Petition to establish the

White Bluffs

American Viticultural Area

Franklin County, Washington

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Petition to Establish the White Bluffs American Viticultural Area

Introduction

This petition proposes the establishment of a new American Viticultural Area (AVA) in the south-central part of the State of Washington to be called "White Bluffs" (Figure 1). It is submitted on behalf of the owners and managers of the vineyards within the boundaries of the proposed AVA. The proposed AVA is situated entirely within the boundaries of the 17,802 sq. mi. Columbia Valley AVA.

As proposed, the White Bluffs AVA encompasses 93,738 acres (146 sq. mi.) on a plateau that borders the eastern shore of the Columbia River as it flows generally southwesterly through the Pasco Basin. Within the proposed AVA are currently 1127 acres of vineyards and one winery (Figure 2, Appendix 1).

The proposed AVA has viticultural characteristics, based on topography and climate, which are distinctive from the surrounding area. They derive from unique characteristics of the geology of the proposed AVA, which is located on a plateau underlain by fluvial and lacustrine sediments of the Pliocene Ringold Formation. The following sections will detail evidence in support of the name, boundaries, and distinguishing features of the proposed AVA. This petition also includes maps of the proposed AVA, a narrative boundary description, and a discussion of the shared and contrasting attributes of the Columbia Valley AVA and the proposed AVA.

Name Evidence

The name of the proposed AVA is "White Bluffs." The AVA takes its name from a steep escarpment composed of sedimentary rock of the Ringold Formation that lies along the eastern bank of the Columbia River and forms the western boundary of the AVA (Figure 3). Russell (1892) describes the location of the White Bluffs as "along the left (east) bank of the Columbia, beginning 12 miles above Pasco and extending 30 miles up the river" (Appendix 2). Merriam and Buwalda (1917), in their defining work on the Ringold Formation, state that: "The White Bluffs follow the river closely from a point ten or twelve miles north of Pasco to the northwestward for about thirty miles. They further noted that: "The crest appears to maintain its height of about five hundred feet above the stream throughout the whole thirty miles" (Appendix 2). More recently, Bjornstad (2006) states that: "The White Bluffs line the north and east sides of the Columbia River for about 30 miles along the Hanford Reach near Richland". The western boundary of the proposed AVA, as defined in this petition, begins 13.8 miles upstream of Pasco and continues to a point 30 miles upstream of Pasco, and therefore coincides with the location of the White Bluffs as described by Russell (1892), Merriam and Buwalda (1917), and Bjornstad (2006). Geologic maps published by Russell (1892) and Newcomb (1958) labeled the cliffs along the western boundary of the proposed AVA as "The White Bluffs". (Appendix 2).

The White Bluffs are clearly visible from the city of Richland where the name "White Bluffs" has been utilized for a street, a brewery, a subdivision, and an elementary school (Appendix 2). The White Bluffs also lend their name to the White

Bluffs Quilt Museum, which describes itself as "a Regional Textile Arts Center, serving the Tri-Cities and the Mid-Columbia Basin" (Appendix 2) and the White Bluffs bladderpod, a threatened species whose native habitat overlaps with the proposed AVA. An area of federal land adjacent to the proposed AVA has been designated as critical habitat for the White Bluffs bladderpod (Appendix 2). The name "White Bluffs" is applied to vineyards within the proposed AVA owned by the Claar Wine Group. On the Washington State Wine Commission webpage for White Bluffs Vineyard, the vineyard and Claar Cellars Winery are described as "located north of Pasco, WA in the White Bluffs area of the Columbia Valley Appellation" (Appendix 2). It is appropriate that the name White Bluffs be applied to the AVA as it is the most prominent and recognizable feature of the area. The White Bluffs are composed of sedimentary rock of the Ringold Formation, which forms the geologic foundation of the proposed AVA and distinguishes it from the surrounding areas.

Boundary Evidence

The boundary for the proposed AVA was devised to encompass a plateau that rises above the surrounding Pasco basin and extends north and east of the Columbia River 10 miles north of the cities of Richland, Kennewick, and Pasco, Washington, (the Tri-Cities) (Figure 4). The boundary also encompasses an area underlain by a thick layer of the Pliocene Ringold Formation, and separates that area from surrounding areas where the Ringold Formation is generally thinner or absent and Columbia River Basalt is exposed. The boundary is largely based on topographic contour lines and the shoreline of the Columbia River. Elevation generally increases when crossing into the proposed AVA from outside its boundaries.

The western boundary of the proposed AVA is a combination of the eastern shore of the Columbia River and the boundary line of the Hanford Reach National Monument. The area west of the river is not within the plateau that defines the AVA and is part of the Hanford Nuclear Reservation and is therefore off-limits to the public. The Hanford Reach National Monument is off-limits for agricultural development. The northern boundary of the AVA is formed primarily by the 950 ft. contour line, which lies along the escarpment that separates the plateau that characterizes the AVA from areas of lower elevation. Part of the northern boundary is formed by section lines and railroads located near the southern limit of exposures of Columbia River basalt. The eastern boundary is formed by topographic contour lines that lie along the eastern escarpment of the plateau that separates it from lower elevation land that slopes eastward toward Esquatzel coulee. The southern boundary consists primarily of contour lines that separate the plateau from lower elevations that slope southward toward the floor of the Pasco Basin and the Columbia River.

Geography

Perhaps the most distinctive feature of the proposed AVA is its geography. The proposed boundaries encircle a broad plateau that rises, on average, 200 feet above the surrounding landscape (Figure 5). Ringold and Koontz coulees divide the plateau into two distinct areas that are capped by flat surfaces known as Columbia Flat and Owens Flat (Figure 5). Merriam and Buwalda (1917) in their study that named the Ringold Formation, the geologic unit that forms the White Bluffs and underlies the plateau, noted that: "The surface extending several miles to the eastward from the summit of the White Bluffs is remarkably even, excepting where interrupted by occasional drainage courses that have cut below its level. The marked evenness and approximate horizontality of this surface as viewed from the summit of the bluffs, and the apparent absence of residual hills upon it, suggest immediately that it is a surface of aggradation rather than one of erosion or of river planation. Its striking parallelism, so far as the unaided eye may judge, with the strata of the Ringold in the face of the White Bluffs, strengthens this idea" (Appendix 2). Newcomb et al., (1972) called the area within the proposed boundaries "the principal plateau feature of the area" describing it as an "upland surface at an altitude of about 1000 feet that extends east and north from the top of the White Bluffs." (Appendix 2)

The plateau escarpments within the proposed AVA provide gently sloping sites with a southern component of aspect, especially along its southern and western margins. Sites with a southern aspect are generally preferred for viticulture in the northern hemisphere, especially at higher latitudes. South-facing slopes absorb more solar energy per unit area than other aspects, which helps to warm the soil and promote an earlier onset of bud break, flowering, veraison, and harvest. Vineyards near the edges of a plateau benefit from their proximity to the escarpment, which allows cold air to drain to lower elevations. Vineyards situated on the plateau lie above colder air that pools on the floor of the Pasco Basin during nocturnal temperature inversions, which lengthens their growing season and reduces the incidence of damage to vines from late spring and early fall frost and freeze events.

Geology

The proposed AVA is underlain by a thick interval of sedimentary rocks named the Ringold formation by Merriam and Buwalda (1917) for exposures near the old Ringold post office that was located at the base of the White Bluffs, within the proposed AVA (Figure 5). Lindsey (1996) described the Ringold as "interbedded, unconsolidated to cemented clay, silt, sand, and granule to cobble gravel" (Appendix 3). The sediments that comprise the Ringold were deposited in lakes and rivers within the center of the Pasco Basin during upper Miocene to middle Pliocene time (8.5-3.4 million years ago). They overlie the Miocene Columbia River Basalt, the ubiquitous bedrock of the Columbia Basin. The proposed AVA is situated near the center of a sedimentary basin that formed on the slowly subsiding upper surface of the Columbia River Basalt and thus contains the best-developed and thickest interval of the Ringold Formation. The plateau within the proposed AVA is composed of a remnant of a thick layer of Ringold Formation that once blanketed much of the Pasco Basin. Erosion by the Columbia River and ice age floods has decreased its areal extent; the White Bluffs escarpment currently represents the erosional front.

Within the proposed AVA, Ringold Formation sediments are overlain in some areas by alternating layers of sand and silt deposited in Glacial Lake Lewis, a temporary lake that formed when the catastrophic ice-age floods that repeatedly swept the Columbia Basin were impounded behind the topographic constriction at Wallula Gap, 15 miles downstream of Pasco on the Columbia River. The thickness of these ice-age sediments, known as the "Touchet beds" is controlled by both elevation (thinner flood sediments at higher elevations) and subsequent erosion, which has reduced their areal extent. The soils throughout the proposed AVA are developed in wind-deposited sand and silt that overlies the Touchet beds (where present) and Ringold Formation. These fine-grained sediments were derived from ice-age flood sediments deposited in the Pasco Basin upwind of the proposed AVA.

The geology of the area within the proposed AVA is distinctive because the underlying rock formations consist primarily of a thick sequence of sedimentary rock of the Ringold Formation (unit Qrl on Figure 6) instead of volcanic rock of the Columbia River basalt (unit Ty on Figure 6), the most common bedrock in the Columbia Basin. Furthermore, the upper part of the Ringold Formation in this area contains an erosion-resistant mineralized layer that has helped to create the plateau that is the principal topographic feature of the proposed AVA. Newcomb (1958) observed: "the uppermost part of the Ringold Formation in the White Bluffs is heavily calcified and silicified to a depth of at least 15 feet. This calcified and silicified caprock is commonly called caliche ... The indurated caliche underlies the 900- to 1000-foot plateau that extends east and north from the White Bluffs...." (Appendix 3). Newcomb et al. (1972) while describing the plateau of the proposed AVA noted: "The surface is underlain by a thin layer of windblown soil and by erratic glaciofluviatile materials (Touchet beds), but it is largely founded on the strong caliche zone at the top of the Ringold strata" (Appendix 3). In areas of the proposed AVA where the caliche zone described by Newcomb lies near the surface, it limits root penetration and soil water holding capacity. Prior to planting, these areas routinely undergo deep ripping with bulldozers to disaggregate the caliche (Figures, 7, 8).

Since the plateau on which the proposed AVA is situated is not directly underlain by or derived from Columbia River basalt, the roots of vines planted on the plateau will never encounter basalt bedrock, which is composed of a suite of minerals (plagioclase feldspar, pyroxene, olivine) very different from those found in the overlying wind-deposited sediment (quartz, potassium feldspar, mica) (Pogue, 2009). This contrasts with other AVAs of the Columbia Basin such as the higher parts of the Red Mountain, Yakima Valley, and Walla Walla Valley AVAs as well as some parts of the Columbia Valley AVA that lie just outside the proposed boundaries (Figure 8). Furthermore, the lake sediments that are found in the upper part of the Ringold Formation have much higher clay content than the ice-age flood sediments that form the substrate for many Columbia Valley AVA vineyards, and thus have distinct textural and drainage characteristics that affect root penetration and water availability. Soils with higher clay content have higher water holding capacity and release water more slowly and progressively than sandier soils, which allows the vines to be less stressed during dry conditions.

Soils

The soils of the proposed AVA are developed in wind-deposited silt (loess) and fine sand overlying sediment deposited by ice-age floods that in turn overlies Ringold Formation. Most of the ice-age flood sediment deposited within the proposed AVA is a mixture of silt and sand that settled out of suspension when the floodwaters pooled behind Wallula Gap on the Columbia River to form glacial Lake Lewis. The maximum elevation Lake Lewis was approximately 1250 ft. and thus the entire area within the proposed AVA was submerged by the largest ice-age floods. The thickness of ice-age flood sediment gradually increases with decreasing elevation since there were multiple ice-age floods of varying intensity and lower elevations were inundated more frequently. Thus, lower elevations surrounding the proposed AVA are more likely to have a thicker interval of flood-deposited sediment than the area within the proposed AVA. The flood deposits surrounding the proposed AVA are also much more likely to consist of coarse-grained gravel rather than fine sand and silt (unit Qg on Figure 6) since they were deposited by fast-flowing currents that swept through the lower elevations that surround the plateau.

In summary, the wind-deposited surficial soils of the proposed AVA rest on ice-age flood sediments that tend to be thinner and more fine-grained than those of the surrounding lower elevations. In areas where the ice-age flood deposits are thin or absent due to erosion, the wind-deposited surficial soil rests on semi-consolidated, permeable, clay-rich sedimentary rocks of the Ringold Formation, as opposed to the hard, impermeable basalt in much of the surrounding area (Figure 8).

Climate

The climate of the proposed AVA is strongly influenced by its distinctive topography, which is dominated by a plateau that rises, on average, 200 ft. above its surroundings. Nocturnal cooling generates cold air that flows away from the upper surface of the plateau toward the surrounding floor of the Pasco Basin. This process produces temperature inversions, where air temperatures increase, rather than decrease with elevation. Vineyards on the basin floor are therefore routinely subjected to morning low temperatures that are significantly lower than those recorded by vineyards located on the plateau and its escarpment.

Sites that have consistently cooler morning temperatures are more prone to spring frosts that can damage the vines after bud break. These sites are also more likely to experience early fall frosts that halt the ripening process before it is complete. Areas where local topography helps to mitigate the negative impact of temperature inversions are thus preferred sites for viticulture since they tend to experience fewer and less severe frost and freeze events and have longer growing seasons.

Figure 9 shows the location of weather stations in the vicinity of the proposed AVA. The stations are part of the Washington State University AgWeatherNet (http://weather.wsu.edu/) with the exception of KWAELTOP3, which is part of the Weather Underground Network (https://www.wunderground.com). Stations Pasco

North and KWAELTOP3 lie within the boundaries of the proposed AVA, and record conditions typical of the proposed AVA.

The spreadsheet in Figure 10 displays average dates of first frost and last frost, and average number of frost-free days (length of growing season) for the 8 AgWeatherNet stations for nine years (2008-2016) and for the KWAELTOP3 station for 3 years (2014-2016). The nine-year data on Figure 8 shows that the North Pasco station had a date of last frost that ranged from 14 to 42 days earlier and averaged 29 days earlier and a date of first frost that ranged from 11 to 25 days later and averaged 18 days later than the other stations. The length of the growing season at the North Pasco station, as measured by the number of consecutive days without freezing temperatures, ranged from 25 to 65 days longer and averaged 45 days longer than the other stations.

For the 3 years for which the KWAELTOP3 data were available, the two stations within the boundaries of the proposed AVA had an average date of last frost that was 29 days earlier than the average date of last frost for stations outside the boundaries. The date of first frost for the stations within the proposed boundaries averaged 8 days later than the stations outside. The length of growing season for the stations within the proposed boundaries averaged 40 days longer than for the stations outside the boundary.

Boundary description

The boundary of the proposed the White Bluffs viticultural area falls within 10 United States Geological Survey 1:24,000 scale topographic maps. They are:

(1) Hanford NE, Washington (1986)

(2) Mesa West, Washington (1986)

(3) Wooded Island, Washington (1992)

(4) Matthews Corner, Washington (1992)

(5) Basin City, Washington (1986)

(6) Eltopia, Washington (1992)

(7) Eagle Lakes, Washington (1986)

(8) Savage Island, Washington (1986)

(9) Richland, Washington (1992)

(10) Columbia Point, Washington (1992)

The proposed White Bluffs viticultural area is located in Franklin County, Washington. The boundary is described below:

(1) The beginning point is on the Richland map at the intersection of Sagemoor Road and Road 68. From the beginning point, follow Road 68 northward, passing onto the Wooded Island map, to the Potholes Canal.

(2) Follow the Potholes Canal westward for 150 ft. to its intersection with the shoreline of the Columbia River.

(3) Follow the Columbia River shoreline northward, passing onto the Savage Island map, to its intersection with the Wahluke Slope Habitat Management Boundary on Ringold Flat.

(4) Follow the Wahluke Slope Habitat Management Boundary northward to its intersection with the 950 ft. topographic contour line along the boundary between sections 16 and 17, township 13 north, range 28 east.

(5) Follow the 950 ft. contour line north and east, passing onto and through the Hanford NE map, and onto the Eagle Lakes map to its intersection with an unimproved road in the SE quadrant of section 32, township 14 north, range 29 east.

(6) Proceed eastward along the unimproved road for 100 feet to the intersection with a light duty improved road (Albany Road), then proceed southward on Albany Road, passing onto the Basin City map, to its intersection with an improved light duty road (Basin Hill Road) along the southern boundary of section 21, township 13 north, range 29 east.

(7) Proceed due south along a straight line for two miles to an improved light duty, road (W Klamath Rd.) then proceed eastward along W Klamath Rd, passing onto the Mesa West map, to its intersection with another improved light duty road (Drummond Rd.).

(8) Follow Drummond Road 0.75 mile north to its intersection with a railroad, then follow the railroad generally east to its intersection with an improved light duty road (Langford Rd.) in the northeastern part of section 4, township 12 north, range 30 east.

(9) Follow Langford Rd. south 0.5 mile to its intersection with the 800 ft. topographic contour line, then follow the 800 ft. contour line generally south, passing onto the Eltopia map, to its intersection with Eltopia West Rd.

(10) Proceed to the east on Eltopia West Rd. for 0.5 mile to its intersection with the 700 ft. topographic contour line, then follow the 700 ft. contour line southward and then northwestward around Jackass Mountain, to its intersection with Dogwood Rd.

(11) Proceed westward along Dogwood Rd. for 1.1 miles, passing onto the Matthews Corner map, to its intersection with the 750 ft. topographic contour line, then follow the 750 ft. topographic contour line generally westward to its intersection with Taylor Flats Rd.

(12) Follow Taylor Flats Rd. southward, passing onto the Columbia Point map, to its intersection with Birch Rd., then follow Birch Rd. westward for 1.0 mile to its intersection with Alder Rd.

(13) Proceed southward on Alder Rd. for 0.7 mile to its intersection with the 550 ft. topographic contour line, then follow the 550 ft. contour line generally westward to its intersection with Sagemoor Rd.

(14) Follow Sagemoor Rd. 0.7 mile westward, passing onto the Richland map, to return to the beginning point.

Attributes of the Proposed White Bluffs AVA Consistent with the Columbia Valley AVA

According to the petitioners, Columbia Valley AVA typically has a growing season of greater than 150 days, growing degree-days exceeding 2000, and average annual precipitation of less than 15 inches. All of these criteria apply to the area included within the boundaries proposed for the White Bluffs AVA.

Distinctions Between the Proposed White Bluffs Mountain AVA and the Columbia Valley AVA

The Columbia Valley, as described in petition for the Columbia Valley AVA, is a "large treeless plain surrounding the Yakima, Columbia, and Snake Rivers". The area within the proposed White Bluffs AVA lies on a plateau, not a plain, and has unique characteristics of geology and climate, detailed elsewhere in this petition, that distinguish it from the surrounding plains.

References Cited

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Pogue, K.R., 2009, Folds, floods, and fine wine: geologic influences on the terroir of the Columbia basin, in O'Connor, J.E., Dorsey, R.J., and Madin, I.P., eds., Volcanoes to Vineyards: Geologic field trips through the dynamic landscape of the Pacific Northwest: Geological Society of America Field Guide 15, p. 1-17.

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Figure Captions

Figure 1 - Map showing locations of Columbia Basin AVAs relative to the boundaries of the proposed White Bluffs AVA.

Figure 2 - Map showing locations of vineyards and winery within the proposed White Bluffs AVA.

Figure 3 - Photograph of the White Bluffs from the Columbia River, looking east. Location is near the midpoint of the western boundary of the proposed White Bluffs AVA.

Figure 4 - Digital elevation model of the central Columbia Basin showing location of the proposed White Bluffs AVA relative to regional topography.

Figure 5 - Digital elevation model of the vicinity of the proposed White Bluffs AVA showing local topography.

Figure 6 - Geologic map of the area of the proposed White Bluffs AVA, from Grolier and Bingham, 1971.

Figure 7 - Photograph of blocks of caliche in High River Vineyard. Blocks were derived from the caliche layer at the top of the Ringold Formation by deep ripping in preparation for planting.

Figure 8 - Photographs of typical soil profiles from within (8A) and from outside (8B) the proposed White Bluffs AVA. Photograph 8A from near High River Vineyard showing wind-deposited silt and sand overlying caliche-rich Ringold Formation. Caliche has been mechanically disaggregated and mixed into overlying sediment. Photograph 8B shows wind-deposited silt and sand overlying basalt bedrock 3 miles east of the proposed boundary. Photo locations shown on Figure 6.

Figure 9 - Map showing locations of stations from which climate data on Figure were obtained.

Figure 10 - Climate data for stations near and within the proposed White Bluffs AVA.

Figures

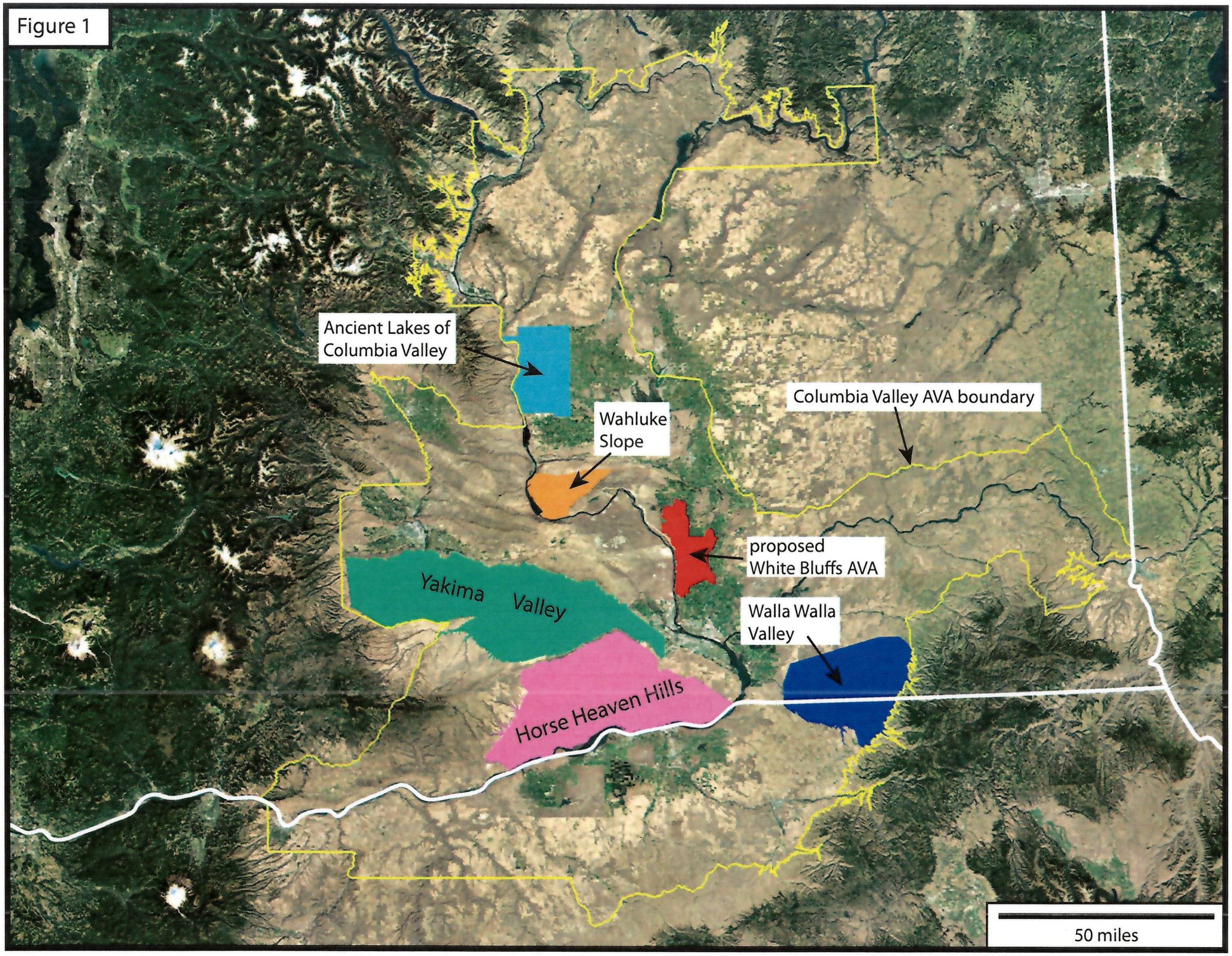


Figure 1
Ancient Lakes of Columbia Valley
Wahluke Slope
Columbia Valley AVA boundary
proposed White Bluffs AVA
Yakima Valley
Walla Walla Valley
Horse Heaven Hills
50 miles

Figure 2

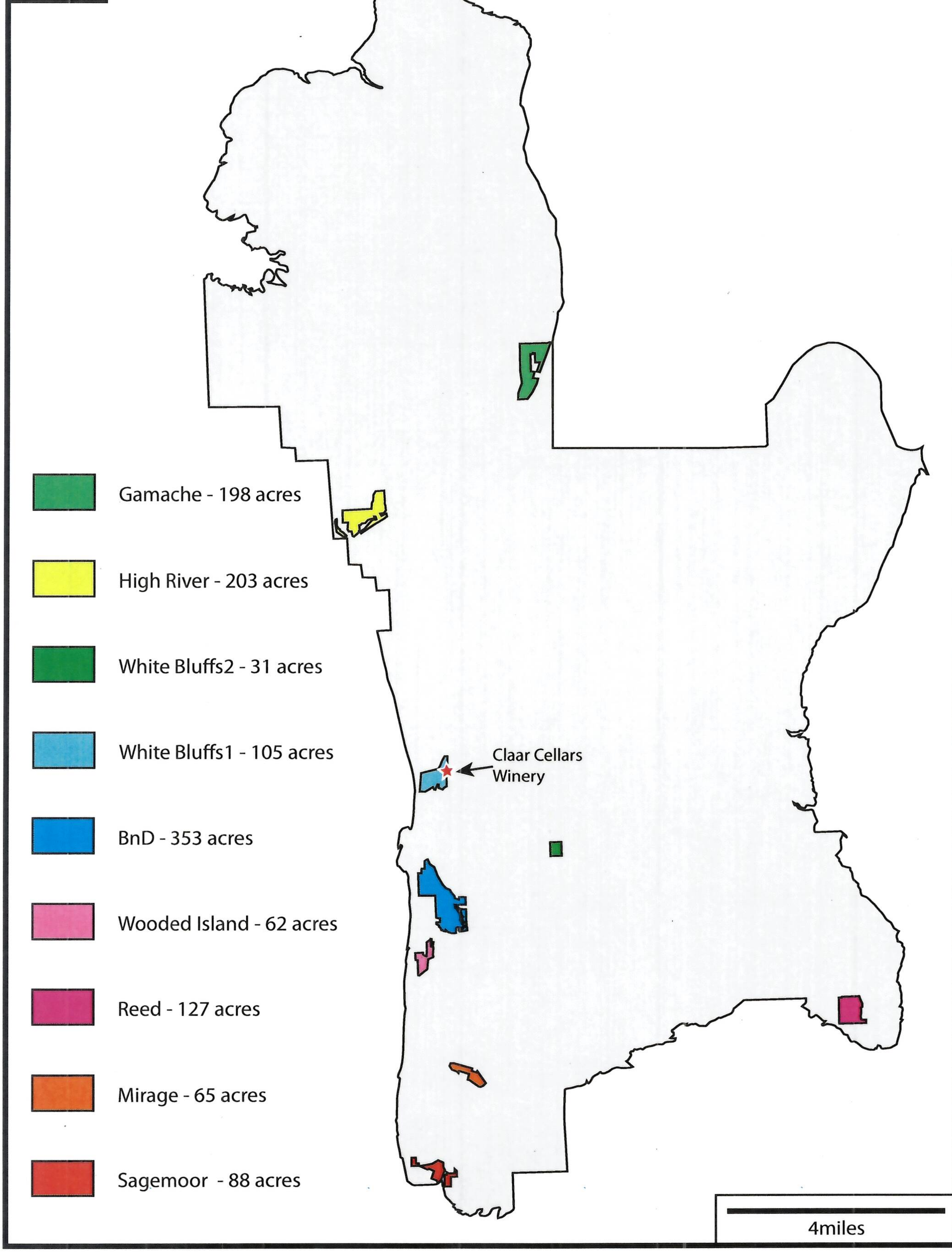
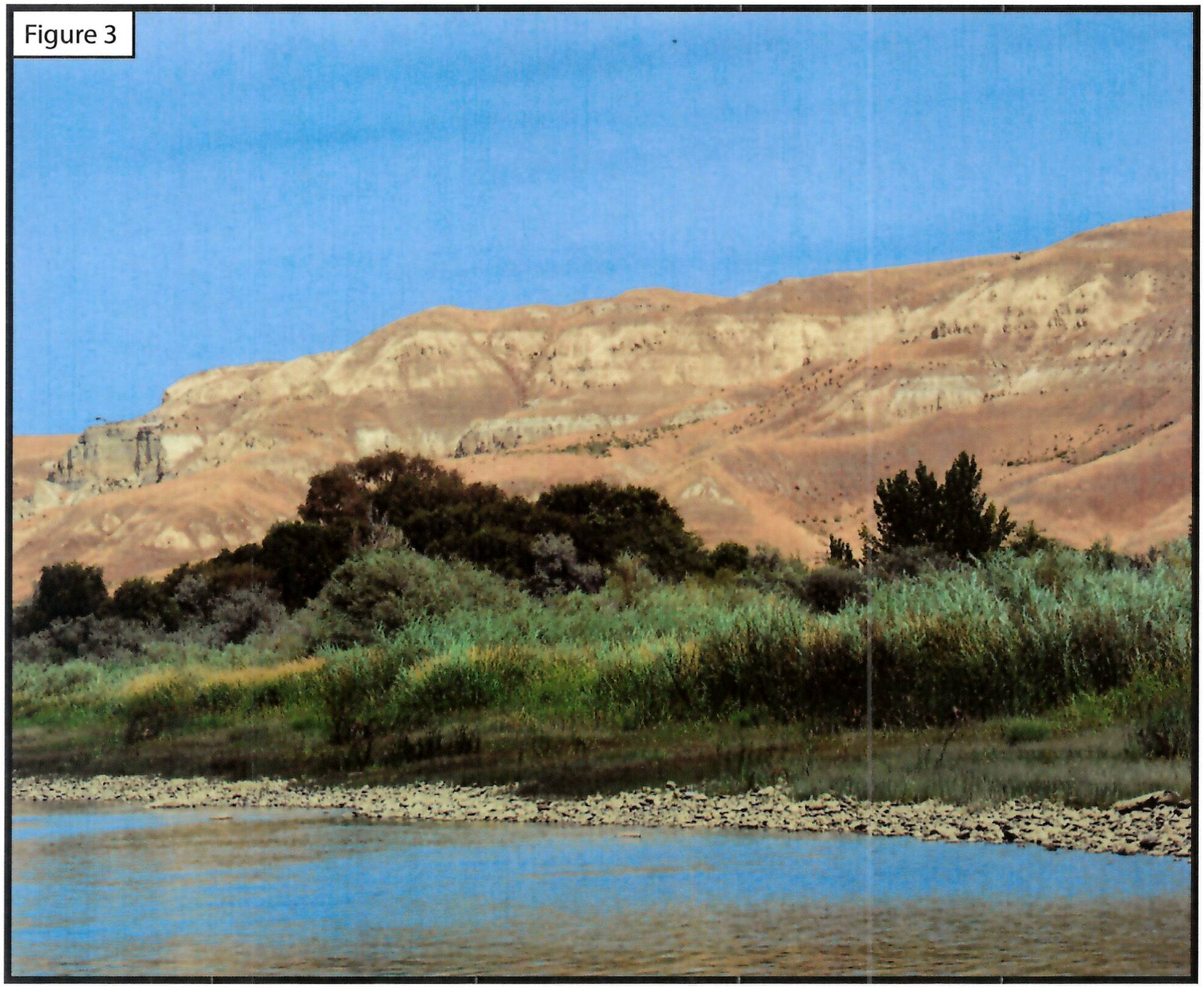

Gamache - 198 acres
High River - 203 acres
White Bluffs2 - 31 acres
White Bluffs1 - 105 acres
BnD - 353 acres
Wooded Island - 62 acres
Reed - 127 acres
Mirage - 65 acres
Sagemoor - 88 acres
Claar Cellars Winery
4miles

Figure 3



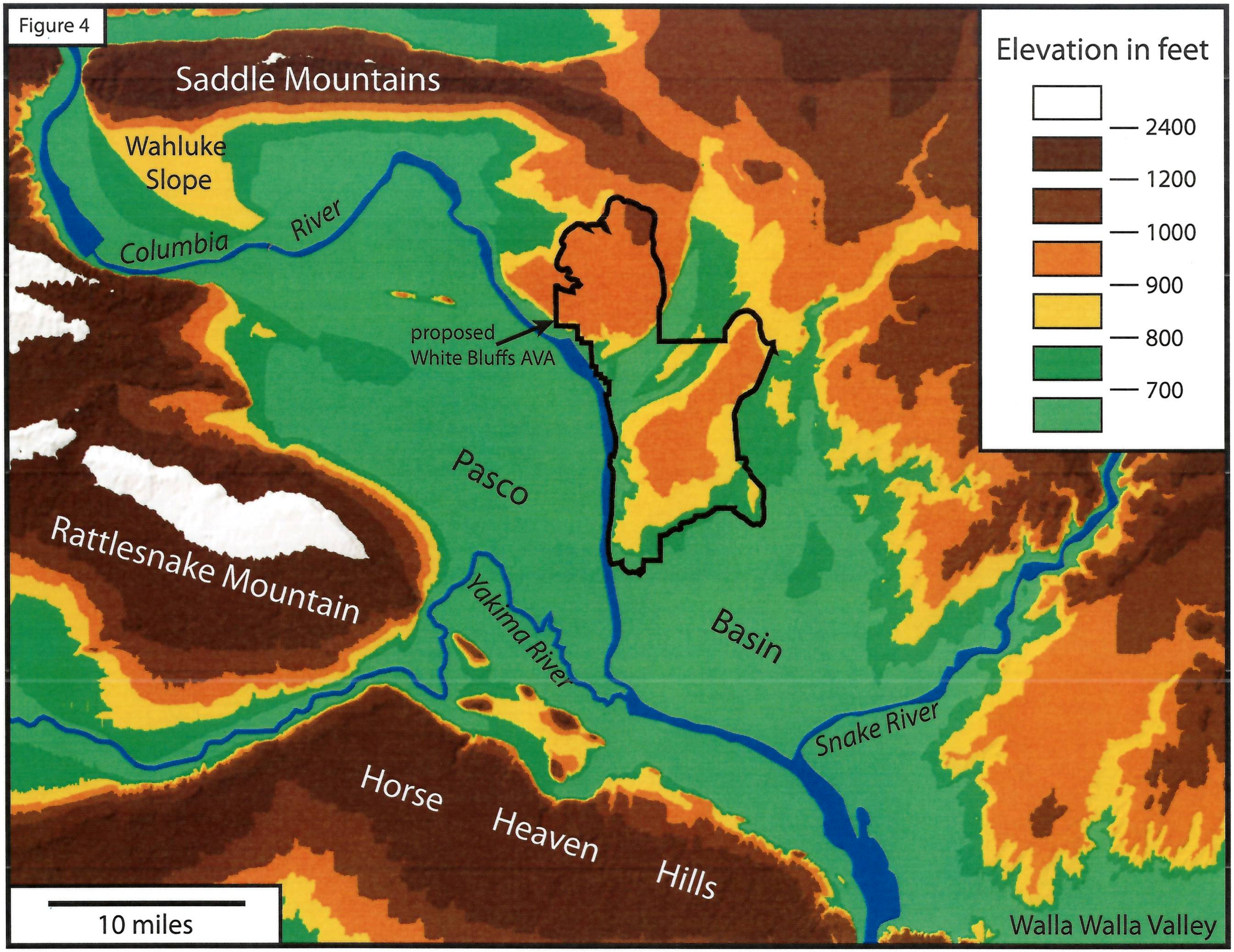


Figure 4
Elevation in feet
2400
1200
1000
900
800
700
Saddle Mountains
Wahluke Slope
Columbia River
proposed White Bluffs AVA
Pasco Basin
Rattlesnake Mountain
Yakima River
Snake River
Horse Heaven Hills
10 miles
Walla Walla Valley

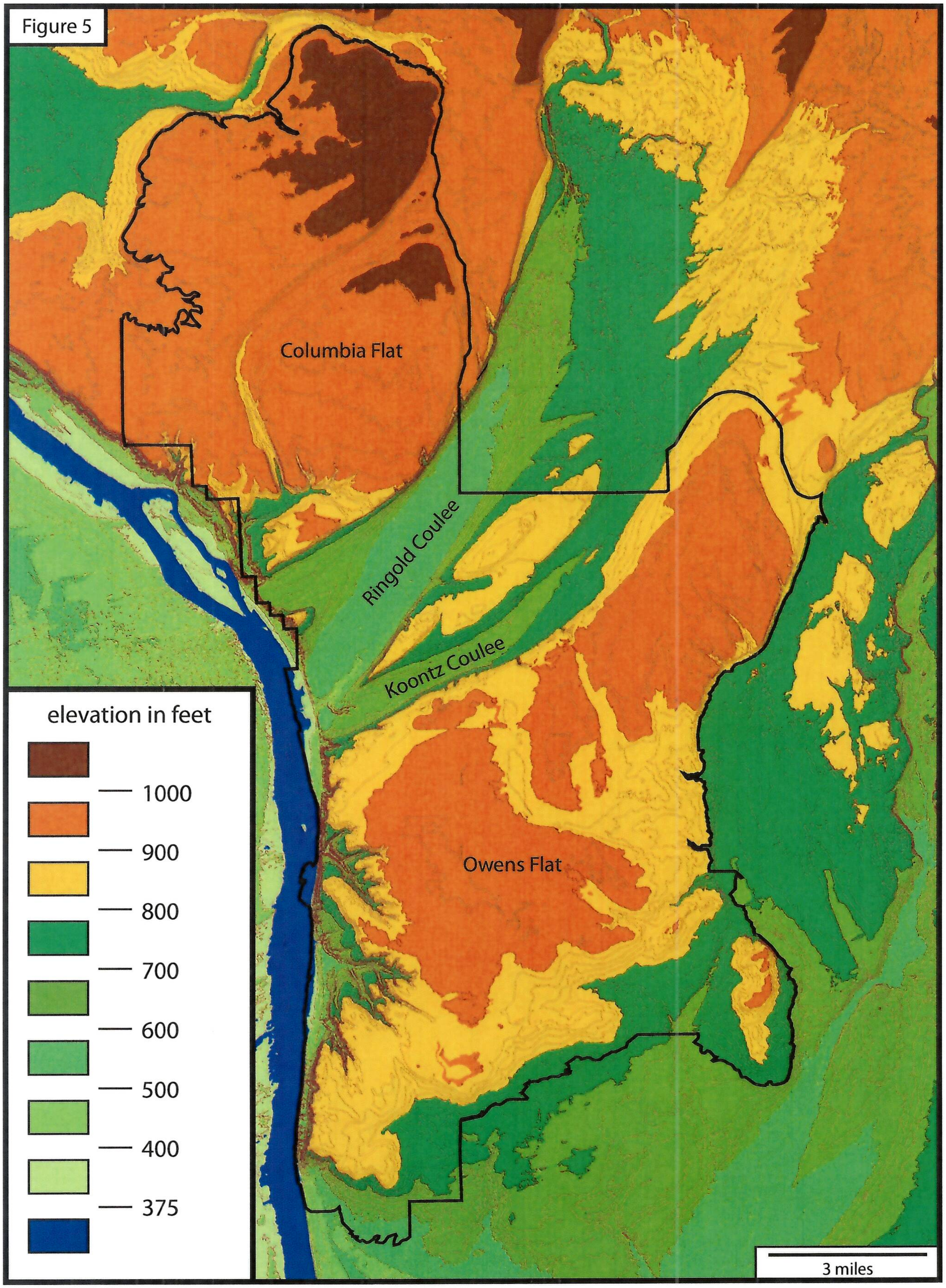


Figure 5
Columbia Flat
Ringold Coulee
Koontz Coulee
Owens Flat
elevation in feet
1000
900
800
700
600
500
400
375
3 miles

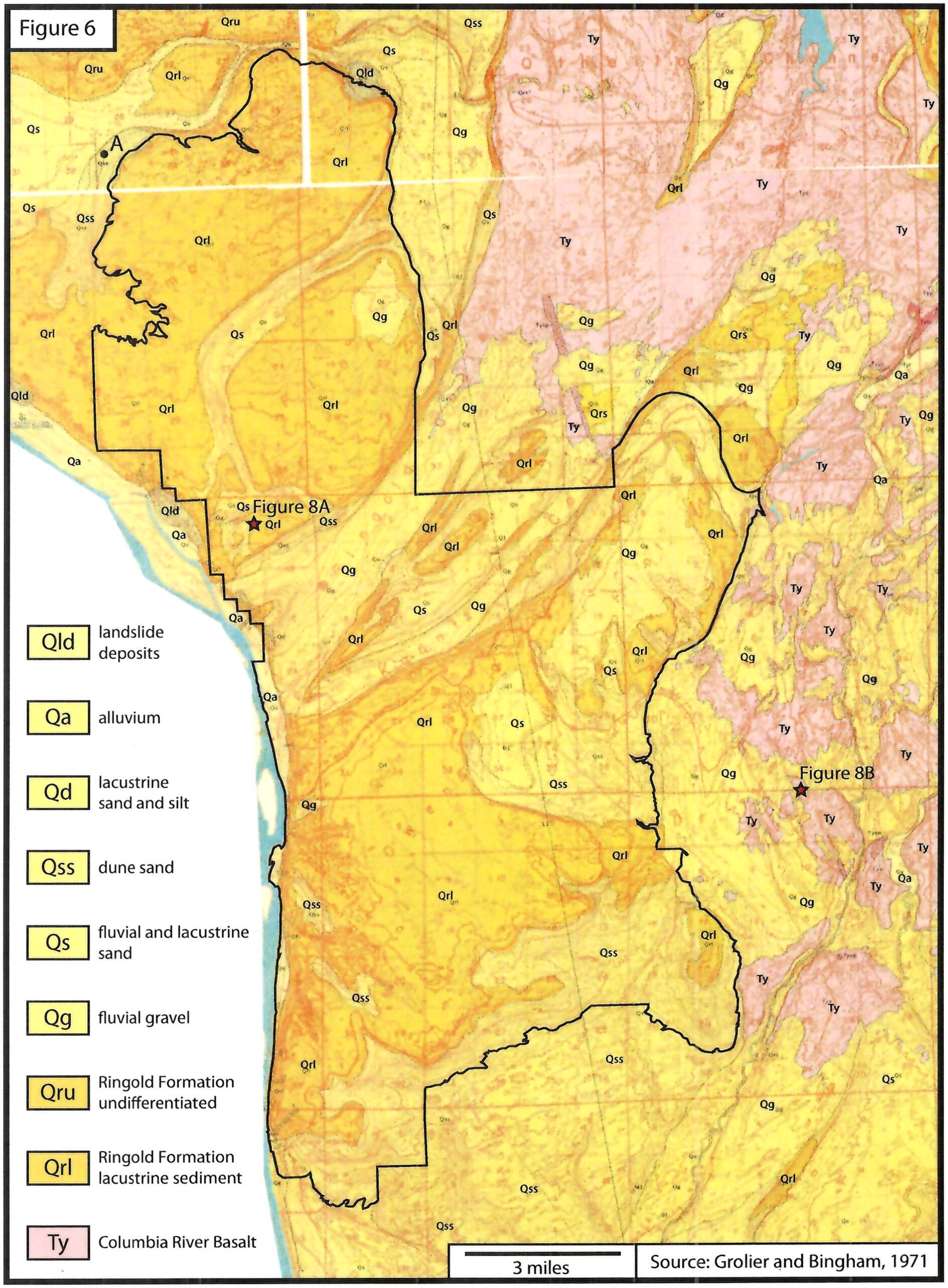
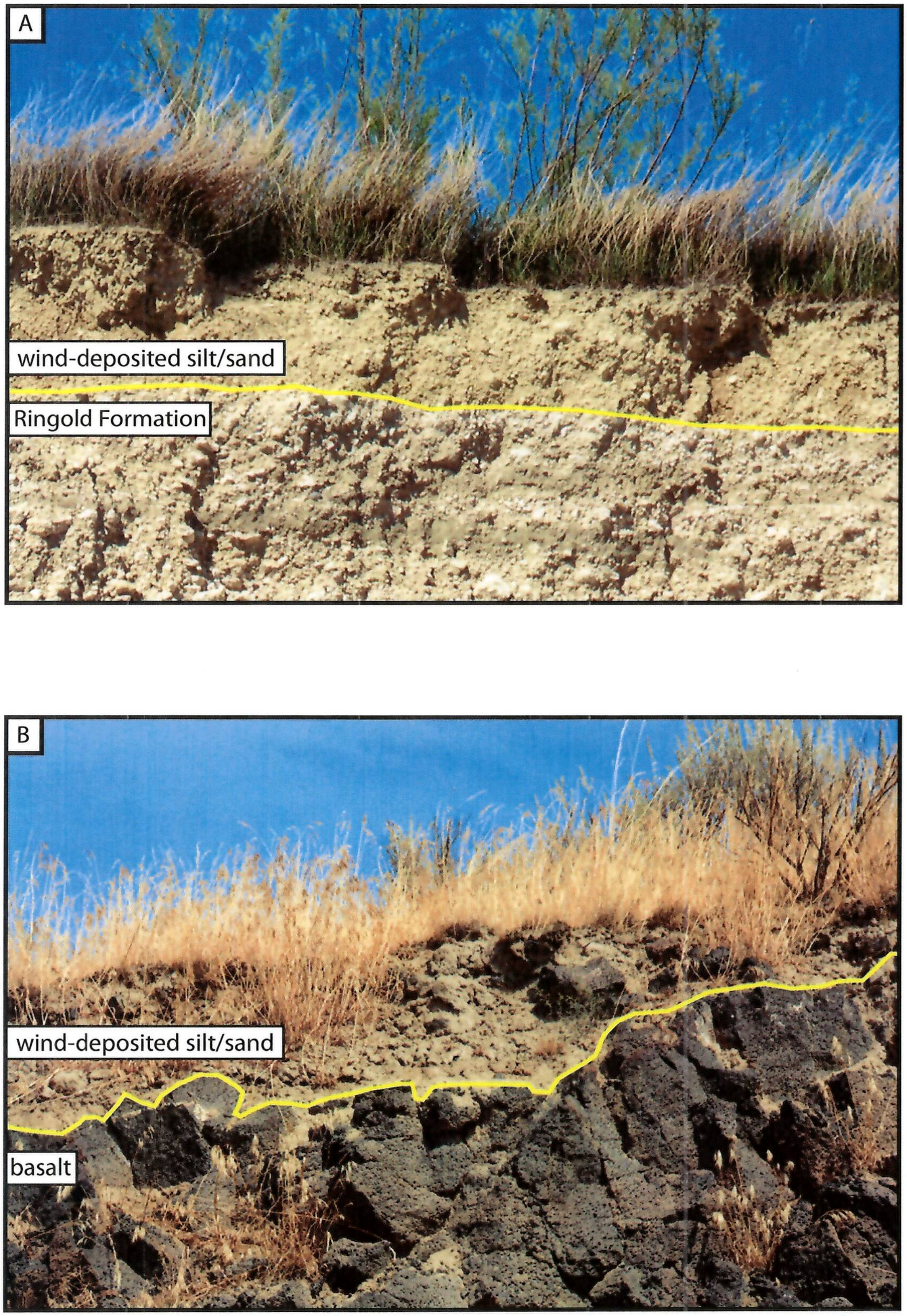


Figure 6
A
Figure 8A
Figure 8B
Qld landslide deposits
Qa alluvium
Qd lacustrine sand and silt
Qss dune sand
Qs fluvial and lacustrine sand
Qg fluvial gravel
Qru Ringold Formation undifferentiated
Qrl Ringold Formation lacustrine sediment
Ty Columbia River Basalt
3 miles
Source: Grolier and Bingham, 1971


Figure 7

Figure 8


A
wind-deposited silt/sand
Ringold Formation
B
wind-deposited silt/sand
basalt

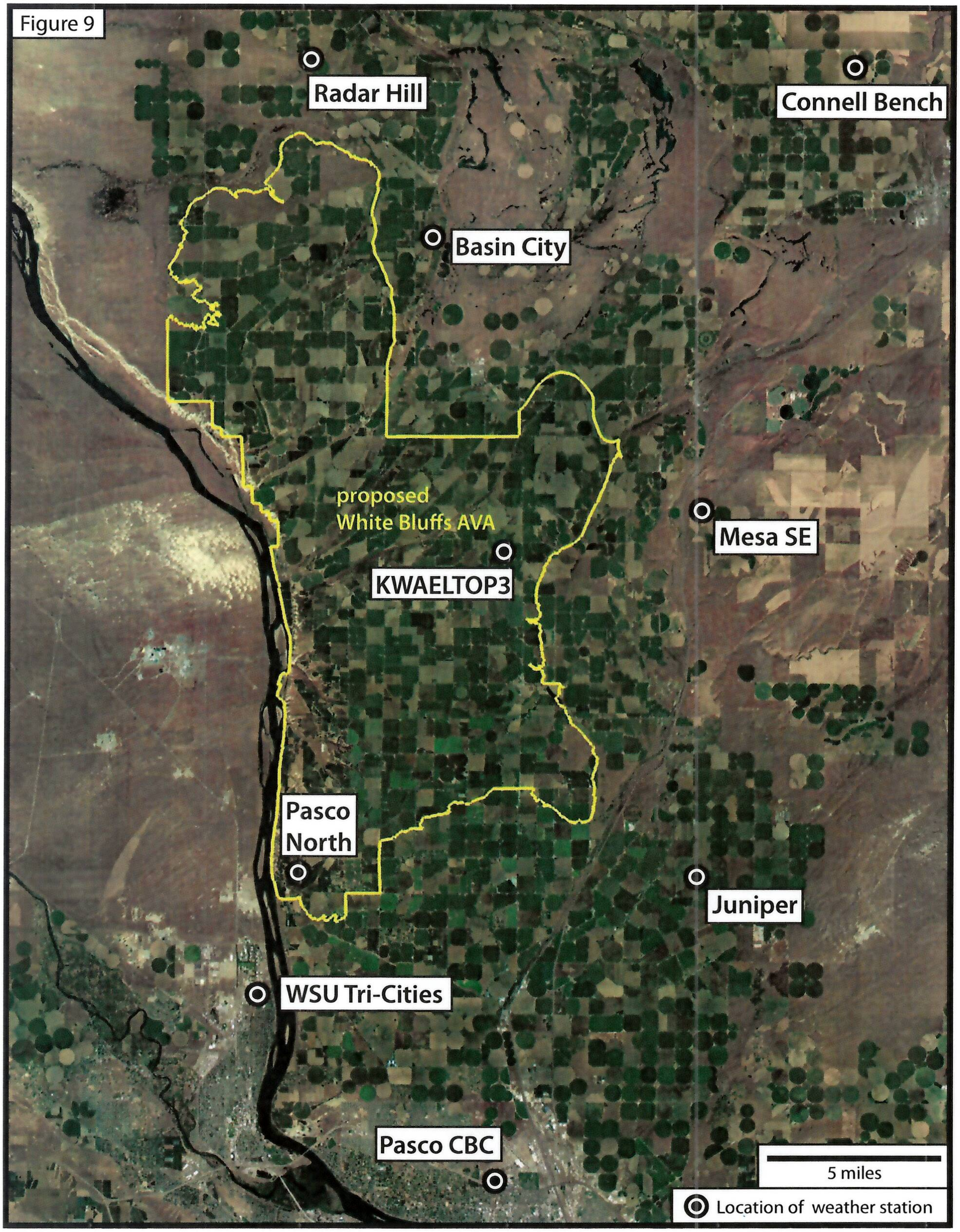


Figure 9
Radar Hill
Connell Bench
Basin City
proposed
White Bluffs AVA
Mesa SE
KWAELTOP3
Pasco
North
Juniper
WSU Tri-Cities
Pasco CBC
5 miles
Location of weather station

Figure 10

CBC Pasco	Last Frost	First Frost	Frost-free days
2016	29-Mar	17-Nov	233
2015	16-Apr	4-Nov	202
2014	14-Apr	11-Nov	211
2013	1-May	15-Oct	167
2012	7-Apr	5-Oct	181
2011	23-Apr	25-Oct	185
2010	7-May	17-Oct	163
2009	24-Apr	10-Oct	169
2008	2-May	9-Oct	160

Mesa SE	Last Frost	First Frost	Frost-free days
2016	30-Mar	11-Oct	195
2015	7-May	25-Oct	171
2014	19-Apr	8-Nov	203
2013	2-May	4-Oct	155
2012	12-May	5-Oct	146
2011	4-May	25-Oct	174
2010	9-May	13-Oct	157
2009	24-Apr	3-Oct	162
2008	2-May	9-Oct	160

Pasco North	Last Frost	First Frost	Frost-free days
2016	18-Mar	18-Nov	245
2015	4-Mar	20-Nov	261
2014	3-Mar	11-Nov	253
2013	24-Mar	29-Oct	219
2012	7-Apr	10-Nov	217
2011	20-Apr	2-Nov	196
2010	10-Mar	20-Nov	255
2009	26-Mar	10-Oct	198
2008	21-Apr	24-Nov	217

Connell Bencl	Last Frost	First Frost	Frost-free days
2016	25-Apr	12-Oct	170
2015	6-May	3-Nov	181
2014	14-Apr	8-Nov	208
2013	1-May	4-Oct	156
2012	11-May	5-Oct	147
2011	17-May	25-Oct	161
2010	24-May	16-Oct	145
2009	26-Apr	3-Oct	160
2008	9-May	9-Oct	153

Radar Hill	Last Frost	First Frost	Frost-free days
2016	28-Mar	16-Nov	233
2015	15-Apr	4-Nov	203
2014	22-Mar	2-Nov	225
2013	16-Apr	29-Oct	196
2012	7-Apr	9-Nov	216
2011	29-Apr	26-Oct	180
2010	4-May	8-Nov	188
2009	24-Apr	30-Sep	159
2008	1-May	12-Oct	164

Basin City	Last Frost	First Frost	Frost-free days
2016	16-Mar	17-Nov	246
2015	5-Mar	4-Nov	244
2014	22-Mar	11-Nov	234
2013	1-May	29-Oct	181
2012	7-Apr	8-Nov	215
2011	19-Apr	25-Oct	189
2010	9-Apr	18-Oct	192
2009	24-Apr	10-Oct	169
2008	21-Apr	12-Oct	174

Juniper	Last Frost	First Frost	Frost-free days
2016	29-Mar	12-Oct	197
2015	26-Apr	4-Nov	192
2014	14-Apr	8-Nov	208
2013	1-May	15-Oct	167
2012	7-Apr	5-Oct	181
2011	4-May	25-Oct	174
2010	6-May	17-Oct	164
2009	24-Apr	10-Oct	169
2008	NA	9-Oct	NA

WSU Tri-Citie:	Last Frost	First Frost	Frost-free days
2016	29-Mar	17-Nov	233
2015	15-Apr	4-Nov	203
2014	14-Apr	11-Nov	211
2013	1-May	29-Oct	181
2012	13-Apr	6-Oct	176
2011	24-Apr	25-Oct	184
2010	10-Apr	17-Oct	190
2009	24-Apr	11-Oct	170
2008	26-Apr	12-Oct	169

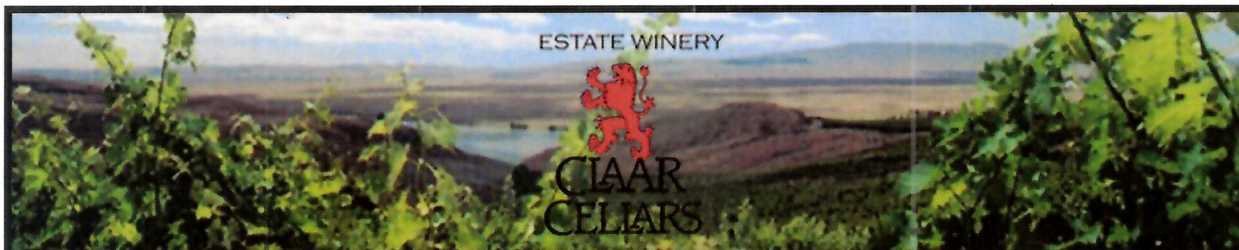
KWAELTOP3	Last Frost	First Frost	Frost-free days
2016	18-Mar	18-Nov	245
2015	5-Mar	20-Nov	260
2014	22-Mar	11-Nov	234

3 year avg	Last Frost	First Frost	Frost-free days
Pasco North	8-Mar	8-Nov	253
KWAELTOP3	15-Mar	16-Nov	246
Average	12-Mar	12-Nov	250
Basin City	14-Mar	11-Nov	241
Radar Hill	13-Apr	7-Nov	220
WSU Tri-Cities	9-Apr	11-Nov	216
CBC Pasco	9-Apr	11-Nov	216
Juniper	13-Apr	29-Oct	199
Mesa SE	18-Apr	22-Oct	190
Connell Bench	25-Apr	28-Oct	186
Average	10-Apr	4-Nov	210

9 year avg	Last Frost	First Frost	Frost-free days
Pasco North	21-Mar	8-Nov	229
Basin City	4-Apr	28-Oct	204
Radar Hill	15-Apr	28-Oct	196
WSU Tri-Cities	17-Apr	25-Oct	191
CBC Pasco	18-Apr	22-Oct	186
Juniper*	19-Apr	17-Oct	181
Mesa SE	26-Apr	14-Oct	169
Connell Bench	2-May	15-Oct	164
Average	19-Apr	21-Oct	184

Appendix 1

Appendix 1



Home | Our Family of Wines | Wine Club | Winery | Blog | Contact Us | Trade

Our Story

CLAAR CELLARS is our family owned Estate Winery. My parents, Audrienne and Russell Claar developed the first farm in 1950 and planted the first grapes in 1980. Bob and I were both Active Duty Naval Officers when in 1983, he retired and I transferred into the Naval Reserve. Since then we have developed over 120 acres of premium vineyards.

Our vineyards are on south and southwest facing hillsides above the Columbia River. In this distinct microclimate, located within the White Bluffs growing region, we are endowed with an almost ideal combination of climate and soil. This region receives more heat than growing areas to the west of us and avoids the more frequent frosts and killer freezes to the east. Also our south facing hillsides allow cold air to drain in the spring and collect more heat during the growing season. Our sandy, rocky soil is especially conducive to growing quality grapes and researchers have frequently stated that this region is one of the best in the state of Washington.

After 13 years of selling grapes to wineries throughout Washington, as well as from New York to Mississippi to New Mexico, and of being told of their unique taste and quality from numerous Winemakers, we decided to take the steps necessary to become an Estate Winery. With the 1997 crush we became an Estate Winery processing and bottling all of our grapes in our own 10,000 square foot facility. In 1999 we added a 4,000 square foot Temperature and Humidity controlled Barrel Building and in 2012 a 10,000 square foot case-good storage facility all of which are heated and cooled through ground water and excess heat produced by the glycol tank cooling system.

We have award-winning Premium wines including: Riesling, Cabernet Sauvignon, Merlot, Chardonnay, Sauvignon Blanc, Syrah, Sangiovese, and newly planted Pinot Gris, Viognier, Malbec and Petite Sirah. Our vineyards and winery are Sustainable with LIVE, IOBC and Salmon Safe certification.

CLAAR CELLARS -- an Estate winery committed to quality!

Crista Claar Whitelatch

https://www.claarcellars.com/Winery

Appendix 1

Vineyards and Wineries

Vineyard	Owner	Location
Bacchus and Dionysis	Sagemoor Vineyards	46.4458, -119.2403
Gamache	Sagemoor Vineyards	46.5831, -119.2029
High River	Shaw Vineyards	46.5478, -119.2665
Mirage	Premiere Columbia Properties	46.3998, -119.2333
Reed	Reed Vineyards	46.4129, -119.0876
Sagemoor	Sagemoor Vineyards	46.3741, -119.2479
White Bluffs1	Claar Wine Group	46.4759, -119.2418
White Bluffs2	Claar Wine Group	46.4580, -119.1980
Wooded Island	Wooded Island Vineyards	46.4299, -119.2494

Winery	Address
Claar Cellars	1081 Glenwood Rd, Pasco, WA 99301

Appendix 2

Why did these landslides occur here? After racing south out of Sentinel Gap, Ice Age floodwaters hit the north side of Umtanum Ridge head on (Figure 5-1). The tremendous force and momentum behind the floodwaters probably caused some run-up onto the ridge before turning east into the Pasco Basin. Floodwaters reached high onto the ridge, sweeping away all the loose material such as rubble and topsoil from the surface, leaving behind bare basalt bedrock. As with other landslides associated with the Ice Age floods, erosion likely undercut the ridge, making it unstable, especially after the sudden rise and fall of hundreds of feet of floodwater. Earthquake tremors during or soon after flooding may have also triggered landsliding.

47. White Bluffs Overlook

Features: Erosional escarpment, modern and ancient landslides, Gable Mountain Bar (No. 60)

Best Observation Points:

Automobile: Follow an unpaved road leading to an escarpment located 8 miles south of SR 24 on the Hanford Reach National Monument (see Plate 8).

Off-road trail: White Bluffs Grade Trail (see Trail Y, Chapter 7)

Elevation: 890 feet

The White Bluffs line the north and east sides of the Columbia River for about 30 miles along the Hanford Reach near Richland. The 500-foot-tall bluffs are made up of ancient river and lake deposits from the ancestral Columbia River and its tributaries. The deposits accumulated in the Pasco Basin until about 3 million years ago and are referred to as the Ringold Formation. Since then, the Columbia River and Ice Age floods have cut back down into the Ringold Formation, removing up to 600 feet of deposits and leaving behind the White Bluffs – what geologists call an erosional escarpment.

A good place to see the bluffs is the White Bluffs Overlook, located on the Wahluke Unit of the Hanford Reach National Monument (Figure 5-4). During the largest Ice Age flood, floodwaters at the overlook would have been 300 feet overhead! Looking downslope from the overlook, immediately below the bluffs, you also can see a lot of low, uneven hills called hummocky topography that are characteristic of a landslide. This landslide is much older and a different style than other, modern landslides occurring along the bluffs. This landslide likely occurred 14,000 years to 15,000 years ago, soon after one of the last Ice Age floods. Unlike modern local landslides, no water is seeping out along the slide, suggesting the water that created this prehistoric slide is no longer present. Also, judging by the rounded and weathered nature of the slump blocks (see Figure 2-31), a long time has elapsed since this slope failed. Another landslide that may be associated with the Ice Age floods can be seen across the river along the north side of Gable Mountain (No. 60) (see Figure 2-32).

Bjornstad, 2006

Appendix 2

ECOS / Species Profile for White Bluffs bladderpod (Physaria douglasii ssp. tuplashensis)

White Bluffs bladderpod (Physaria douglasii ssp. tuplashensis)

Current Range | Federal Register | Recovery | Critical Habitat | Conservation Plans | Petitions | Life History

Search for images on digitalmedia.fws.gov

Taxonomy: View taxonomy in ITIS

Listing Status: Threatened

Where Listed: WHEREVER FOUND

Current Listing Status Summary

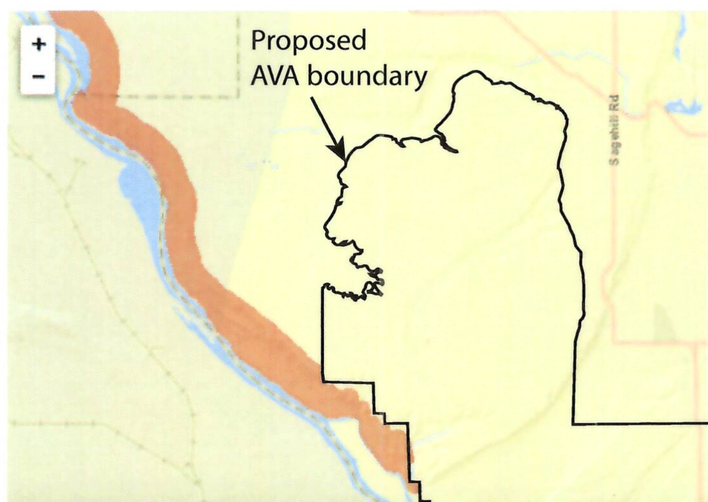
Status	Date Listed	Lead Region	Where Listed
Threatened	05/23/2013	Pacific Region (Region 1)	Wherever found

» Current Range

Population(s)

Wherever found

Zoom in! Some species' locations may be small and hard to see from a wide perspective. To narrow-in on locations, check the state and county lists (below) and then use the zoom tool.



https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=Q3HR

Appendix 2

consists, as noted by earlier writers, chiefly of light-colored muddy sandstones and sandy clays, and in minor part of fine gravels, volcanic ash and calcareous strata.

The following is an estimated section of the Ringold formation in the White Bluffs three to four miles below Hanford:

	Feet
7. Loose yellowish clayey sand (summit of section)	85
6. Gray limestone, often brecciated, irregular in thickness, forming a resistant layer	3
5. Cream-colored clayey sandstone, lacking resistance to weathering	75
4. Brownish-yellow clayey sandstone, distinctly but thickly bedded, more resistant, standing out as bluffs	75
3. Yellow sandy clay, unindurated, poorly stratified	25
2. Cream-colored clay, thinly bedded, including occasional thin layers of sandy material, giving quite prominent outcrops	25
1. Nearly white clayey sandstone, in places pure sand, with occasional thin gravel layers of polished quartz pebbles. Fossils occurring near top of this member, which extends from the Columbia River up to an elevation of about 175 feet above the river	175
Approximate thickness of section exposed above Columbia River	503

Viewed from a distance individual beds may appear quite persistent in the face of the bluffs, but the bulk of the material is not thoroughly classified as to size, and therefore not sharply stratified. The coarser materials are waterworn. Occasionally beds of coarse angular materials, chiefly basaltic in character, are found at the top of the bluffs, but these are evidently later deposits laid down in channels cut in the Ringold by water courses heading in the country to the east and north. The strata of the Ringold lack induration and are notably softer than most exposures of the Ellensburg. While they exhibit steep slopes, especially where the Columbia has recently cut into the base of the bluffs, exposures tend to assume rounded outlines and a subdued topography, even under the prevalent conditions of semi-aridity.

Physiography and Structure.—Direct observations on the structure of the Ringold were limited to the White Bluffs exposures, but certain inferences as to the attitude of these beds in other parts of the area seem possible from physiographic considerations. So far as could be judged, the strata in the White Bluffs lie parallel to the water surface of the Columbia River. All recognized cases of apparent deformation seem to be due to landslide.

The White Bluffs follow the river closely from a point ten or twelve miles north of Pasco to the northwestward for about thirty

Merriam and Buwalda, 1917

Appendix 2

miles. The bluffs end at a point across the river and a short distance below the town of White Bluffs. Where the beds are not locally reduced by erosion, the crest line of the bluffs is remarkably even (pl. 13, fig. 2). Without having determined its elevation above the river at many points, the crest appears to maintain its height of about five hundred feet above the stream throughout the whole thirty miles.

Between the northwestern end of the White Bluffs and Priest Rapids, a distance of fifteen to eighteen miles upstream, no high bluffs occur, but low light-colored exposures appear some distance from the river. The dissected character of this area indicates that it has suffered marked degradation in contrast to the relatively undissected areas lying to the east of the Columbia in the Ringold region. The more marked dissection has probably resulted from the greater drainage derived from the Saddle Mountains to the north.

The White Bluffs, extending along the east side of the Columbia River, have no counterpart in similar features on the opposite side of the stream. To the west of Hanford is an area with a rolling topography, on which occur occasional outcrops of soft beds similar to those in the White Bluffs. This area extends westward to the base of the Yakima Range and has a maximum width of perhaps sixteen miles. Practically all of it lies at less elevation above the Columbia than the top of the White Bluffs. It is believed that the Ringold once extended over this region of low hills between Hanford and the base of the Yakima Range, and that it was largely cut away by the Columbia before it had shifted eastward to its present position, and while its channel lay at a higher level. It has been this gradual shifting eastward, continued to the present time, which has produced the White Bluffs on the east side of the Columbia, in contrast to the degraded character of the area on the west side. The cause of the shifting cannot be stated with certainty, but it is probably due in part to deflection of the stream by the north side of the Yakima Range.

The surface extending several miles to the eastward from the summit of the White Bluffs is remarkably even, excepting where interrupted by occasional drainage courses which have cut below its level. The marked evenness and approximate horizontality of this surface as viewed from the summit of the bluffs, and the apparent absence of residual hills upon it, suggest immediately that it is a surface of aggradation rather than one of erosion or of river planation. Its striking parallelism, so far as the unaided eye may judge,

Merriam and Buwalda, 1917

Appendix 2

with the strata of the Ringold in the face of the White Bluffs, strengthens this idea. Unfortunately extensive observations have not been made on the structure of the Ringold over more than a small portion of the area in which it is exposed, so that it cannot be stated with certainty that upturning and bevelling have not occurred in some of its marginal areas.

Mode of Deposition.—The available data indicate that the Ringold formation was deposited in a basin the walls of which were essentially the Yakima Range on the west, the Saddle Mountains on the north, and the lava plateaus on the east and south. It is probable that the flat area extending east from the White Bluffs and lying about five hundred feet above the Columbia is to be regarded as an undissected remnant of the aggradational surface developed at the close of the period of deposition, and indicates the elevation to which the basin was filled.

The Columbia cuts through high ranges like the Saddle Mountains instead of flowing around them, and is an antecedent stream in this part of its course; in pre-Ringold time its channel therefore lay across the area now occupied by these sediments. The presence of the Columbia in this region at the time the sediments were laid down, and the similarity of the sediments to those transported by the stream at the present day, make it probable that the Columbia deposited this formation. Whether the strata were laid down in a lake formed in the course of the stream, or as flood plain deposits, is not certain, as the limited time spent in the area did not permit an examination of the peripheral areas to determine the presence or absence of such evidence as beaches, bars, and other lacrustal features. The muddiness of the Ringold sandstones and the sandiness of the clays are, however, to be contrasted with the cleaner strata usually produced by the efficient classifying agencies of lacustral waters. The apparent scarcity or absence of freshwater molluscan remains, usually quite common in lacustral beds, and the presence at different localities of scattered bones of land mammals, also favor the belief that the deposits are largely of flood-plain origin.

Area.—Without having mapped its boundaries, the Ringold formation appears to the writers to occupy an area of at least 300 square miles, and may extend over 500 or 600 square miles. To the north the beds apparently reach to the lower slopes of the Saddle Mountains. Their eastward limit is not known, but it is certainly several miles to the east of the Columbia. Their southern boundary likewise has

Merriam and Buwalda, 1917

Appendix 2

White bluffs on the Columbia.—The conspicuous white bluffs along the left bank of the Columbia, beginning 12 miles above Pasco and extending 30 miles up the river, are formed by the edges of soft strata of fine, thin-bedded sand and clay with layers of pure white volcanic dust, which were deposited as horizontal sheets in Lake John Day and have not since been disturbed. This is the most typical section of John Day beds to be seen in Washington. The cliffs have a maximum height of about 600 feet, but are in general about 500 feet high. The river is still cutting away their bases at several points, and its general tendency is still to work eastward, leaving a low, sand-covered plain on its right shore. As suggested while describing Rattlesnake mountain, this remarkable eastward shifting of the Columbia may perhaps be due to a movement of the rocks to the east of Rattlesnake fault.

The character of the loose unconsolidated material forming these bluffs is shown by the following section observed near this southern end:

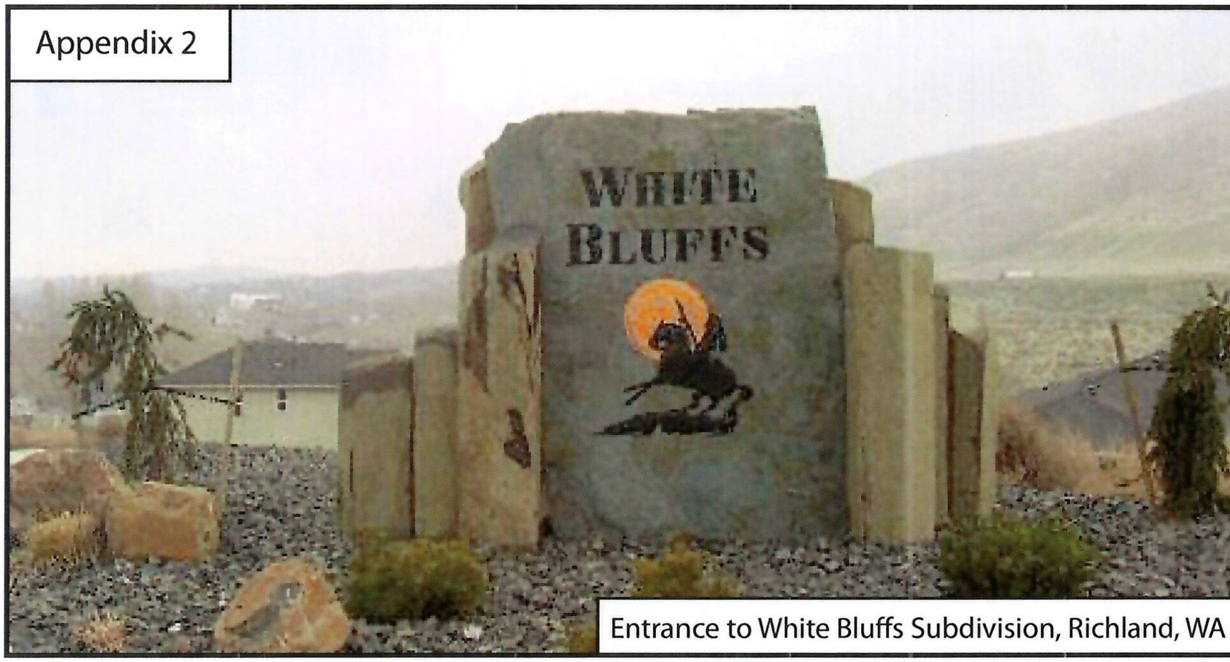
	Feet.
Light yellowish sand, loose and incoherent	20
Hard cemented layer, light yellow, "alkali"	6–10
Thin-bedded, yellowish, sandy clay, with thin yellow lines, weathering into monumental forms, passing into	100
Fine clay with volcanic dust	10
White volcanic dust[1]	20
Loose, fine yellow sand, changing to	15
Greenish clay, passing into	20
Yellowish sand, with concretions	15
Yellowish sand, compact at base, cross bedded	50
Fine, light, sandy clay	50
Pebbles, sometimes wanting	1
Light-colored, sandy clay, with large flat concretions	35
Yellow sand, passing into clay, sometimes concealed by terraces of water-worn stones, to river	150

The dividing lines between the various beds above are not sharp, the strata are conformable throughout and pass one into another by insensible gradations. The strata were formed by continuous sedimentation far from shore, and are remarkable on account of the immense amounts of volcanic dust scattered through them.

On the face of the bluffs the fossil bones of large animals have been found, but these have not been studied and their significance is not known. Similar fossils from the exposures of the same system on John Day river have been studied by Leidy, Marsh, Cope, and Bettany, and found to present a strange array of mammals, all of which are now extinct. The White bluffs afford favorable ground for collecting fossil bones and would, I think, well repay careful search.

Russell, 1892

Appendix 2



Entrance to White Bluffs Subdivision, Richland, WA

WHITE BLUFFS
ELEMENTARY SCHOOL

White Bluffs Elementary
1250 Kensington Way
Richland, WA 99352
(509) 967-6575 -phone
(509) 628-2982 -fax

YouTube 73

https://www.whitebluffselementary.com/

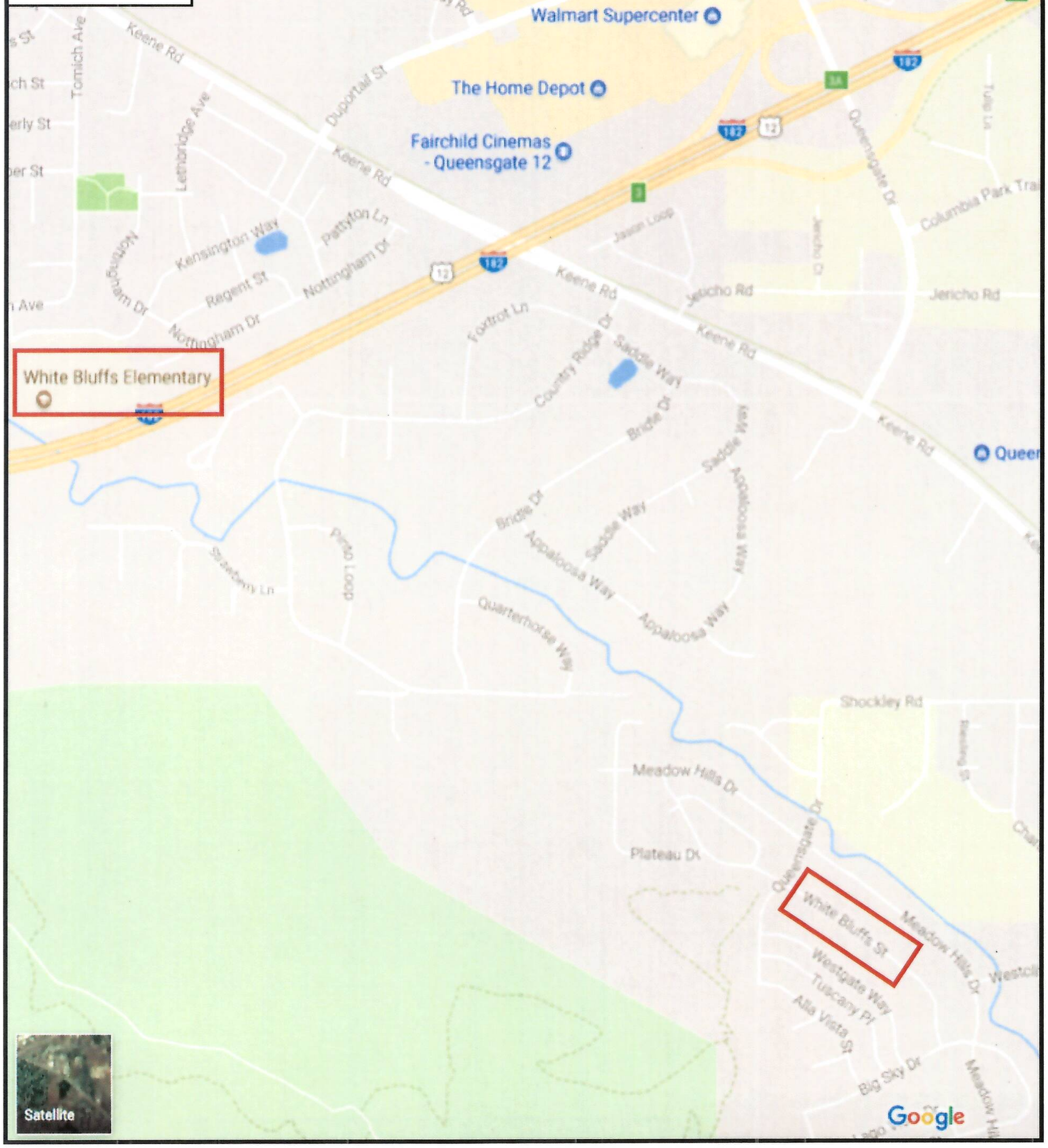
2034 Logston Blvd., Richland, WA (new address we moved) (509) 578-4558

Mon-Wed: 4:00 pm – 8:00 pm | Thurs-Fri: 4:00 pm – 9:00 pm | Sat: 12:00 pm – 8:00 pm MUST BE 21 TO VIST OUR TAP ROOM

WHITE BLUFFS
BREWING

http://www.whitebluffsbrewing.com

Appendix 2



Google Maps image of part of Richland, WA showing location of White Bluffs Elementary school and White Bluffs St.

Appendix 2

White Bluffs Quilt Museum

to preserve and teach...

294 Torbett Street
Richland, WA 99354
(509) 943-2552

Hours **How to Help** **Membership Information** **Contact Us** **Calendar**

Welcome to the White Bluffs Quilt Museum.
Our next exhibit: "It's all about Flowers"

The White Bluffs Quilt Museum presents it's latest exhibit, "It's all about Flowers". This selection of "Flower themed" quilts includes selections from the museum's permanent collection.

~~~

"Preserving Your Textiles" - Flood Damaged Textiles

To our sister communities affected by flood waters,
we have posted information on preserving and properly cleaning
your flood damaged textiles. This includes quilts and all other treasured textile items.

~~~

September - Gotta Have It! and Pop-up Patchwork Sale

White Bluffs Quilt Museum will sponsor a "mini" Stash Sale on September 23rd.
And... *Friday, September 22 and again on Saturday,September 23*
we will sponsor another..."Pop-up Patchwork" Quilt Sale.

~~~

The **White Bluffs Quilt Museum** is a Regional Textile Arts Center, serving the Tri-Cities and the Mid-Columbia Basin. The Center serves both as a museum and a support organization for the Quilting, Spinning, Weaving and Basketry Guilds of Eastern Washington. These groups have been a part of this community for over 40 years and represent over 1,000 fiber artists.

Thanks to the generosity of the Benton County Commissioners, the Center received funding to lease a store front in 2007. In May of 2012, we moved to a larger location in downtown Richland. This location provides space for classes, meetings, and an area dedicated to our museum, gallery and member textile marketplace. All classes and events are held at this facility.

The **White Bluffs** goal is to acquire a facility that will serve as a Textile Arts Center for this Region. Our mission is to promote and celebrate the art and craft of quilting and textile arts as American art forms; and to enhance our community by providing a welcoming place where people

http://www.whitebluffscenter.org/
~~~

Appendix 2

WASHINGTON STATE WINE

MENU

...ATE WINERY

CLAAR CELLARS

White Bluffs Vineyard

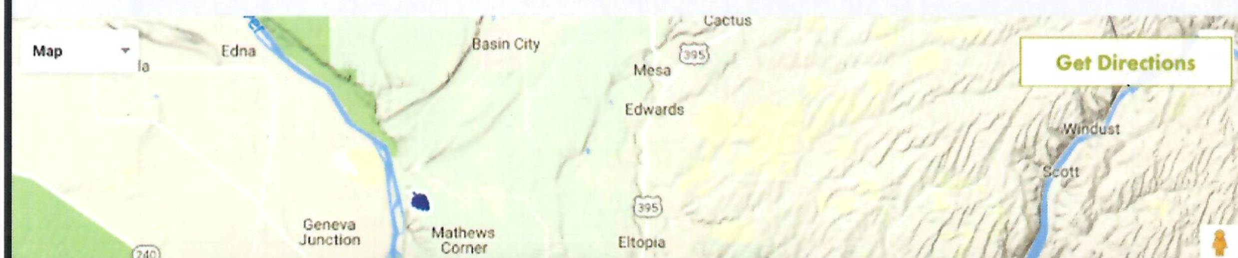
CLOSED TO THE PUBLIC

The Claar Cellars vineyards and winery are located north of Pasco, WA in the White Bluffs area of the Columbia Valley Appellation.

WEATHER

Sunny 67°F

Washington State Climate Map



https://www.washingtonwine.org/vineyards/white-bluffs-vineyard/

Appendix 3

Appendix 3

(1987), and Smith (1988). In the remainder of this paper all rivers referred to are the Late Neogene ancestral predecessors of the modern rivers, unless otherwise stated.

Throughout the middle Miocene (prior to Ringold deposition) the Columbia River flowed from north to south along the western margin of the Columbia Basin adjacent to volcanic terranes that predate the modern Cascade volcanic arc (Warren, 1941; Baker and others, 1987; Fecht and others, 1987; Smith, 1988). Throughout the rest of this paper this volcanic terrane is informally referred to as the ancestral Cascades. At the same time the Salmon-Clearwater and Palouse Rivers flowed to the west down the sloping paleosurface referred to as the Palouse Slope (Fecht and others, 1987). The Yakima River generally flowed into the southwestern corner of the Columbia Basin. The Snake River did not begin to flow into the central Columbia Basin until the latest Pliocene or early Pleistocene (Baker and others, 1987). Prior to this the Snake River may have entered the Columbia River system to the south, in the western Umatilla Basin (Lindsey and others, 1993, 1996; Tolan and others, 1996).

Prior to 14.5 Ma the position of the Columbia River was controlled by the west-dipping paleoslope of the Columbia Basin and west-flowing flood basalts (Fecht and others, 1987). As flood basalt volcanism decreased in intensity (during Saddle Mountains time, 14.5 to 6.5 Ma), continued uplift in the western Columbia Basin centered on the Hog Ranch-Naneum Ridge anticline, relative to subsidence in the Pasco Basin, began to displace the Columbia River to the east (Waters, 1955; Fecht and others, 1987; Smith, 1988). Near the end of flood basalt volcanism in the late Miocene (approximately 8.5 Ma) the Columbia River began to encroach on the central Pasco Basin, and Ringold deposition began.

THE RINGOLD FORMATION

Suprabasalt terrigenous clastic sediments assigned to the Ringold Formation (and correlative Snipes Mountain Conglomerate) are present throughout much of the south-central Columbia Basin (Waters, 1955; Schmincke, 1964; Newcomb and others, 1972; Grolier and Bingham, 1978; Myers, Price, and others, 1979; Tallman and others, 1979, 1981; Fecht and others, 1987; Smith and others, 1989). Regionally, the Ringold Formation consists of interbedded, unconsolidated to cemented clay, silt, sand, and granule to cobble gravel (Newcomb, 1958; Newcomb and others, 1972; Fecht and others, 1987; Smith and others, 1989; Lindsey and Gaylord, 1990; Reidel and others, 1994). Exposures of the Ringold Formation are present in: (1) the White Bluffs adjacent to the Columbia River (Fig. 4), (2) on Eureka Flat north of Wallula Gap, (3) in the Quincy and Othello Basins north of the Saddle Mountains, and (4) on benches and slopes adjacent to basalt uplifts such as Rattlesnake Mountain, the Saddle Mountains, and the Frenchman Hills (Figs. 1 and 3). At and near the Hanford Site the Ringold Formation is largely restricted to the subsurface, and outcrops are limited to the flanks of anticlinal ridges, the White Bluffs, and Eureka Flat (Figs. 1 and 4).

Previous Studies

All post-Columbia River Basalt sediments (including strata now assigned to the Ringold) in the central Columbia Basin and in the adjacent Washington Cascades were originally assigned to the Ellensburg Formation by Smith (1901). Smith's stratigraphy was later modified by Merriam and Buwalda

Figure 4 (facing page). Generalized surficial geologic map of the Pasco Basin. Ringold outcrops are shown in the black and white mottled pattern. The White Bluffs are found where this pattern is present adjacent to the Columbia River. Significant Ringold outcrops are not present on the Hanford Site (from Reidel and others, 1992).

Lindsey (1996)

Appendix 3

STRATIGRAPHIC FEATURES OF THE RINGOLD FORMATION

Character and Extent of the Strata in the Type Locality

The Ringold formation in the southern part of its type locality consists of two main lithologic units: the conglomerate member having an exposed thickness of about 115 feet, and an overlying unit of fine-grained sediments about 505 feet in thickness. This upper unit of fine-grained deposits consists mostly of beds of coherent silt, sand, gravel, clay, and volcanic ash. The most prevalent type of material is a weak siltstone containing some interbedded layers of fine sand. Layers of semicompact fine sand make up large sections of the bluffs. The thickness of the individual beds of sand and silt ranges from less than an inch to 10 feet or more. The ash layers range from mere laminar partings to beds 3 or 4 feet thick.

Few of the thin beds extend laterally more than 400 or 500 feet, but some of the thick layers are continuous for several miles. Also, some of the gross layers, in which much the same type of material has a thickness of many tens of feet, can be followed horizontally for miles along the bluffs. That extensive character is especially apparent in the more coherent materials, such as the main conglomerate layer and some of the compact silt layers. The main conglomerate layer extends both above and below river level, in the general altitude range of 290 to 455 feet, along the southern part of the White Bluffs, but only the upper 115 feet has heretofore been included in the Ringold formation.

As previously noted by Culver (1937, p. 60) and other workers, the uppermost part of the Ringold formation in the White Bluffs is heavily calcified and silicified to a depth of at least 15 feet. This calcified and silicified caprock is commonly called "caliche," though it lacks the nitrate constituents inherent in true caliche. The indurated caliche underlies the 900- to 1,000-foot plateau that extends east and north from the White Bluffs. The caliche forms a resistant caprock to the section exposed in the White Bluffs, but is absent beneath the surfaces cut in the Ringold by glacial melt water during the Wisconsin glacial stage and by post-glacial erosion.

The Ringold formation contains the fossilized bones of many types of vertebrate animals and some scattered carbonized wood and other plant matter. On the basis of the vertebrate fossils, the age of the beds was determined as Pleistocene by Merriam and Buwalda (1917), and the fossils were further determined as of middle to late Pleistocene age by Jean Hough (Strand and Hough, 1952).

Material similar in lithology to the type Ringold formation extends downward to the basalt bedrock—or to a thin transitional deposit that may be a pre-Ringold weathering, or soil, zone at the top of the basalt. Although no paleontologic evidence has been secured to prove the material below river level as an extension of the type Ringold formation, the lithologic similarity and the stratigraphic continuity of those "below-river-level beds" are believed to establish them definitely as a downward extension of the Ringold formation of the type locality.

Newcomb (1958)

Appendix 3

open joints and crossflow openings. Below the water table, movement of water through the interflow zones of the basalt is in response to a pressure gradient and, under similar conditions, can take place as readily in horizontal as in tilted aquifers.

The forces of deformation produced excessive strain on some of the basalt and developed planes of shear. Whether the deformation is in the form of tight folding with interflow slippage or solely in the form of shear rupture and fault displacement, gouging and grinding of the rock generally reduces its permeability at the shear planes. These zones of crushed rock can be barriers to ground-water movement. Such barriers cause the damming of ground water and, in some areas, may confine ground water so that it has pressure levels relatively close to the surface (Newcomb, 1961a).

The potentiometric surface of the ground water in the basalt, as known from relatively few wells beneath the reservation, is generally at about the level of the water table in the overlying Ringold Formation. Along the axial area of the Pasco syncline, the water level in the basalt is near that of the Columbia River. In the area between The Horn, on the Yakima River, and the Columbia River, the water level in the basalt stands near the level of the Yakima River. At well 10/28–10G1, north of Richland, the potentiometric surface is about 35 feet above the water table, which is at about the level of the nearby Columbia River. The basalt in the eastward-plunging synclines of upper Cold Creek and Dry Creek valleys, in and west of the reservation, contains confined ground water, apparently confined behind structural barriers that cross the lower ends of the valleys.

Wells drilled to a general depth of 600 to 1,000 feet in upper Cold Creek valley (well 13/25–30G1 in table 1), at West Richland (9/28–5C1), and at old Ringold (12/28–24N1) obtain confined water with yields of about 1,000 gpm (gallons per minute). The potential water yields of the basalt have not been tested in large areas of the synclinal structure beneath the reservation.

RINGOLD FORMATION

A slight warping type of deformation characterizes the conglomerate zone and the subconglomerate part of the Ringold Formation in the basinal area beneath the reservation. This warping elevated the conglomerate about 100 feet higher beneath the high terraces than along the axis of the Pasco syncline. This uplift, along with the subsequent erosion and the deposition of the glaciofluviatile and fluviatile deposits, gave the reservation its gravelly terrain and created the excellet drainage conditions of the high terraces.

PHYSIOGRAPHY

A résumé of the geologic features at the surface clarifies their origin and method of formation and should help in the proper and efficient use of the topography as well as the subsurface materials. The constructional features, such as mountain slopes, plateau surfaces, terraces, and valley plains, along with the destructive or erosional features, such as river bluffs, canyons, landslides, declivities, and blowouts, are the result of geological events that have formed this industrial site.

MOUNTAIN SLOPES

Despite minor subsequent erosion, many of the mountain slopes in and to the west and south of the reservation represent the basalt surfaces much like they were when they were more nearly horizontal. The southwest slopes of Rattlesnake Mountain, the apronlike slope descending from an altitude of 1,200 feet on that mountain to the Cold Creek valley, the broad ridge southwest of The Horn (on the Yakima River), and many lesser surfaces are largely dip slopes on the top of a resistant basalt flow. In many such places the top layer may be one that formed at the original top of the basalt accumulation. Other mountain surfaces, such as the top of Red Mountain and the crests of the dome-shaped mountains north of Dry Creek valley, are now subaerial erosion surfaces beveled across many basalt flows and interflow layers.

The whole north slope of Rattlesnake Mountain and smaller areas on other mountain slopes, such as those on the north side of Gable Mountain and on Umtanum Ridge west of the area shown on plate 1, consist of rock debris that has slumped and slid to its present position. Many of the lower slopes of the mountains have been mantled by alluvial wash from the higher parts and by materials transported from elsewhere. The north and east slopes of most of the ravines, hills, and mountains have a heavier cover of windblown soil than do the south and west, the wind-struck, slopes.

PLATEAUS

The principal plateau feature of the area is the upland surface at an altitude of about 1,000 feet that extends east and north (beyond the area of pl. 1) from the top of The White Bluffs. This surface is underlain by a thin layer of windblown soil and by erratic glaciofluviatile materials, but it is largely founded on the strong caliche zone at the top of the Ringold strata. To the north and east of The White Bluffs, this plateau extends for many tens of

Newcomb et al. (1972)