toward the Columbia River. I was awestruck at how large the vineyard was. And how lush it was. There was little evidence of much damage, although there were considerable suckers shooting up from the base of many of the grapevines. The grapevines looked like shaved French poodles with hairy feet, ears, and tops. The vineyard looked like it was in need of some shearing. On either side of a road that runs through the middle of the vineyard, the rows of vines ran against the slope of the vineyard and were oriented north and south. The rows of vines ran a half mile in each direction. At the south end of the rows was a line of large poplar trees, as wind breaks.

This vastness contrasted sharply with the more developed Yakima Valley. Cold Creek and Indian Wells warmed us up to this scale, but I was still immensely impressed as we drove to the top of the Wahluke Slope. On the highway driving east out of Mattawa, there was a series of orchards and vineyards set against the hillside of the Saddle Mountains. Each block was about 40 acres, set apart from one another by wind breaks. Below on the flats were fields of potatoes, alfalfa, mint, and corn. It was dazzling and inspiring, that land can be so productive and plentiful.

We stopped to visit the Rosebud Ranches, owned by Don and Norma Toci. In a letter to Walt, they had recalled how they first came to grow grapes on the Wahluke Slope. They had become interested in wines when touring Preston Wine Cellars in the mid-'70s. Bill and JoAnn Preston weren't there at the time, but their son Mark inspired the Tocis with his enthusiasm for the vineyard and the wines they produced. Norma Toci wrote, "In the fall of 1978 we contracted enough grape cuttings to plant 40 acres. (I wanted to plant 160 but Don had a fit!) We did not have a farm yet but we were looking. The realtor we were dealing with was an old man by the name of George Calvert who had been the justice of the peace in years past in Moses Lake. He knew this country very well and had been an astute 'old-timer' who knew soils. He showed us the Wahluke Slope and said in all seriousness, 'This is a wonderful country, a long way from market, harsh sometimes and hell on horses and women, but a good country.' He was right about all that!"

The Tocis uprooted from Arizona with this enthusiasm, their Arizona farm being a victim of suburban sprawl. Their initial 40-acre planting, in 1979, consisted of 20 acres of White Riesling and 20 acres of Chenin Blanc, which has blossomed to 253 acres of wine grapes. Don Toci, with a degree in agronomy at the University of Arizona, epitomizes one large element of the Washington wine industry: he is an independent, well-to-do farmer turned grape grower with the wonderful but risky innocence of not being wine knowledgeable or wine sophisticated but, rather, a thoroughbred farmer.

Down the slope was Weinbau Vineyard, now managed by Sagemoor Farms. It is a sprawling 364-acre vineyard planted mostly to

Chardonnay. We chose not to stop, but from the van it looked surprisingly good. There was very little evidence of damage. We were getting pretty good at drive-by sightings; George and Walt could identify from the van the varieties according to the color of the vines or by their growth characteristics. Semillon leaves, for instance, are a lighter green. Next to Weinbau Vineyard is the former Langguth Winery, looking rather abandoned and isolated in this land of wide-open space.

From Weinbau we headed south and crossed the Columbia again at the Vernita Bridge. This time we drove southeast on Highway 240, skirting the Hanford Site, along the backside of the Rattlesnake Hills. It was early afternoon and I was getting a bit tired, and also a little perturbed at myself that I couldn't keep up with these men in their mid-eighties. The warm sun and the monotony of the brown hills was lulling me into a drowsy state.

Abruptly Walt broke the silence: "One explanation for why those Chardonnay blocks at Cold Creek are different may have to do with the shade from the hills to the south," pointing to Yakima Ridge just southwest of us.

I knew that Walt wasn't going to leave that puzzle alone. Continuing, he added, "Remember how Paul Portteus suggested that the 65° F January days may have activated his Chardonnay vines? Well, the same thing probably happened at Cold Creek, except at Cold Creek part of the vineyard may be in the shadow of the Yakima Ridge in January when the sun is so low. It may be that the top block, Block E10, may have been in the sun while the lower block wasn't, thus remaining cool and dormant."

I smiled. This man is incredible.

—*Red Mountain*—

We arrived at Red Mountain in the afternoon. The temperatures were reaching the low '80s, hot enough for me. Our first stop was Klipsun Vineyards. We entered the vineyard from the road that runs along the Yakima River. The vineyard looked its normal perfect self: clean-cut grass between the rows and manicured vines. We got out of the car and looked closer. There were a few scattered dead vines amongst the Semillon vines and those vines that looked healthy were devoid of fruit clusters. It was going to be a thin harvest.

A check on the Merlot and Sauvignon Blanc also showed a minimum of fruit. These vines had been severely pruned after the winter

2002 WASHINGTON WINE GRAPE ACREAGE SURVEY

COMPILED BY:

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Washington Wine Grape Acreage, January 1, 2002 - by AVA's

Variety	Puget Sound		Yakima		Red Mountain		Columbia Valley 1/		Walla Walla 1/		Other		State Total	
	Total	Bearing	Total	Bearing	Total	Bearing	Total	Bearing	Total	Bearing	Total	Bearing	Total	Bearing
White Varieties:														
Chardonnay	0	0	3,130	2,920	50	40	3,380	3,250	60	60	20	20	6,640	6,290
Chenin Blanc	0	0	150	150	20	20	280	280	0	0	0	0	450	450
Gewurztraminer	0	0	410	320	10	10	230	190	10	10	10	10	670	540
Muscat Canelli	0	0	20	10	0	0	80	80	0	0	0	0	100	90
Pinot Gris	10	10	210	140	0	0	90	60	0	0	20	20	330	230
Sauvignon Blanc	0	0	250	220	20	20	440	440	0	0	0	0	710	680
Semillon	0	0	140	140	10	10	400	390	0	0	0	0	550	540
Voignier	0	0	100	30	0	0	120	10	10	10	0	0	230	50
White Riesling	0	0	910	750	10	10	1,260	1,160	10	10	10	10	2,200	1,940
Other White	30	30	20	10	20	10	30	20	0	0	20	20	120	90
Total White	**40**	**40**	**5,340**	**4,690**	**140**	**120**	**6,310**	**5,880**	**90**	**90**	**80**	**80**	**12,000**	**10,900**
Red Varieties:														
Cabernet Franc	0	0	230	220	20	20	460	460	40	20	0	0	750	720
Cabernet Sauvignon	0	0	1,100	1,050	250	230	4,360	3,650	330	190	10	10	6,050	5,130
Lemberger	0	0	160	130	20	10	50	40	0	0	0	0	230	180
Malbec	0	0	30	10	0	0	50	30	10	10	0	0	90	50
Merlot	0	0	1,940	1,790	150	140	3,680	3,550	200	140	10	10	5,980	5,630
Pinot Noir	20	10	150	150	0	0	80	60	0	0	40	40	290	260
Sangiovese	0	0	80	40	20	10	110	80	10	10	0	0	220	140
Syrah	0	0	580	440	70	50	1,350	1,070	100	50	0	0	2,100	1,610
Zinfandel	0	0	10	10	0	0	60	50	0	0	0	0	70	60
Other Red	20	20	30	10	40	20	90	40	20	10	20	20	220	120
Total Red Varieties	**40**	**30**	**4,310**	**3,850**	**570**	**480**	**10,290**	**9,030**	**710**	**430**	**80**	**80**	**16,000**	**13,900**
TOTAL ALL	**80**	**70**	**9,650**	**8,540**	**710**	**600**	**16,600**	**14,910**	**800**	**520**	**160**	**160**	**28,000**	**24,800**

1/ The Oregon acreage in the Columbia Valley AVA is 481 and in the Walla Walla Valley AVA is 279. This brings the Columbia Valley AVA total to 17,081 acres and the Walla Walla Valley AVA total to 1,079 acres.

Columbia Valley AVA Wine Grape Acreage

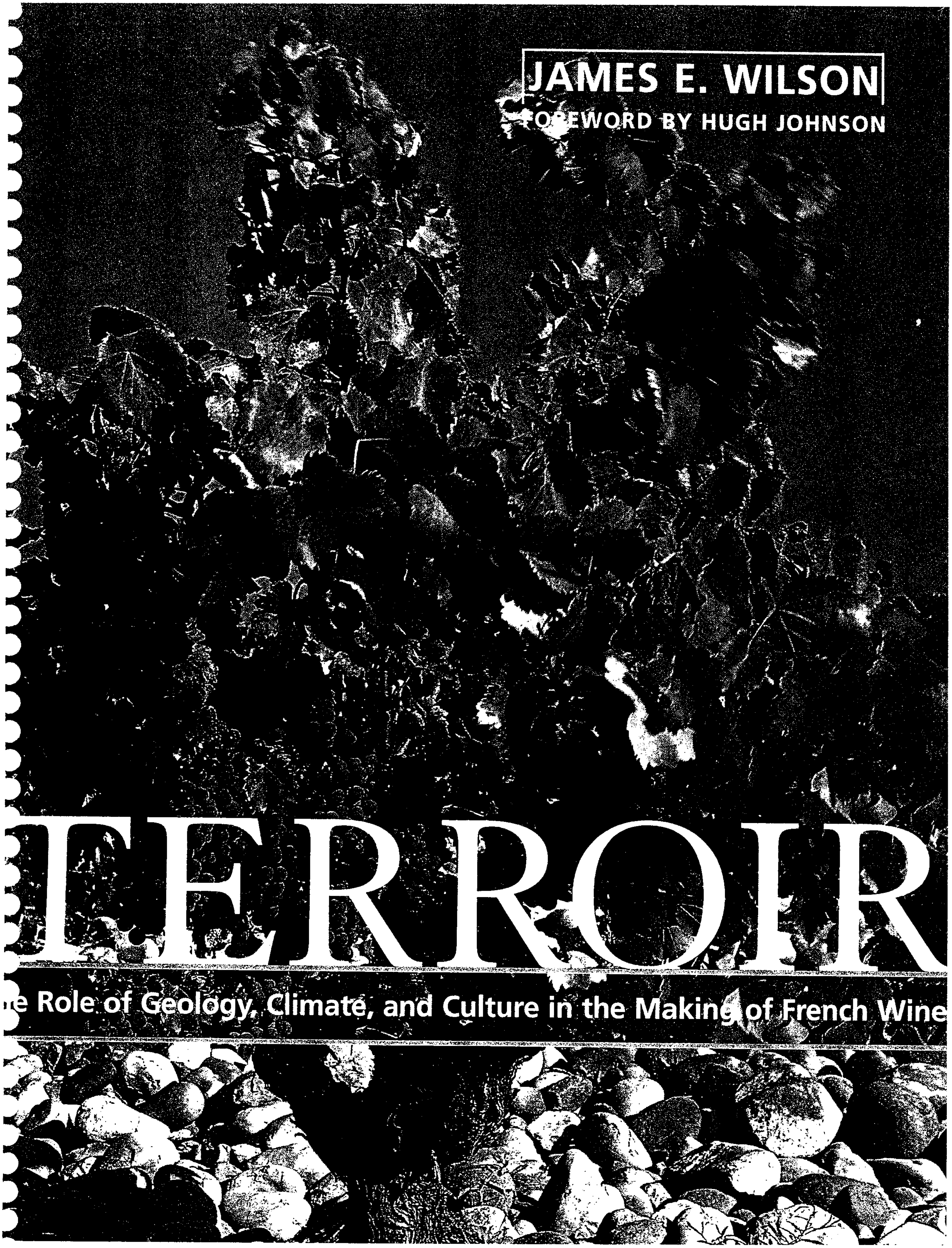
The Columbia Valley AVA extends across the state line into the Oregon counties of Gilliam, Morrow, Sherman, Umatilla and Wasco. Approximnately 59 percent of the state's wine grape acreage is located in this region. The Columbia Valley accounts for 64 percent of the state's acreage of red varieties and 53 percent of the state's acreage of white varieties.

The Columbia Valley AVA was subdivided into the following regions: Wahluke Slope, Royal Slope, Columbia Basin/Snake River, Alderdale Ridge, Columbia Gorge, Canoe Ridge, Cold Creek, Mattawa, Wallula and Other. Acreage estimates by variety and subregion of the Columbia Valley are shown in the table below. Data for the Canoe Ridge, Cold Creek, and Wallula regions were combined to avoid disclosing information about individual operations.

Columbia Valley AVA Total Wine Grape Acreage, January 1, 2001 - by Region

Variety	Wahluke Slope	Royal Slope	Col. Basin/ Snake River	Alderdale Ridge	Columbia Gorge	Mattawa	Combined Regions 1/	Other	Columbia Valley Total
White Varieties:									
Chardonnay	290	160	650	370	40	350	520	1,000	3,380
Chenin Blanc	40	0	30	10	0	0	0	200	280
Gewurztraminer	20	0	40	0	40	0	0	130	230
Muscat Canelli	0	0	0	10	0	0	40	30	80
Pinot Gris	0	0	30	0	0	0	10	50	90
Sauvignon Blanc	40	0	100	40	0	10	20	230	440
Semillon	20	0	30	0	0	60	0	290	400
Voignier	10	0	10	50	0	10	10	30	120
White Riesling	130	0	220	30	0	50	190	640	1,260
Other White	10	0	0	20	0	0	0	0	30
Total White	**560**	**160**	**1,110**	**530**	**80**	**480**	**790**	**2,600**	**6,310**
Red Varieties:									
Cabernet Franc	60	190	60	100	0	50	60	130	460
Cabernet Sauvignon	640	0	400	660	10	600	710	1,140	4,360
Lemberger	0	0	0	30	10	0	0	20	50
Malbec	0	0	0	20	0	0	10	20	50
Merlot	380	170	430	500	10	700	790	700	3,680
Pinot Noir	10	0	50	0	10	0	0	10	80
Sangiovese	20	0	30	20	0	10	30	0	110
Syrah	250	120	150	230	10	130	120	340	1,350
Zinfandel	20	0	0	40	0	0	0	0	60
Other Red	10	0	30	40	0	10	0	0	90
Total Red	**1,390**	**480**	**1,150**	**1,640**	**50**	**1,500**	**1,720**	**2,360**	**10,290**
TOTAL ALL	**1,950**	**640**	**2,260**	**2,170**	**130**	**1,980**	**4,230**	**4,960**	**16,600**

1/ *Includes Canoe Ridge, Cold Creek, and Wallula-for publication.*


JAMES E. WILSON
FOREWORD BY HUGH JOHNSON
TERROIR
e Role of Geology, Climate, and Culture in the Making of French Wine

Dedication

To Elloie

Terroir
The Role of Geology, Climate, and Culture in the Making of French Wines
by James E. Wilson

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Appendices

Terroir, a unique French term

Terroir has become a buzz word in English language wine literature. This lighthearted use disregards reverence for the land which is a critical, invisible element of the term. The true concept is not easily grasped but includes physical elements of the vineyard habitat – the vine, subsoil, siting, drainage, and microclimate. Beyond the measurable ecosystem, there is an additional dimension – the spiritual aspect that recognizes the joys, the heartbreaks, the pride, the sweat, and the frustrations of its history. Because terroir is so meaningful, let's help to define it by considering how some of the wine experts have described the concept.

To understand the wines of the Côte d'Or, Matt Kramer maintains that one must understand the concept of terroir. He points out that the physical attributes are not too difficult to comprehend, but there is what he calls the "mental aspect." Kramer's explanation of "mental aspect" is that winegrowers feel each terroir should be allowed to be itself and produce the wine for which nature endowed it. The winemaker's "signature" (vinification style) is permissible, so long as it does not substitute for terroir. That is, vinification should not make the wine taste significantly different than the "natural" wine that would be produced from a particular tract.

In the *Wine Atlas of France*, Hugh Johnson expresses essentially the same interpretation: "the land itself chooses the crop that suits it best." Otherwise, he says, "Why have all French growers not settled for the same grapes, the same techniques, the same ideal of what a good wine should be?" For Johnson, a sense of place, an awareness of terroir, is the key to understanding the wines of France. He suggests that knowing sidestreets, lanes, and history, intensifies this sense of place. (I would suggest that knowing the geology of a vineyard also gives it a special identity.)

Gérard Seguin, the Bordeaux enologist, laments that there are no in-depth studies of the ecosystem of terroir, and suggests it is because of the many factors involved. This lack of studies is particularly regrettable, says Séguin, for terroir plays an important role in the quality of wines. By his definition, quality terroirs are where the habitat permits complete but slow maturation of the grapes.

Daniel Querre, a grower in St.-Emilion and onetime General Attorney for the Jurade de Saint-Emilion, questions any attempt to explain a particular terroir, if only its obvious physical conditions are described. He points out that grapevines find something "precious – almost sacred" in their deep rooting. He compares the deep rooting of vines to the incense (gum) tree in the arid limestone country of Somaliland. He admits that many might shrug their shoulders at this "something," but he asks how else can we explain the sensory differences between two wines grown under the same physical conditions. Without the mystery of the "unknown something," Querre says, "I cannot explain how, simply by smelling it, one can distinguish a 'Cheval' from a 'Figeac'."

The writers of Larousse's *Wines and Vineyards of France* emphasize the mental aspect of terroir, it being the link visualized by a consumer between his wine and the winegrower who produced it.

In a commercial example, the British magazine *The Economist* describes how the concept of terroir has been used by the French to counter efforts by the European Union (the E.U., formerly E.C.) to deal with wine simply as a "brand" (a class of goods) in international trade. The French contend that good (and great) wine can come only from certain severely limited environments – the terroirs. The terroir pinpoints the geographical location of a vineyard with a specific climate, soil, and exposure. In other words, a wine is not just a commodity like sugar beet, but a distinct product from a unique place.

In the commodity sense, U.S. wine writer and critic Robert Parker says, "Think of *terroir* as you do salt, pepper, and garlic. In many dishes these flavorings represent an invaluable component, imparting wonderful aromas and character. But if consumed alone, they are usually difficult to swallow." Among other factors beyond *terroir* that influence the style of the wine, Parker suggests discovering the producers who make wines worth drinking and enjoying.

In all honesty, some question whether it is a valued term at all. I puzzle at their real appreciation of wine. The name slips easily into – or through – one's silent reading vocabulary, but if one wishes to pronounce it, it is *tair-wahr*.

Terroir may sound pedantic, strange, and certainly "foreign." Why not just use the more familiar word "vineyard" – especially in a book avowed to be easily readable? As a matter of fact, I confess that I am inconsistent in the use of terroir and vineyard. My intent has been to reserve the use of terroir for specifically named quality vineyards. I trust there will be a mutual Franco-American tolerance for my lack of consistency. Hopefully, this explanation will acquaint the reader with the term and its meaning so that it slips comfortably into, rather than through the reader's vocabulary.

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(b) Approved Maps. The appropriate maps for determining the boundary of the Wahluke Slope viticultural area are eight United States Geological Survey 1:24,000 scale topographic maps. They are titled:

(1) Beverly Quadrangle, Washington, 1965;

(2) Beverly SE Quadrangle, Washington – Grant Co., 1965;

(3) Smyrna Quadrangle, Washington – Grant Co., Provisional Edition 1986;

(4) Wahatis Peak Quadrangle, Washington – Grant Co., Provisional Edition 1986;

(5) Coyote Rapids Quadrangle, Washington, Provisional Edition 1986;

(6) Vernita Bridge Quadrangle, Washington, Provisional Edition 1986;

(7) Priest Rapids NE Quadrangle, Washington, Provisional Edition 1986; and

(8) Priest Rapids Quadrangle, Washington, 1948; photo revised 1978.