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Geology and Wine 11. Terroir of the Western Snake River Plain, Idaho, USA

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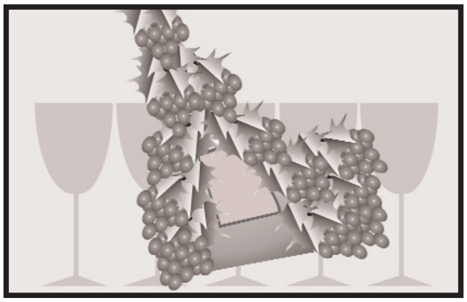
Article abstract

This article explores the unique combination of factors that shape the terroir of Idaho's principal wine grape-growing district. Most Idaho wine grape vineyards are located in the Western Snake River Plain (WSRP) rift basin (~43°N, ~117°W) on soils derived from lake, river, volcanic and wind-blown sediments. The underlying Tertiary and Quaternary rocks record the geologic history of ancient Lake Idaho, its interaction with basaltic volcanism, and subsequent Pleistocene fluvial processes and catastrophic floods. The arid to semi-arid, mid-latitude steppe climate of the WSRP provides fewer growing degree days than American Viticultural Areas (AVAs) in Walla Walla, Washington and Napa Valley, California, but still allows cultivation of *Vitis vinifera* grapes. Other differences include lower precipitation, higher solar radiation during the growing season, and greater threat of cold injury. Wine grapes grown in the WSRP require irrigation, and irrigation is used to manage canopy size and manipulate vine physiology. Wine grape acreage in Idaho has increased dramatically since 1993 and is estimated, in 2003, at about 500 ha with the white wine cultivars Riesling, Chardonnay, and Gewürztraminer comprising about 60% of production, and Cabernet Sauvignon, Merlot and Syrah as principal red wine cultivars.

SERIES



Geology and Wine 11. Terroir of the Western Snake River Plain, Idaho, USA

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SUMMARY
This article explores the unique combination of factors that shape the terroir of Idaho's principal wine grape-growing district. Most Idaho wine grape vineyards are located in the Western Snake River Plain (WSRP) rift basin (~43°N, ~117°W) on soils derived from lake, river, volcanic and wind-blown sediments. The underlying Tertiary and Quaternary rocks record the geologic history of ancient Lake Idaho, its interaction with basaltic volcanism, and subsequent Pleistocene fluvial processes and catastrophic floods. The arid to semi-arid, mid-latitude steppe climate of the WSRP provides fewer growing degree days than American Viticultural Areas (AVAs) in Walla Walla, Washington and Napa Valley, California, but still allows cultivation of *Vitis vinifera* grapes. Other differences include lower precipitation, higher solar radiation during the growing season, and greater threat of cold injury. Wine grapes grown in the WSRP require irrigation, and irrigation is used to manage canopy size and manipulate vine physiology. Wine grape acreage in Idaho has increased dramatically since 1993 and is estimated, in 2003, at about 500 ha with the white wine cultivars Riesling, Chardonnay, and Gewürztraminer comprising about 60% of production, and Cabernet Sauvignon, Merlot and Syrah as principal red wine cultivars.

RÉSUMÉ
Le présent article porte sur la combinaison particulière de facteurs qui définit le terroir du principal district viticole de l'État d'Idaho. La plupart des vignobles de l'Idaho sont situés dans le bassin de fossé tectonique (~43°N, ~117°O) de la Western Snake River Plain (WSRP), sur des sols formés de sédiments lacustres, fluviatiles, volcaniques et éoliens. Les couches tertiaires et quaternaires sous-jacentes témoignent des événements constitutifs de l'histoire géologique de l'ancien lac Idaho, de phénomènes interactifs dont il a été le théâtre, soit un volcanisme basaltique, ainsi que des processus fluviatiles et des inondations catastrophiques pléistocènes. Bien que le climat aride à semi-aride de steppe en altitude moyenne de la WSRP comporte moins de degrés-jours de croissance que les zone les zones viticoles étasuniennes (AVA) de Walla Walla de l'État de Washhington et de la vallée de Napa de l'État de Californie, il permet tout de même la culture des raisins de *Vitis vinifera*. De plus, cette région reçoit moins de précipitations, plus d'ensoleillement durant la saison de croissance, et elle est davantage exposée aux meurtrissures du froid. Les vignes de raisins de cuve cultivés dans la WSRP doivent être irriguées, l'irrigation permettant d'agir sur l'ampleur du feuillage et sur la physiologie du vin. La superficie de culture du raisin de cuve en Idaho s'est considérablement accrue depuis 1993 pour atteindre 500 ha environ en 2003, les cultivars à vin blanc de Riesling, Chardonnay, et Gewürztraminer constituant 60 % de la production, et ceux du Cabernet Sauvignon, du Merlot et du Syrah constituant les principaux cultivars à vin rouge.

INTRODUCTION
Best known for scenic beauty, whitewater rivers, and quality potatoes, the state of Idaho is receiving medals for premium red, white, and ice wines produced from Idaho-grown *Vitis vinifera* L. grapevines. Idaho normally is associated with high mountains and cold temperatures, but southwestern Idaho's low elevation and relatively moderate climate is suitable for growing European wine grapes. The Snake River Plain (SRP) is a crescent-shaped belt of sagebrush-covered volcanic rocks ranging in width from 65 to 100 km, and stretching roughly 600 km across southern Idaho; the principal wine grape-growing district is located in the Western part of the Snake River Plain (WSRP, Figs 1, 2). Geologically, the WSRP is distinguished from the Eastern Snake River Plain (ESRP, Fig. 1) by the much greater proportion of sedimentary rocks relative to basalts and a more fault-bounded, rift-

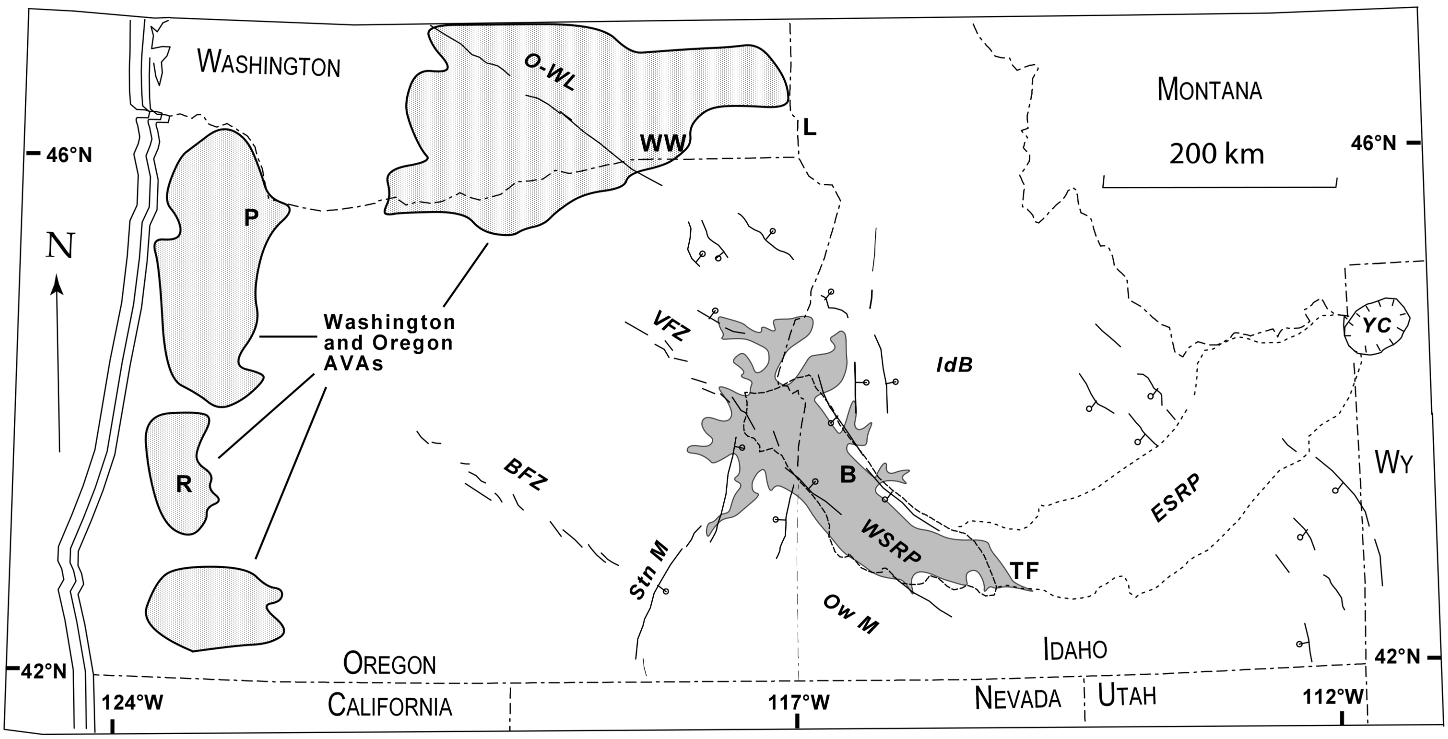

Figure 1. Map showing the location of the Western Snake River Plain (WSRP) relative to other major grape-growing regions and tectonic elements in the Pacific Northwest. Hells Canyon of the Snake River lies along the Idaho-Oregon border from the WSRP north to Lewiston. Physiographic and structural features (Ball and bar symbols indicate the downthrown side of the fault): BFZ, Brothers Fault Zone; ESRP, Eastern Snake River Plain; IdB, Idaho Batholith; O-WL, Olympic-Wallowa Lineament; Ow M, Owyhee Mountains; Stn M, Steens Mountains; VFZ, Vale Fault Zone; WSRP, Western Snake River Plain; YC, Yellowstone Caldera. Cities: B, Boise; L, Lewiston; R, Roseburg; P, Portland; TF, Twin Falls; WW, Walla Walla. AVA refers to American Viticultural Area, as designated by the Alcohol and Tobacco Tax and Trade Bureau (TTB) formerly called the Bureau of Alcohol, Tobacco and Firearms (BATF). Geology modified from Wood and Clemens (2002).

basin geometry. Yellowstone and Grand Teton National Parks lie at the eastern terminus of the SRP and contain the headwaters of the Snake River, which drains about 283,000 km^2 during its ~1120 km trek across the SRP and down Hells Canyon, before joining the Columbia River en route to the Pacific Ocean (Fig. 3). Irrigation from the Snake River has been instrumental for much of Idaho agriculture, including viticulture.

The WSRP includes parts of 10 Idaho counties and a small part of Oregon, but 75% of commercial wine grape acreage, including the largest vineyard at 150 ha, is located in Idaho's Canyon County [United States Department of Agriculture (USDA), Idaho Agricultural Statistics Service, 1999; Fig. 2]. Elevation in the WSRP ranges from about 660 to 1100 m a.s.l. (USDA, 1972) and vineyards are located at elevations ranging from 695 to 890 m. The WSRP is at a similar latitude (43°N to 44°N) as wine regions in France, Italy and Spain, and chapters of its geologic history are similar to the history of the neighbouring states of Washington and Oregon (Meinert and Busacca, 2000). In Idaho, European wine grape production north (~47°N) or east (~114°W) of the WSRP is limited by low winter minimum temperatures and limited length of growing season.

The history of wine production in Idaho is similar to that of neighbouring states and the province of British Columbia, Canada (Meinert and Busacca, 2000; Taylor et al., 2002), dating to the mid-1800s when French and German immigrants cultivated European grapes and produced wines near the confluence of the Snake and Columbia rivers. Native North American grape species that host pests detrimental to European vines, like the insect phylloxera [*Daktulosphaira vitifoliae* (Fitch)], were not present in this region, and own-rooted European vines were successfully cultivated. After the United States' prohibition of alcohol (1920-1933), wine grape production did not recover until around 1970. Idaho created a state commission in 1984 to promote growth and development of the grape and wine industry. Acreage and number of wineries increased steadily such that by 1998, wine grapes were Idaho's fourth largest fruit crop (USDA, Idaho Agricultural Statistics Service, 1999). Between 1993 and 1999, the latest year for which official statistics are available, acreage and number of vineyards doubled to 262 ha in 27 vineyards. An informal 2003 survey by the Idaho Grape Growers and Wine Producers Commission of 35 of its ~50 grower members, suggested further doubling of acreage to about 489 ha with > 50% of vineyards at ≤ 6 ha. Cultivar acreage, based on 65% of estimated total acreage, suggests a predominance of white wine cultivars (60%) including Riesling (32%), Chardonnay (18%), and Gewürztraminer (7%). Principal red wine cultivars by acreage are Cabernet Sauvignon (19%), Merlot (12%), and Syrah (5%). An extensive

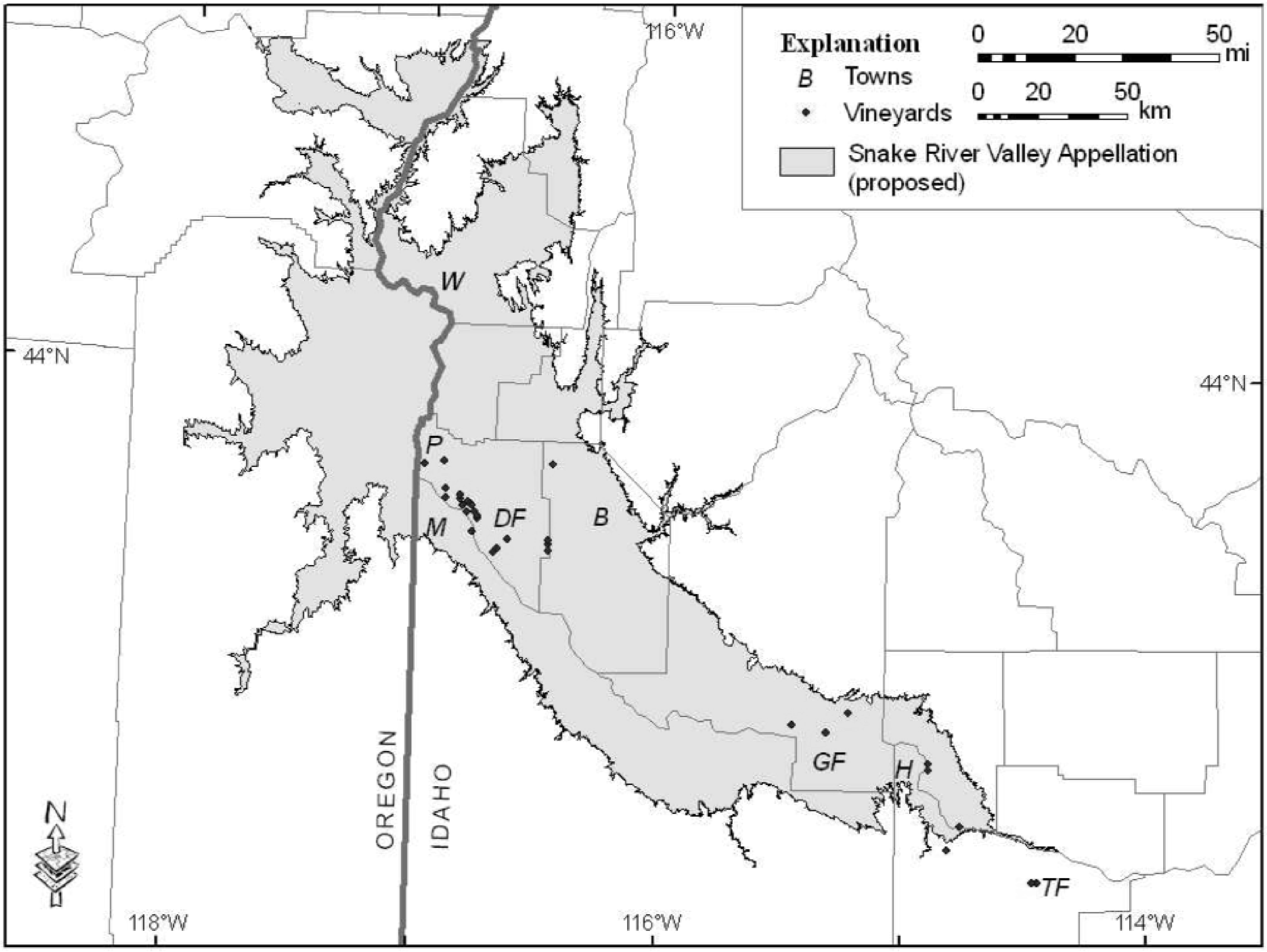

Figure 2. Map of the Western Snake River Plain grape-growing region, noting the locations of vineyards. Shaded area marks the extent (at an elevation of 1050 m a.s.l.) of Pliocene Lake Idaho, and is the boundary of the proposed Snake River Valley AVA. The Sunnyslope area referred to in the text is the cluster of vineyards west of Deer Flat (DF), which is located in Canyon County. Towns shown are Weiser (W), Boise (B), Parma (P), Marsing (M), Glenns Ferry (GF), Hagerman (H), and Twin Falls (TF).

amount of arable land is available for future plantings, limited more by access to water for irrigation than by land suitability. The Idaho Grape Growers and Wine Producers Commission currently is petitioning for the first designated American Viticultural Area (AVA) in Idaho, to be delimited by the 1050 m a.s.l. elevation boundary of ancient Lake Idaho (Fig. 2).

TERROIR OF IDAHO'S WESTERN SNAKE RIVER PLAIN

Physiography

The SRP is a large, arcuate-shaped, topographic depression, mostly filled with volcanic rocks, that crosses the entire state (Fig. 1). The westward-flowing Snake River lies near the southern boundary of the SRP and historically has provided water for much of the region's agriculture (Fig. 3). The river has formed either a steep-walled canyon where it incises thick piles of basaltic lava flows, or a more open valley where it cuts Tertiary and Quaternary lacustrine and fluvial sediments. The eastern part of the SRP is higher in elevation and too cold for *V. Vinifera*, so most Idaho wine originates from the WSRP, most notably the Sunnyslope area in Canyon County (Fig. 2), where the vineyards are located on the tops and flanks of a series of ridges between Homedale and Lake Lowell, just east of the town of Marsing (43°33'N, 116°48'W) on the Snake River (Fig. 4). Though the vineyards are located within a few kilometers of the Snake River, most slopes would support only native vegetation, such as sagebrush, rabbitbrush, and bunch grasses, were it not for widespread irrigation from a large number of irrigation canals. A second cluster of vineyards is located near Glenns Ferry (42°57'N, 115°18'W) in Elmore County (Fig. 2), and there also are vineyards near Lewiston (46°25'N, 117°01'W; Fig. 1) in northern Idaho.

Geologic Setting

The geologic history of southwestern Idaho resembles that of eastern Washington with its flood basalts, north-

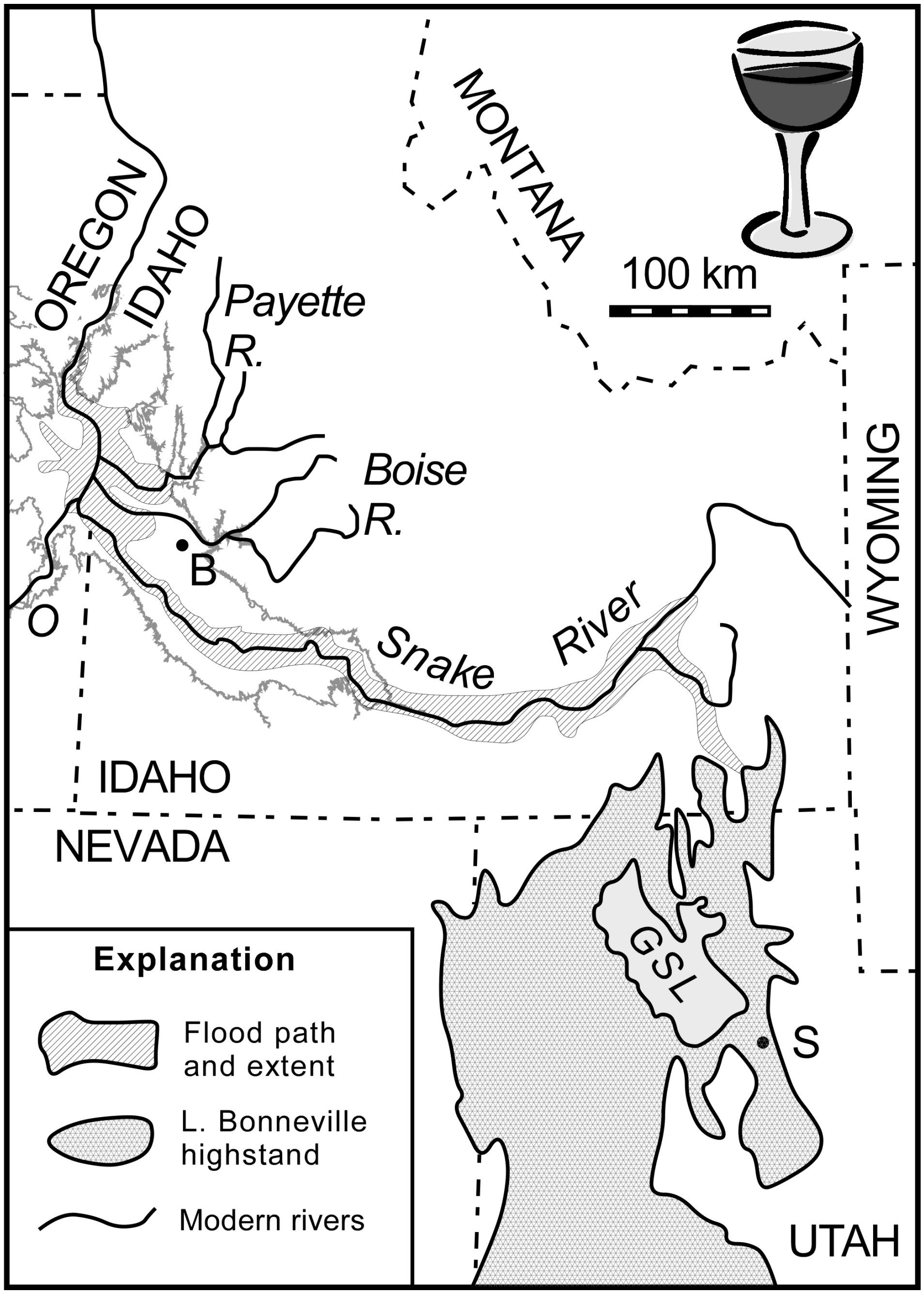

Figure 3. Regional map of the WSRP showing modern river drainages and outline of late Pleistocene Lake Bonneville with its associated outburst flood (flood path and extent), after O'Connor (1993). Abbreviations: O (Owyhee River), B (Boise), S (Salt Lake City), GSL (modern Great Salt Lake).

west-trending structures, extensive loess blankets, and glacial outburst floods (Meinert and Busacca, 2000, 2002). However, Idaho's geologic history includes Lake Idaho, a paleo-system of lakes and floodplains which, at its maximum, stretched 240 km northwest-to-southeast from what is now the Oregon-Idaho state line (117°W) to just west of Twin Falls (42°33.5'N, 114°28'W; Fig. 2).

North of the SRP are Cretaceous granites of the Idaho Batholith, along with assorted Eocene volcanic rocks, older sedimentary rocks, and the Miocene (14-17 Ma) Columbia River Basalts of the Weiser embayment (Figs. 1, 2). South of the WSRP are 12-15 Ma volcanic rocks of the Owyhee Mountains that overlie the southern extension of the granitic basement. The WSRP is a northwest-trending, 300-km long and 70-km wide intracontinental rift basin, whose margins are well-defined boundary faults that parallel other structural zones such as the Olympic-Wallowa lineament and Brothers fault zone (Fig. 1) in Oregon and Washington (Wood and Clemens, 2002). In contrast, the eastern SRP is a structural downwarp, associated with extension and magmatism along the track of the Yellowstone hot spot. This mantle plume helped generate the voluminous basalt-rhyolite volcanism of the SRP, and the Pleistocene-Recent Yellowstone caldera of Yellowstone National Park (Pierce et al., 2002).

The major faulting which down-dropped the centre of the WSRP began about 12 Ma and ended by approximately 9 Ma, although minor warping and structural adjustment may have continued locally (Wood, 2004). Rhyolitic flow domes mark the margins; basaltic volcanic rocks interbedded with the earliest sediments show that volcanism and early basin formation were contemporaneous (Wood and Clemens, 2002). A generalized stratigraphic sequence is given in Table 1. Vineyards are planted on soils derived from many units, but most notably the sands and silts of the Pliocene Glenns Ferry Formation, local basalts, the Tenmile and Terrace gravels, and finer grained Holocene deposits of the Bonneville Flood (Fig. 4).

As the rift formed, water accumulated in a series of lakes, floodplains and wetlands, with marginal beaches and streams. Fish and terrestrial vertebrate fossils are abundant locally in the complex sequence of lacustrine and related floodplain-to-shoreline facies sedimentary rocks which make up the Tertiary Idaho Group deposits of paleo-Lake Idaho. Sediments deposited in Lake Idaho include sand, silt, and clay as well as local volcanic ash. Lake level rose and fell as the basin subsided; the maximum extent of Lake Idaho was about 4 million years ago, near what is currently the 3600-ft (1100-m) elevation contour (Wood and Clemens, 2002).

To the east, in the Hagerman Fossil National Monument (42°49'N, 114°57'W), basalts interbedded with several hundred feet of Glenns Ferry sediments have been dated at 3.4 Ma (Hart et al., 1999). By approximately 2 Ma, floodplain and marsh sediments of the later part of the Glenns Ferry Formation were deposited east of

Marsing on the Chalk Hills topographic ridge (Wood, 2004; Reppening et al., 1994) that underlies the Bitner vineyards. Lizard Butte (Fig. 4) is a phreatomagmatic basaltic volcano that erupted through wet lake and floodplain sediments. A short distance southeast of Marsing, near Pickles Butte and Idaho's largest vineyard, is a subaerial basalt flow that buries stream gravels of the ancestral Snake River. The age of the basalt flow, dated at 1.58 Ma by the Ar^{40}/Ar^{39} method, demonstrates that by early Pleistocene time, the WSRP had completely transformed from a filling rift basin to an incised lowland (Othberg, 1994). The draining of Lake Idaho was a consequence of headward erosion of ancestral Hells Canyon by the Snake-Salmon river system coupled with Lake Idaho overtopping a divide and draining northward through the ancestral Hells Canyon. Although timing of this event is poorly constrained, the initial spillover most likely occurred between 2 and 4

Table 1: General stratigraphy of the WSRP, modified from Wood and Clemens (2002). Q = Quaternary; T = Tertiary.

Epoch/Period	Age (Ma)	Group	Rock Unit
Holocene Q	14,500 yrs.	Bonneville Flood	Sediments
Pleistocene	0-2 Ma	Terrace Gravels	River Gravels w/ local basalt
	< 2 Ma	Snake River Group	Basalt flows, hydrovolcanoes
Pliocene T		Tenmile Gravel	Gravels
(2-5 Ma)	2-5 Ma?	Idaho Group	Glenns Ferry Formation, or
		~~	Terteling Springs Fm. (N. side)
Miocene T	7-10 Ma?	Idaho Group	Chalk Hills Formation
(5-24 Ma)		Older Basalts/Seds	inc. Banbury/Poison Creek Fm.
	11-12 Ma?	Margin Rhyolites	"Dry Rhyolites"
	12-15 Ma	Idavada Volcanics	Rhyolites, Volcanics of Owyhee Co.
	14-17 Ma	Columbia River Group	Basalts

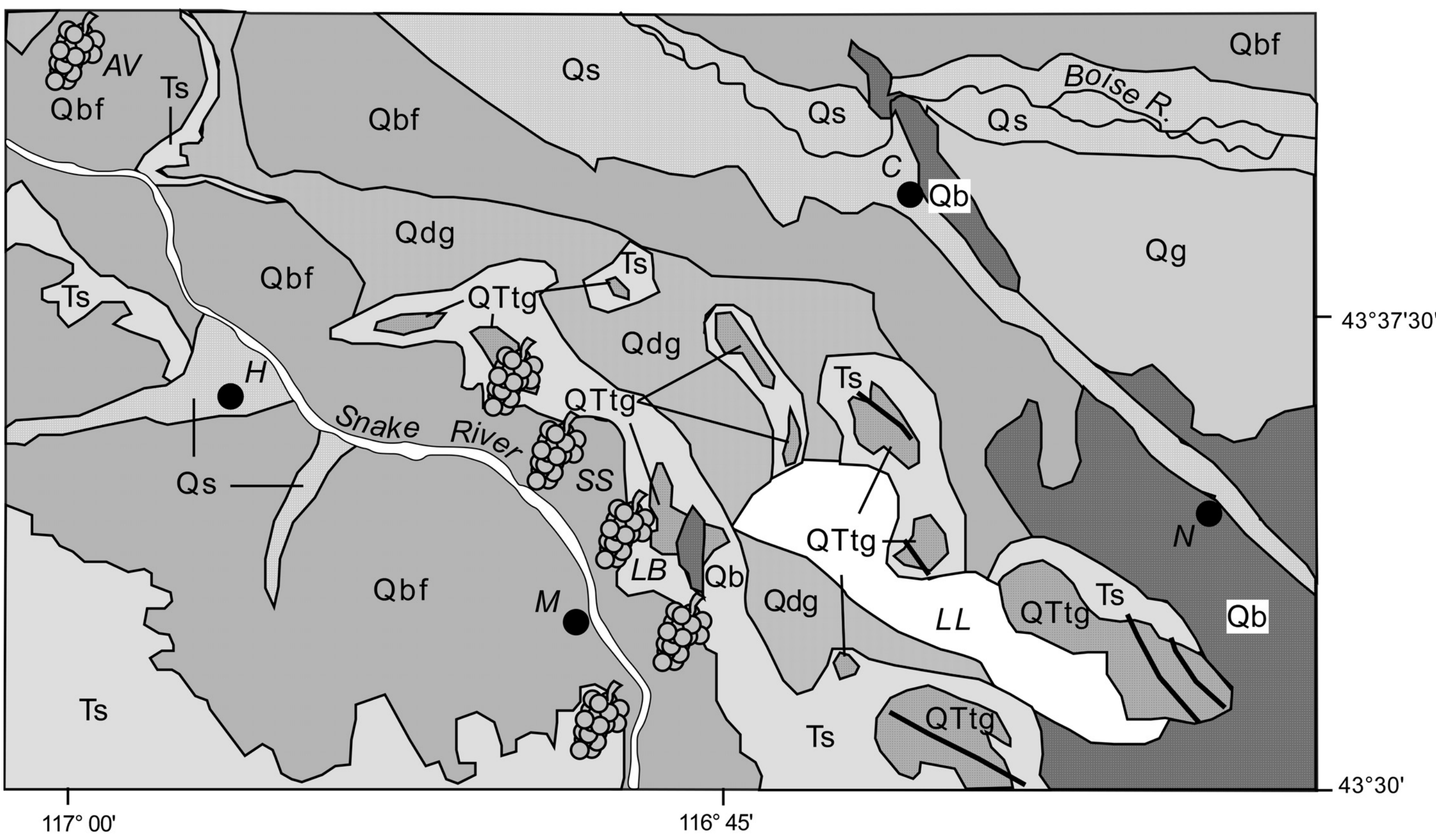

Figure 4. Simplified geologic map for major WSRP grape-growing region, modified from Othberg and Stanford (1992). Towns are Homedale (H), Marsing (M), Caldwell (C), Nampa (N), with other features of Sunnyslope (SS), Lake Lowell (LL), Arena Valley (AV), and Lizard Butte (LB). Wineries and general areas of vineyards shown schematically by grape clusters; others are east of this map. Geologic units: Qs, Quaternary alluvium/surficial deposits; Qbf, Bonneville Flood deposits undifferentiated; Qg, Quaternary terrace gravels, younger; Qdg, Deer Flat Terrace Gravel; Qb, Quaternary basalts; QTtg, Tenmile Gravel; and Ts, Tertiary lacustrine and fluvial sediments, Idaho Group. Heavy black lines are faults. Table 1 gives generalized stratigraphy.

Ma with subsequent slow downcutting of the divide (Wood and Clemens, 2002).

Draining of the lake and lowering base level allowed incision of the old lacustrine sediments by the ancestral Boise River, forming a stepped series of Quaternary stream terrace gravels that mark previous river base level stands (Othberg, 1994; Othberg and Stanford, 1992). The oldest, the Tenmile Gravel (Table 1), caps the northwest-trending ridge of Glenns Ferry sediments at Sunnyslope, where many vineyards are located (near 43°35'N, 116°47'W), and towards Chalk Hills where additional vineyards are located (Fig. 4). A younger, lower elevation terrace gravel, known as the Gravel of Deer Flat Terrace, overlies the Tertiary sediments and flanks the ridges. Several vineyards are planted on the sandy pebble gravel of the Deer Flat Terrace, which is locally overlain by loess. Terrace elevations were controlled by paleo-base levels, and in turn, those terrace elevations dictate the vineyard elevations and influence land use.

The Bonneville Flood, which occurred 14,500 years ago, is the most recent geologic event important to the vineyards of Idaho (Scott et al., 1982). This catastrophic flood resulted from erosion of a low divide that was overtopped by a northern arm of Lake Bonneville, the ancestral Great Salt Lake in Utah (Fig. 3). The resulting deluge of water down the Snake River lasted 6 months (D. Currey, personal communication, 2005) and the discharge peaked at about 1 million $m^3 \bullet s^{-1}$ at the Lake Bonneville outlet (O'Connor, 1993). This single flood event created the western Snake River Canyon of today. Because the discharge was variable over the duration of the flood, multi-metre-sized boulders to sand to silt-sized sediments were deposited (Fig. 5). During the highest flood discharges, water was hydraulically backed up by constricted flow through Hells Canyon, causing relatively quiet water to pond in the lower reaches of the Snake, Payette, Boise, and Owyhee river valleys (Othberg, 1994; Fig. 3). As a result, from Hells Canyon south to Marsing, fine-grained slackwater silt blankets the late Pleistocene terraces below an elevation of 747 m a.s.l. (2,450 feet), which is lower than the early Pleistocene Deer Flat Terrace (Othberg and Stanford, 1992). Vineyards in Arena Valley northwest of Marsing are located adjacent to a circular erosion feature where the late Pleistocene Whitney terrace was scoured by late stages of the Bonneville Flood (Fig. 4).

Pedological Description

Soil type in the WSRP varies somewhat according to the lithology of the parent material, and the timeframe and climate under which the soil developed. Surficial loess, sand, and Bonneville Flood slackwater silts are the predominant parent materials at the vineyards, and the soils normally contain abundant quartz and feldspar grains derived from the Tertiary units, though fields near the basaltic vents may contain more clay and mafic minerals.

Older soils generally tend to be more complex and show more extensive duripan (caliche) development and clay-rich B-horizons (Othberg, 1994). In some areas, soil has developed on a blanket of loess up to 4 m thick (Othberg and Stanford, 1992). The Bonneville Flood sediments are younger than the loess and typically show little soil development. Soils on the Deer Flat Terrace Gravel, which underlies some vineyards, contain more than 25% pedogenic clay and a buried duripan greater than one metre thick. Soils on the older Tenmile Gravel, which underlies ridge-top vineyards, may have 50% clay and a 2-m thick duripan (Othberg, 1994). The thicker, platy duripans promote alkaline soils and may impede subsurface drainage and root penetration by the vines.

Vineyard locations in the Sunnyslope area were spatially compared with their underlying soil characteristics listed in the NRCS Soil Survey Geographic (SSURGO) Database. The soil database for Canyon County lists over 50 soil series and eight associations. The GIS analysis revealed no single soil series common among the vineyards; 19 vineyards are located on 11 soil series that share many characteristics. Most soils underlying the vineyards in the Sunnyslope area are silty to sandy loams where silt percentages range from 58% to 67% in the upper horizons (USDA, 1972). The series are characterized as moderately to extremely well-drained, moderately calcareous and alkaline subgroups of aridisols and entisols; they have moderate to high cation exchange capacities. Most of the soils are fairly shallow (<1 m) with soil depth an inverse function of slope (i.e., steeper slopes have shallower soil depths). All the soils used for agriculture (that is, not range or urban) require surface irrigation (USDA, 1972). The combination of moderate to steep slopes, moderately to excessively drained soils, and easily eroded sediments places further limitations on land use in the region. The soils associated with the vineyard sites typically are characterized as not being prime farm land (i.e., having moderate to

Figure 5. Boulders in Bonneville Flood Melon Gravels, at Celebration Park along Snake River, south of Melba, Idaho.

severe limitations; USDA, 1972), with prescribed uses ranging from irrigated pasture to fruit orchards (where hard freezes are not a danger). Prime farm land in the area (i.e., having higher soil water availability, deeper soil depths, lower gradient slopes) is used primarily for large scale row crop operations such as sugar beets, alfalfa, corn, and onions. More recently, prime farmland on the urban fringes has been converted to housing subdivisions.

Climate

The climatic factors of precipitation (amount and seasonal pattern), growing season length, and growing degree days (e.g., Winkler et al., 1974) all affect grape and wine quality (van Leeuwen et al., 2004; Jones and Davis, 2000) and thus contribute strongly to terroir. The WSRP is located in the continental interior of the western U.S. approximately 500 km east of the Cascade Range (Fig. 1). Even with its continental interior location, the region is on a climatic hinge line and exhibits influences of both continental and marine climates. Winter months (November 1 through March 30) provide two-thirds of the precipitation for the region (Fig. 6). Winter precipitation is caused both by storms from the Gulf of Alaska tracking under the influence of the dominant westerlies at this latitude (Godfrey, 1999), and more tropical moisture originating near Hawaii tracking under the influence of the subtropical jet stream and producing what is colloquially referred to as the “Pineapple Express.” Whereas winters may be cold and overcast, the summer growing season (April 1 through September 30) is characterized by warm, dry days with a possible average of 70% of sunshine [Western Regional Climate Center (WRCC), 2005; http://www.wrcc.dri.edu/].

Climatic Comparisons

Thirty-year monthly climate normals, covering the period from 1971-2000, were obtained from the National Climate Data Center’s (NCDC) online archives (http://www.ncdc.noaa.gov/oa/ncdc.html) for four locations in the WSRP (Glenns Ferry, Weiser, Parma, and Deer Flat Dam, Idaho). These Idaho climate normals were compared to climate data from other grape-growing regions (Walla Walla, Washington; Roseburg, Oregon; and Napa, California) in the western United States (Table 2; Fig. 6). The NCDC climate normals summarize mean values for monthly maximum and minimum temperatures and precipitation.

Despite latitudinal and situational variation among the regions, seasonality of precipitation is strikingly similar (Fig. 6). All four regions experience a pronounced summer precipitation minimum, with the Napa climate station recording only a trace of July precipitation. Despite a similar seasonal precipitation pattern, the WSRP receives about half the annual precipitation of the other regions (Fig. 6). The lower annual precipitation in the WSRP may be partly attributed to the rain shadows created by the Cascade, Sierra Nevada, and more locally the Owyhee ranges.

Temperature is what most distinguishes the different regions, resulting at least in part from differences in elevation. The WSRP ranges from 640 to 765 m, compared to a low of 12 m at Napa and to 365 m at Walla Walla. The mean annual temperature in the WSRP of 10.8°C is the lowest in the regional comparison group, and is close to the 10°C isotherm described as the poleward temperature limit for cultivation of European grapes (Jones et al., 2004; De Blij, 1983). The WSRP also has significantly lower mid-winter (January) mean minimum temperatures than the other western US districts, and two months, December and January, have mean temperatures below 0°C (Fig. 6). Whereas these mean temperatures are not solely limiting, they provide evidence for the potential of damage from severe cold temperatures (i.e., <-18°C, Table 2; Winkler et al., 1974). This potential for deep freezing temperatures has implications for viticultural practices.

The temperature contrast between the WSRP and the other

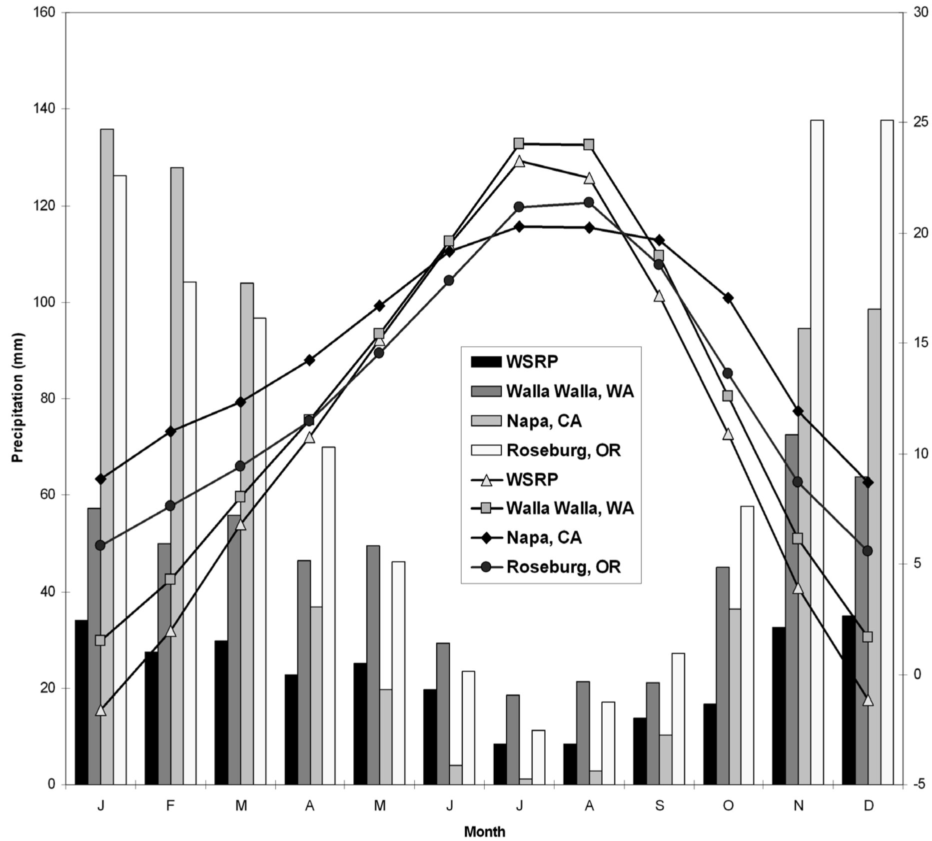

Figure 6. Comparison of climate variables, with mean precipitation as bars and mean temperature as lines, for the averaged WSRP stations; Walla Walla, Washington; Napa, California; and Roseburg, Oregon, in the western United States. Data were compiled from online archives available through the National Climate Data Center and the Western Regional Climate Center, Desert Research Institute, Reno, Nevada (http://www.wrcc.dri.edu/summary/).

regions also translates into differences in length of growing season (i.e., number of days during the growing season with less than 50% probability of reaching 0°C; Winkler et al., 1974). With its higher elevation and more interior location resulting in colder winters, the WSRP has the shortest growing season of the regions in Table 2, and this may be a limiting factor for some grape varieties.

Another climate factor, continentality, is defined by the annual range in temperature and reflects remoteness from moderating ocean influences; higher temperature ranges indicate a greater degree of continentality. Napa and Roseburg have the most moderate temperature ranges, reflecting their proximity to the ocean, whereas the WSRP has mean monthly temperatures that vary by almost 25°C (Fig. 6). This range is slightly greater than at Walla Walla and much greater than at Roseburg, which is at the same 43°N latitude but has a monthly mean temperature range of only 16°C.

Growing Degree Days

Growing degree days (GDD) is a summation of accumulated heat units as measured by days during the growing season (April 1 to October 31 in the northern hemisphere) with a mean temperature over an established base (10°C for grapes; Winkler et al., 1974); under the 10°C temperature base threshold, little growth or development of wine grapes occurs. Growing degree days also can be used as an indicator of the timing, independent of the calendar, of phenological events including dates of budbreak, bloom, veraison (onset of berry ripening) and harvest.

The climate data indicate that the Walla Walla Valley and Napa districts each fall within the Winkler Region III range (1666-1944 Base 10°C GDD), with higher growing degree days than the WSRP and Roseburg districts, which are within the Winkler Region II range (1389-1665 Base 10°C GDD; Table 2; Fig. 7). The higher growing degree days rating for Napa Valley reflects the relatively warm early growing season, whereas values for Walla Walla reflect high temperatures during June through August. In contrast, Roseburg has the lowest growing degree day rating, reflecting that district's marine influence and generally low summer temperatures. Seasonal temperatures rise quickly in the WSRP, with an average last and first day of 0°C frost on May 10 and September 29, respectively. Thus, the WSRP has a shorter growing season than the other three districts.

Table 2: Climate Data for the WSRP and other grape growing districts in the western United States. Column heading abbreviations: MAT, Mean Annual Temperature; MAP, Mean Annual Precipitation; GDD, Growing Degree Days; GSL, Growing Season Length; XMT, 30-year extreme minimum winter temperature (event year in parenthesis); CNT, Continentality (mean annual temperature range). Data compiled from the National Climate Data Center (http://www.ncdc.noaa.gov).

Station Name	Elev (m)	Location (lat/long)	MAT (°C)	MAP (mm)	GDD 10°C	GSL 0°C	XMT (°C)	CNT (°C)
Parma Exp. Station, Idaho	698	43.8°N 116.95°W	9.9	283	1342	140	-32 (1990)	25
Weiser, Idaho	646	43.67°N 116.68°W	11.0	307	1637	136	-34 (1990)	27
Deer Flat Dam, Idaho	765	43.59°N 116.75°W	11.6	258	1626	165	-30 (1989)	24
Glenns Ferry, Idaho	752	43.61°N 116.57°W	10.5	248	1413	125	-32 (1989)	24
WSRP	**715**		**10.8**	**274**	**1504**	**142**		**25**
Roseburg, Oregon	130	43.2°N 123.36°W	13.0	855	1484	218	-16 (1989)	16
Walla Walla Airport, Washington	355	46.05°N 118.28°W	12.3	530	1715	206	-11 (1985)	23
Napa State Hospital, California	11	38.28°N 122.27°W	15.0	672	1753	259	-10 (1990)	12

Viticultural Practices

Successful production of wine grapes in the WSRP requires careful consideration of site and cultivar selection, number of frost-free days, and availability of supplemental water. Risk of frost damage is minimized by locating vineyards on slopes with good air drainage towards river or valley bottoms (Fig. 8a). Vineyards tend to be located on hillsides with a southern or southwestern aspect to maximize heat unit accumulation and to avoid direct exposure to prevailing northwesterly winds. Vines are generally planted in north-south rows to facilitate cold air drainage and to provide equal sunlight exposure on both sides of the vine canopy (Fig. 8b). The predominant vine training system is cordon-trained, spur-pruned, with vertical shoot positioning on a six wire trellis. Common in-row spacing is 2.1 m with 2.7 m between rows. Target shoot length is about 1.5 m. Dormant vines typically are pruned manually to two (red cultivars) or three (white cultivars) bud spurs, yielding 24 to 28 (red) or 36-42 (white) buds per vine. Some growers mechanically pre-prune dormant vines, and many mechanically harvest their grapes.

An estimated 60% of total producing wine grape acreage in the WSRP is composed of fairly cold hardy, white wine cultivars (Riesling, Chardonnay, and Gewürztraminer) that have a low heat unit requirement to reach maturity (Wolfe, 1998). The red wine cultivars Cabernet Sauvignon, a late maturing cultivar with a relatively high heat unit requirement (Wolfe, 1998), and Merlot, a less cold hardy cultivar (Wolfe, 1998), comprise about a third of producing acreage, and many new plantings include red wine cultivars with similar temperature requirements.

The large range (about 280) in GDD among WSRP weather station sites as depicted in Table 2, as well as the successful commercial production of Cabernet Sauvignon and Merlot, highlights the importance of the vineyard

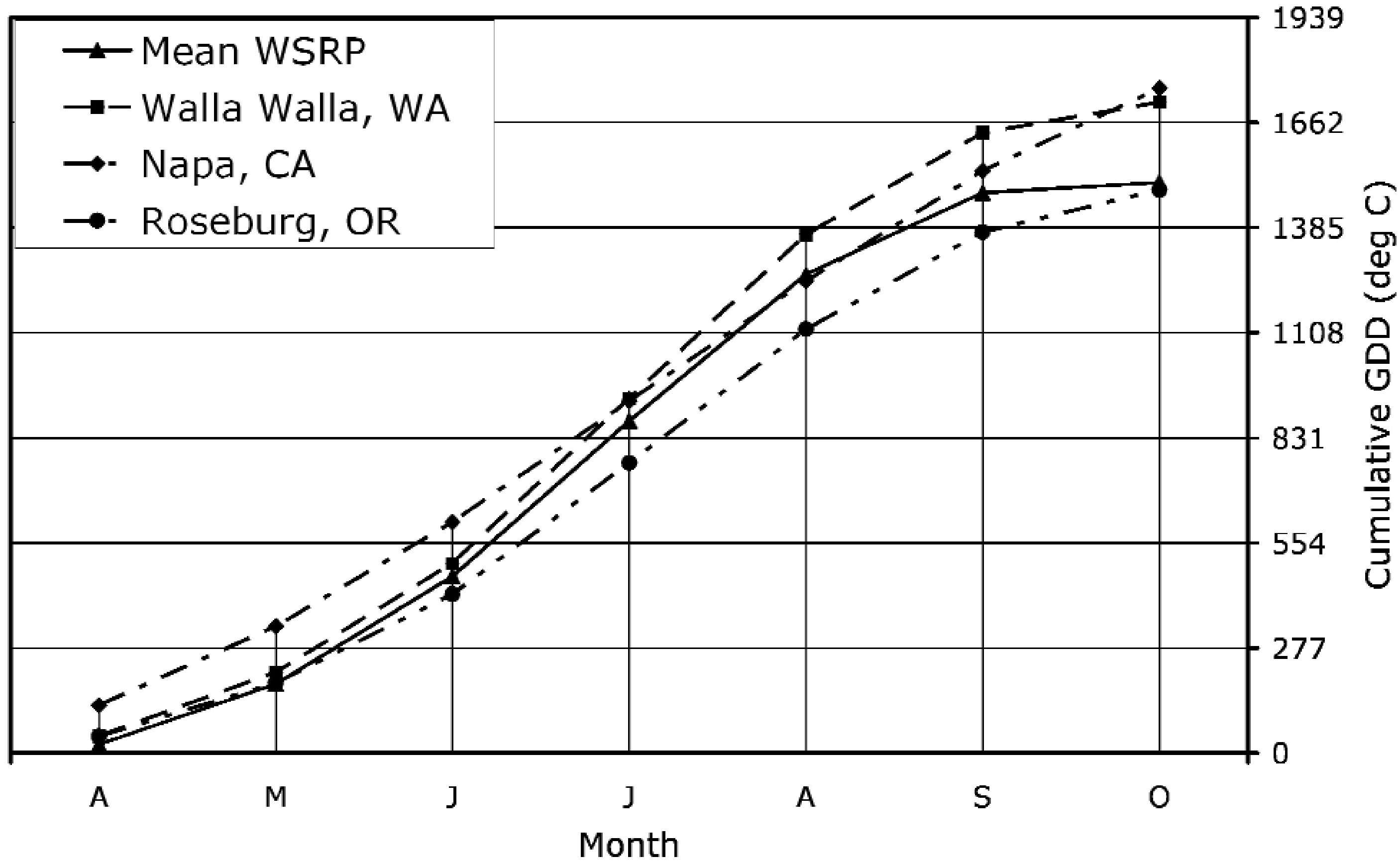

Figure 7. Mean cumulative growing degree days (GDD) from 1971-2000 for the four averaged WSRP stations; Walla Walla, Washington; Napa, California; and Roseburg, Oregon, calculated from National Climate Data Center from average monthly maximum and minimum temperatures between April 1 and October 31 using a base temperature of 10°C.

mesoclimate. For example, a 140-day growing season with 1442 growing degree days is reported for the Idaho Parma Experimental weather station in Table 2 (Fig. 2). However, temperature data collected in a hillside vineyard planted in 1997 with a northern aspect and north-south row orientation recorded 1581, 1851, and 1644 growing degree days at the Parma Experiment Station (simple average, base 10°C, daily temperature), respectively over three vintages (2002-2004). The average number of frost-free days needed in this vineyard for fruit to reach maturity was 147-150 for Merlot, 150-154 for Chardonnay, and 160 or more for Cabernet Sauvignon and Syrah (Table 3). Fruit composition of each cultivar at harvest reached optimum brix (~23%; this is a measure of sugar concentration in the grapes), pH (~3.6), and titratable acidity (0.6 g/dl), suggesting adequate season duration and temperature accumulation. The growing season and heat unit accumulation data in Table 2 suggest that the climate in

Table 3: For own-rooted, *Vitis vinifera* L. vines (wine grapes of European origin) planted in 1997 at the Parma Experimental Station, Idaho, table shows: Average number of days from budburst to harvest (DTM); Harvest percent brix (a measure of sugar concentration in the grapes); pH; titratable acidity (TA); and berry weight of fruit harvested in 2002, 2003, and 2004 from the cultivars listed.

Cultivar (clone)	DTM (days)	Brix (%)	pH	TA (g/dl)	100 berry weight (g)
Merlot (01)	147	23.6	3.56	0.52	104.5
Merlot (08)	149	24.0	3.70	0.51	105.5
Chardonnay (29)	154	22.9	3.38	0.75	97.9
Chardonnay (49)	150	23.1	3.38	0.74	102.5
Cabernet Sauvignon (02)	162	24.1	3.65	0.45	95.9
Cabernet Sauvignon (04)	160	23.3	3.62	0.46	95.0
Cabernet Sauvignon (11)	171	23.7	3.51	0.59	104.0
Syrah (07)	164	24.3	3.73	0.50	113.7

Parma is marginal for cultivation of Merlot and Chardonnay and not suitable for production of Cabernet Sauvignon or Syrah, yet vineyard heat unit accumulation and number of frost-free days suggest a suitable vineyard mesoclimate for production of these red wine cultivars.

Vine cold-hardiness is not well understood because of its complex interaction with environmental conditions, including temperature and photoperiod (Howell, 2000), tissue maturity (Goffinet, 2000), and vine water status (Wample et al., 2000), but growers in the WSRP minimize yield loss from cold injury by adopting preventative cultivation practices. For example, own-rooted cuttings are planted at a depth of 30 to 36 cm to facilitate root survival in the event of above ground vine loss from prolonged low temperature. The vines are trained to two trunks (Fig. 8b) with each trunk forming a unilateral cordon that extends to one side or other of the vine. In the event of cold damage, the second trunk can be used to replenish damaged wood. The absence of phylloxera in the region permits cultivation of own-rooted rather than grafted vines, enabling trunk re-establishment without replanting. Despite these cultivation practices, injury from prolonged minimum mid-winter low temperature was anecdotally reported in the very cold years of 1989 and 1990. Another common type of cold injury observed in the WSRP occurs during winter dormancy when several days of high solar radiation and warm ambient temperature precede an abrupt return to freezing or near freezing temperature.

Figure 8a. Cliffside Vineyard planted on gently tilted Lake Idaho sediments of the Glenns Ferry Formation (Pliocene), facing west. The Snake River lies at the base of the steep slope, along the line of green trees and houses.

Figure 8b. North-south rows of grape vines at Skyline Vineyard with a basaltic cinder pit in distance adjacent to Sawtooth Vineyard, facing north. Vines are planted with double trunks and require drip irrigation.

The low annual and growing season precipitation and the shallow soils in the WSRP facilitate manipulation of vine physiology through irrigation management. Most irrigation water is obtained from annually recharged snowpack in mountain ranges surrounding the WSRP and is delivered through an extensive network of reservoirs and canals. The majority of vineyards are irrigated with above ground drip lines, although some vineyards utilize overhead sprinklers or furrows. Irrigation scheduling is used to prepare for the first fall frost by imposing water stress on the vine to encourage periderm formation on green shoots. Periderm is a visible indicator of tissue maturity and has been associated with bud and cane cold hardiness (Goffinet, 2000). Irrigation is then normally applied prior to the first fall frost to bring soil moisture up to field capacity in an effort to protect roots during the winter. Growers also manipulate vine water stress during the growing season to shift growth from vegetative to reproductive structures (Greenspan, 2005) and to control canopy as well as berry size. Regulated deficit irrigation is used to control plant water status and to optimize fruit quality during the growing season. Ongoing research is being conducted by researchers at the USDA-Agricultural Research Service in Parma, Idaho, to understand how vine water status influences grape components that contribute to wine quality.

CONCLUSIONS

The Western Snake River Plain is the principal wine grape-growing district in

Idaho. Formation of the WSRP began between 9 and 12 Ma with major extensional faulting and volcanism resulting in a down-dropped topographic basin. Over approximately the next 7 million years, Lake Idaho and associated streams and floodplains deposited a succession of fine-grained sand, silt, and ash, with the lake high stand reaching up to near the present-day 1100-metre topographic contour of the WSRP. After Lake Idaho drained about 2 Ma, the ancestral Boise River incised these Tertiary sediments, forming a stepped series of Quaternary stream terrace gravels surrounding remnant highlands of the earlier sediments. The final major geologic event to shape the region occurred about 14,500 years ago when Lake Bonneville discharged catastrophically into the Snake River canyon, enlarging it and leaving behind widespread flood deposits from conglomerates to silt over-bank deposits. Vineyards are planted on all of these Tertiary to Quaternary units where the landscape allows cold air drainage.

Low temperatures and a short growing season limit the range of European wine grape cultivars that are suitable for production in the WSRP. However, late maturing, less cold hardy cultivars like Cabernet Sauvignon and Merlot currently comprise an estimated 31% of producing acreage in the WSRP, suggesting that vineyard mesoclimate is critical for production success. Furthermore, controlled irrigation is a critical tool for managing vine cold hardiness.

The geologic and physiographic diversity within the WSRP suggests that subregions, such as the Marsing Valley, the Hagerman Valley, Glenns Ferry region, and Boise Foothills, may emerge as future viticultural areas. Much work remains to document the key elements of Idaho terroir that may enhance future vintages.

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