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Rattlesnake Hills structures (Class A) No. 565

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Synopsis	The Rattlesnake Hills structures form part of several regional-scale northwest-trending lineaments, including the Cle Elum-Wallula deformed zone (CLEW), the Rattlesnake-Wallula trend, alignment, or lineament (RAW), and the Olympic-Wallowa lineament (OWL), in the southeastern part of the Yakima fold belt of south-central Washington. These structures are primarily expressed as a series of anticline segments that are cut and underlain by south- to southwest-dipping thrust or reverse faults in rocks of the Miocene Columbia River Basalt Group. The anticline segments that characterize the southeastern part of the Rattlesnake Hills uplift are en echelon double-plunging anticlines (brachyanticlines). The faults are buried by Quaternary loess, landslide, and glacial outburst flood deposits along much of their length. Quaternary age growth or tightening of other folds in the Yakima fold belt, and perhaps of the Rattlesnake Hills folds, has been suggested and inferred from several local and regional geologic relations in the Yakima fold belt (Campbell and Bentley, 1981 #3513; Reidel, 1984 #5545; Reidel and others, 1994 #3539). Contemporaneous

	contraction across the region suggests that the Yakima folds are favorably oriented in the current strain field and accommodate the strain through active folding and possibly faulting (Pratt, 2012 #7397; Bjornstad and others, 2012 #7394 citing unpublished Zachariasen and others, 2006). As summarized by Bjornstad and others (2012 #7394), global positioning system (GPS) "data indicate relatively low (<1 mm/yr) but non-zero convergence across the Yakima fold belt…. In general, these rates are higher than those calculated on Quaternary faults." Based on the growing consensus that the Frenchman Hills folds are cored by buried Quaternary fault, the faults are reassigned to Class A as opposed to the prior Class B classification.
Name comments	Structures associated with the Rattlesnake Hills extend northwest for about 60 km, from near Wallula Gap at the Columbia River to Rattlesnake Mountain in southeastern Washington; from Rattlesnake Mountain, these structures continue west-northwest about another 60 km to near Union Gap and Moxee City along the Yakima River. These structures are shown on 1:100,000- and 1:250,000-scale geologic maps of this region (Schuster, 1994 #4653; Reidel and Fecht, 1994 #4657; Schuster, 1994 #5566; Schuster and others, 1997 #3760). These structures are also included in several regional-scale lineaments, including the Cle Elum-Wallula deformed zone (CLEW), the Rattlesnake-Wallula trend, alignment, or lineament (RAW), and the Olympic-Wallowa lineament (OWL) (Reidel and others, 1994 #3539). Named structures include the Rattlesnake Mountain fault and anticline, and the Rattlesnake Hills fault, anticline, and structure (Newcomb, 1970 #3761; Shannon and Wilson Inc., 1977 #4661; Farooqui, 1977 #4663). **Fault ID:** These structures are included in fault number 77 of Geomatrix Consultants, Inc. (1995 #3593).
County(s) and State(s)	BENTON COUNTY, WASHINGTON YAKIMA COUNTY, WASHINGTON
Physiographic province(s)	COLUMBIA PLATEAU
Reliability of location	Good Compiled at 1:100,000 scale. *Comments:* Location of fault from GER_Seismogenic_WGS84 (http://www.dnr.wa.gov/publications/ger_portal_seismogenic_features.zip, downloaded 05/23/2016) attributed to 1:100,000-scale geologic maps (Reidel and Fecht, 1994 #4657; Schuster, 1994 #4653, 1994 #5566).

Geologic setting	The Rattlesnake Hills, Rattlesnake Mountain, and "the Rattles" appear to define parts of a single anticlinal-ridge uplift that shows a dog-leg form in map view. This anticlinal-ridge uplift lies in the central to southeast part of the Yakima fold belt, a structural-tectonic sub province of the western Columbia Plateaus Province (Reidel and others, 1989 #5553; 1994 #3539). The Yakima fold belt consists of a series of generally east-trending narrow asymmetrical anticlinal ridges and broad synclinal valleys formed by folding of Miocene Columbia River basalt flows and sediments. In most parts of the belt the folds have a north vergence with the steep limb typically faulted by imbricate thrust faults. According to Reidel and others (1989 #5553) these frontal faults are typically associated with the areas of greatest structural relief. In the few places where erosion exposes the frontal faults deeper in the cores of the anticlinal ridges the faults are seen to become steeper with depth (as steep as 45–70°). Along their lengths the anticlines are commonly broken into segments ranging between 5 and 35 km long with boundaries defined by abrupt changes in fold geometry. Anticlinal ridges of the Yakima fold belt began to grow in Miocene time (about 16–17 Ma), concurrent with eruptions of Columbia River basalt flows, and continued during Pliocene time and may have continued to the present (Reidel and others, 1989 #5553; 1994 #3539). Named and unnamed, east- and northwest-striking thrust faults cut the north and south limbs of the Rattlesnake Hills anticlinal uplift. The Rattlesnake Hills anticlinal uplift forms one of the many anticlinal ridges that comprise the Yakima fold belt in south-central Washington. The southeastern part of the Rattlesnake Hills structures form part of a prominent northwest-trending lineament, the Rattlesnake-Wallula alignment or lineament (RAW) that is primarily expressed as a series of en echelon double-plunging anticlines (brachyanticlines) (Newcomb, 1970 #3761; Farooqui, 1977 #4663; Kienle, 1977 #4664; Kienle, 1977 #4665; Swanson and others, 1980 #3574; Tolan and Reidel, 1989 #3765) underlain by southwest-dipping thrust or reverse faults (Schuster, 1994 #4653; Reidel and Fecht, 1994 #4657; Schuster and others, 1997 #3760). These northwest-striking folds and faults of the southeastern part of the Rattlesnake Hills uplift appear to link or merge with northwest-striking high-angle faults of the Wallula fault system [846] to the southeast. Relations of the Rattlesnake Hills structures to adjacent or overlapping faults of the Wallula fault system [846], however, are not clear and commonly these two northwest-trending zones of structures are referred to as the Rattlesnake-Wallula trend, alignment, or lineament (RAW) (Reidel and others, 1994 #3539). "Youthful tectonic features" were noted by Mann and Meyer (1993 #3535) along the north flank of Rattlesnake Mountain, but folds and faults of the Rattlesnake Hills uplift are only known to

	deform rocks of the Columbia River Basalt Group (Miocene).
Length (km)	107 km.
Average strike	N61°W
Sense of movement	Thrust *Comments:* The Rattlesnake Hills structures are primarily expressed as a series of anticline segments that are cut and underlain by south- to southwest-dipping thrust or reverse faults in rocks of the Miocene Columbia River Basalt Group (Schuster, 1994 #4653; Reidel and Fecht, 1994 #4657; Schuster and others, 1997 #3760). The anticline segments that characterize the southeastern part of the Rattlesnake Hills uplift are en echelon double-plunging anticlines (brachyanticlines) (Newcomb, 1970 #3761; Farooqui, 1977 #4663; Kienle, 1977 #4664; Kienle, 1977 #4665; Swanson and others, 1980 #3574; Tolan and Reidel, 1989 #3765). This en echelon pattern of these folds has led some investigators to infer either left-lateral or right-lateral strike-slip displacement on faults underlying these folds (Glass, 1977 #3792; Farooqui, 1977 #4663; Barrash and others, 1983 #4675; Mann and Meyer, 1993 #3535). Blakely and others (2014 #7406) note that the drainages outboard of the range-front fault do not line up with the mouths of the canyons incised into Rattlesnake Mountain. They suggested as much as 250 m of right-lateral offset of drainages. However, field and desktop mapping observations by Coppersmith and others (2014 #7402) and Slack and others (2014 #7686) are interpreted to suggest that the style of faulting is primarily thrust or reverse along the range-front fault and the gas field structure resulting from primarily northeast-southwest compression. Coppersmith and other's (2014 #7402) alternative interpretation for the misalignment of drainages and canyon mouths is that the drainages north of the rangefront are consequent streams eroding headward (upslope), subsequent to the last surface faulting event, and during deposition of the local fan sequence.
Dip	19-35° S. *Comments:* The faults that underlie the Rattlesnake Hills are rarely exposed; few observational dip measurements have been published. Mège and Reidel (2001 #7407) report a mean fault dip of 19-35° for the Rattle Snake Mountain thrust fault and 22-36° for the Rattlesnake Hills-Ahtanum Ridge fault based on a combination of field measurements and accessible seismic profiles. Geomatrix Consultants, Inc. (1995 #3593; 1996 #4676) used dips of 30°, 45°, and 60° in their analysis of earthquake hazards associated with the Rattlesnake Hills structures.

Paleoseismology studies	
Geomorphic expression	These structures are coincident with (and take their name from) the Rattlesnake Hills, a series of low hills underlain by resistant basalts of the Columbia River Basalt Group. The topographic high expressed by the Rattlesnake Hills is the principle geomorphic expression of the anticlinal uplift and related folds and faults of the Rattlesnake Hills structures. Structures along the southeastern part of the Rattlesnake Hills are primarily expressed as a series of en echelon double-plunging anticlines (brachyanticlines) that form isolated hills, such as Badger Mountain, Red Mountain, and Candy Mountain (Newcomb, 1970 #3761; Farooqui, 1977 #4663; Swanson and others, 1980 #3574; Tolan and Reidel, 1989 #3765). Total cumulative vertical stratigraphic separation of Quaternary deposits across both the range-front and gas field structures estimated from the reconstructed projections range from 20±3 m to 30±3 m, with an average value of approximately 25 m (Coppersmith and others 2014 #7402). Average structural relief from folding is 619 m (maximum 775 m) near Rattlesnake Mountain and 335 m (maximum 460 m) for the Rattlesnake Hills (Coppersmith and others, 2014 #7402).
Age of faulted surficial deposits	The Rattlesnake Hills structures are primarily expressed in Miocene rocks of the Columbia River Basalt Group, but are buried by Quaternary loess, landslide, and glacial outburst flood deposits along much of their length (Schuster, 1994 #4653; Reidel and Fecht, 1994 #4657; Schuster and others, 1997 #3760), and Mann and Meyer (1993 #3535) report "youthful tectonic features" along the north flank of Rattlesnake Mountain. Detailed mapping by Coppersmith and others (2014 #7402) shows four Quaternary-age alluvial fan units; the youngest two map units (estimated age of <70 ka) are not deformed. The ages of the fan deposits are not constrained by radiometric or luminescence ages, but the deformed units are inferred to be as old as 800 k.y.
Historic earthquake	
Most recent prehistoric deformation	undifferentiated Quaternary (<1.6 Ma) *Comments:* The timing of the most recent movement on this structure remains unresolved. Coppersmith and others (2014 #7402) reports Quaternary tectonic activity in the Rattlesnake Mountain study area is observed along at least two structures: the range-front fault and the gas field anticline. Late Quaternary units are not deformed by the most recent surface rupture (of the main Rattlesnake Mountian front); therefore,

	Coppersmith and others (2014 #7402) conclude faulting occurred prior to 13-70 ka. Abstract by Slack and others (2014 #7686) suggest middle Pleistocene coseismic surface deformation. Numerous earlier studies infer Quaternary displacement (Geomatrix Consultants Inc., 1995 #3593, 1996 #4676. Geomatrix Consultants, Inc. (1995 #3593) classified parts of these structures as active in the middle and late Quaternary (<780 ka). Quaternary age growth or tightening of other folds in the Yakima fold belt, and perhaps of the Rattlesnake Hills folds, has been suggested and inferred from several local and regional geologic relations in the Yakima fold belt (Campbell and Bentley, 1981 #3513; Reidel, 1984 #5545; Reidel and others, 1994 #3539)
Recurrence interval	*Comments:* Piety and others (1990 #3733) used uplift rates calculated from 11 Ma volcanic rocks to estimate recurrence intervals of 250-12,500 years based on displacement per events of 0.02-1.0 m.
Slip-rate category	Less than 0.2 mm/yr *Comments:* Coppersmith and others (2014 #7402) and Slack and others (2014 #7686) conclude that long-term and Quaternary displacement rates are comparable in the study area. Their Quaternary rate of 0.03-0.09 mm/yr is based on vertical separation (30 m, -8m, +3 m) of fan deposit estimated to be 380-800 ka; in addition, they report a more tightly constrained preferred rate of 0.04-0.06 m/k.y. (25-30 m/424-600 k.y.), which honors the best-estimated average 230Th/U-series age for the displaced cataclysmic flood deposits in the central part of the study area. Their estimate for the long-term rate of displacement is 0.06 m/k.y., which falls within the extreme estimates for Quaternary displacement. The long-term estimate is based on post- Saddle Mountains Basalt (6-10 Ma) topography of 618 m. Bjornstad and others (2012 #7394) report a similar long-term vertical rate of 72.5 m/m.y. in table 2.1 (0.0725 mm/yr). Older studies report similar long-term rates of vertical displacement. Piety and others (1990 #3733) report 885 m of uplift of 11 Ma volcanic rocks, which yield uplift rates of 0.08 mm/yr. Geomatrix Consultants, Inc. (1995 #3593) used uplift of 152-365 m of 10.5 Ma volcanic rocks to estimate slip rates of 0.02-0.07 mm/yr. Geomatrix Consultants, Inc. (1996 #4676) used uplift of 323-762 m of 10.5 Ma volcanic rocks and estimated fault dips of 30°, 45°, and 60° to estimate slip rates of 0.036-0.145 mm/yr across the Rattlesnake Hills structures. All estimates suggest low rates for possible Quaternary slip and folding along these faults and folds of the Rattlesnake Hills structural trend.
Date and	2016

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References	#4675 Barrash, W., Bond, J., and Venkatakrishnan, R., 1983, Structural evolution of the Columbia Plateau in Washington and Oregon: American Journal of Science, v. 283, p. 897-935. #7394 Bjornstad, B.N., Winsor, K., and Unwin, S.D., 2012, A summary of fault recurrence and strain rates in the vicinity of the Hanford site: Topical report prepared for the U.S. Department of Energy under contract DE-AC05-76RL01830, 90 p. #7406 Blakely, R.J., Sherrod, B.L., Weaver, C.S., Wells, R.E., and Rohay, A.C., 2014, The Wallula fault and tectonic framework of south-central Washington, as interpreted from magnetic and gravity anomalies: Tectonophysics, v. 624–625, p. 32–45, doi:10.1016/j.tecto.2013.11.006 #8537 Bruhn, R.L., 1981, Preliminary analysis of deformation in part of the Yakima fold belt—South-central Washington: unpublished report, 28 p. #3513 Campbell, N.P., and Bentley, R.D., 1981, Late Quaternary deformation of the Toppenish Ridge uplift in south-central Washington: Geology, v. 9, p. 519–524. #7402 Coppersmith, R., Hansen, K., Unruh, J., Slack, C., 2014, Structural analysis and Quaternary investigations in support of the Hanford PSHA, Appendix E *in* Coppersmith, K.J., Bommer, J.J., Hanson, K.L., Unruh, J., Coppersmith, R.T., Wolf, L., Youngs, R., Rodriguez-Marek, A., Al Atik, L., Toro, G. and Montaldo-Falero, V., Hanford sitewide probabilistic seismic hazard analysis: Richland, Washington, Pacific Northwest National Laboratory report PNNL-23361, http://www. hanford. gov/page. cfm/OfficialDocuments/HSPSHA. #4663 Farooqui, S.M., 1977, Geologic evaluation of structures in a Columbia Plateau—Subappendix 2RH, Chapter 5.0, Geologic studies—Wallula Gap to Badger Coulee: Technical report to Washington Public Power Supply System, WPPSS Nuclear Project No. 1, v. 1, 12 p. #3593 Geomatrix Consultants, Inc., 1995, Seismic design mapping, State of Oregon: Technical report to Oregon Department of Transportation, Salem, Oregon, under Contract 11688, January 1995, unpaginated, 5 pls., scale 1:1,250,000.

#4676 Geomatrix Consultants, Inc., 1996, Probabilistic seismic hazard analysis DOE Hanford site, Washington: Technical report to Westinghouse Hanford Company, Richland, Washington, under Contract WHC-SD-W236A-TI-002, Rev.1, February, 1996, 366 p.

#3792 Glass, C.E., 1977, Preliminary safety analysis report, *in* Remote sensing analysis of the Columbia Plateau, appendix 2R K: Washington Public Power Supply System Nuclear Project No. I, v. 1, p. 15, 9 pls.

#4664 Kienle, C.F., 1977, Geologic evaluation of structures in a Columbia Plateau—Subappendix 2RH, Chapter 6.0, Detailed mapping of the Bend of the Rattlesnake Hills structure: Technical report to Washington Public Power Supply System, WPPSS Nuclear Project No. 1, v. 1, 8 p.

#4665 Kienle, C.F., 1977, Geologic evaluation of structures in a Columbia Plateau—Subappendix 2RH, Chapter 7.0, Reconnaissance mapping of the Rattlesnake-Wallula lineament, Eastern Rattlesnake Hills, and Yakima Ridge: Technical report to Washington Public Power Supply System, WPPSS Nuclear Project No. 1, v. 1, 5 p.

#3535 Mann, G.M., and Meyer, C.E., 1993, Late Cenozoic structure and correlations to seismicity along the Olympic-Wallowa Lineament, northwest United States: Geological Society of America Bulletin, v. 105, p. 853–871.

#7407 Mège, D., and Reidel, S.P., 2001, A method for estimating 2D wrinkle ridge strain from application of fault displacement scaling to the Yakima folds, Washington: Geophysical Research Letters, v. 28, p. 3545–3548, doi: 10.1029/2001GL012934.

#3761 Newcomb, R.C., 1970, Tectonic structure of the main part of the basalt of the Columbia River Group Washington, Oregon, and Idaho: U.S. Geological Survey Miscellaneous Geologic Investigations I-587, 1 sheet, scale 1:500,000.

#3733 Piety, L.A., LaForge, R.C., and Foley, L.L., 1990, Seismic sources and maximum credible earthquakes for Cold Springs and McKay Dams, Umatilla Project, north-central Oregon: U.S. Bureau of Reclamation Seismotectonic Report 90-1, 62 p., 1 pl.

#7397 Pratt, T.L., 2012, Large-scale splay faults on a strike-slip fault system—The Yakima folds, Washington State: Geochemistry, Geophysics, Geosystems, v. 13, Q11004, doi: 10.1029/2012GC004405.

#5545 Reidel, S.P., 1984, The Saddle Mountains—The evolution of an anticline in the Yakima fold belt: American Journal of Science, v. 284, p. 942-978.

#3539 Reidel, S.P., Campbell, N.P., Fecht, K.R., and Lindsey, K.A., 1994, Late Cenozoic structure and stratigraphy of south-central Washington, *in* Lasmanis, R., and Cheney, E.S., eds., Regional geology of Washington State: Washington Division of Geology and Earth Resources, p. 159-180.

#5553 Reidel, S.P., Fecht, K.R., Hagood, M.C., and Tolan, T.L., 1989, The geologic evolution of the central Columbia Plateau, *in* Reidel, S.P., and Hooper, P.R., eds., Volcanism and tectonism in the Columbia River flood-basalt province: Geological Society of America Special Paper 239, p. 247-264.

#4657 Reidel, S.R., and Fecht, K.R., 1994, Geologic map of the Richland 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open-File Report 94-8, 21 p., scale 1:100,000.

#3760 Schuster, E.J., Gulick, C.W., Reidel, S.P., Fecht, K.R., and Zurenko, S., 1997, Geologic map of Washington-southeast quadrant: Washington Division of Geology and Earth Resources Geologic Map GM-45, 20 p. pamphlet, 2 sheets, scale 1:250,000.

#4653 Schuster, J.E., 1994, Geologic map of the east half of the Toppenish 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open-File Report 94-10, 15 p., scale 1:100,000.

#5566 Schuster, J.E., 1994, Geologic map of the east half of the Yakima 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 94-12, 19 p. pamphlet, 1 sheet, scale 1:100,000.

#4661 Shannon and Wilson Inc., 1977, Geologic evaluation of structures in a Columbia Plateau—Subappendix 2RH, Chapter 3.0, Regional geology: Technical report to Washington Public Power Supply System, WPPSS Nuclear Project No. 1, v. 1, 11 p.

#7686 Slack, C., Hansen, K., Coppersmith, R., and Unruh, J., 2014, Evidence for Quaternary Reverse Slip of Rattlesnake Mountain Fault, Yakima Fold Belt, Eastern Washington [abs.]: Seismological Reseach Letters, v. 85, no. 2, p. 545.

	#3574 Swanson, D.A., Wright, T.L., Camp, V.E., Gardner, J.N., Helz, R.T., Price, S.M., Reidel, S.P., and Ross, M.E., 1980, Reconnaissance geologic map of the Columbia River Basalt Group, Pullman and Walla Walla quadrangles, southeast Washington and adjacent Idaho: U.S. Geological Survey Miscellaneous Investigations Map I-1139, 2 sheets, scale 1:250,000. #3765 Tolan, T.L., and Reidel, S.P., 1989, Structure map of a portion of the Columbia River flood-basalt Province, *in* Reidel, S.P., and Hooper, P.R., eds., Volcanism and tectonism in the Columbia River Flood-Basalt Province: Geological Society of America Special Paper 239, 1 sheet, scale 1:500,000.