Jump to Navigation

Quaternary Fault and Fold Database of the United States

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Frenchman Hills structures, unnamed faults of the Frenchman Hills uplift (Class A) No. 561c

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Synopsis	**General:** The east-trending Frenchman Hills structures include the Frenchman Hills and Lind Coulee faults that show evidence suggestive of Quaternary offset (West and Shaffer, 1988 #5549; Shaffer and West, 1989 #5551; Geomatrix Consultants Inc., 1990 #5550). The Frenchman Hills anticline and related folds and some faults of the Frenchman Hills uplift, however, are only known to deform rocks of the Miocene Columbia River Basalt Group. Quaternary age growth or tightening of other folds in the Yakima fold belt, and perhaps of the Frenchman 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	and possibly faulting (Pratt, 2012 #7397; Bjornstad and others, 2012 #7394 citing unpublished Zachariasen and others, 2006).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 one or more buried Quaternary faults, the faults are reassigned to Class A as opposed to the prior Class B classification. **Sections:** This fault has 3 sections. Sections defined here differ in lateral extent from the fault sources prescribed by Coppersmith and others (2014 #7402). Their western section is longer than section 561c.
Name comments	**General:** **Section:** Refers to the east-trending Frenchman Hills anticline and related folds and other faults that coincide with the east-trending Frenchman Hills and Frenchman Hills uplift. These folds are the most prominent features of the Frenchman Hills anticlinal uplift, and they are shown and portrayed in numerous geologic maps and reports of this region (Grolier and Bingham, 1971 #5542; West and Shaffer, 1988 #5549; Geomatrix Consultants Inc., 1990 #5550; Reidel and Fecht, 1994 #5565; Schuster and others, 1997 #3760). Named features include the Frenchman Hills anticline and the Lind Coulee flexure, which are named for the Frenchman Hills and Lind Coulee, respectively (Grolier and Bingham, 1971 #5542). The Frenchman Hills anticline coincides with and extends the length of the Frenchman Hills from the Columbia River eastward to about 8 km directly southeast of Potholes Reservoir (Reidel and Fecht, 1994 #5565; Schuster and others, 1997 #3760). Geomatrix Consultants Inc. (Geomatrix Consultants Inc., 1990 #5550) reported that the Frenchman Hills anticline can be divided into at least three structural segments, based on changes in the trend of the fold and the geomorphic expression of lineaments associated with faulting. From west to east these segments are called the West Canal, Powder Ranch, and Lind Coulee segments. The Lind Coulee flexure is principally a syncline and anticline that are present north of the eastern end of the Frenchman Hill anticline and directly south of the Potholes Reservoir and the Lind Coulee fault (Reidel and Fecht, 1994 #5565; Schuster and others, 1997 #3760). Sinuous, east-trending folds and faults west of the Frenchman Hills and Columbia River extend west to about the Kittitas Valley and appear to be continuations of the folds and faults in the Frenchman Hills. These folds and faults west of the Columbia River are included herein, but were not included in studies and discussions of the Frenchman Hills structures by Grolier and Bingham (1971 #5542) and Geomatrix Consultants Inc. (1990 #5550).

County(s) and State(s)	KITTITAS COUNTY, WASHINGTON GRANT 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 maps by Reidel and Fecht (1994 #5565), Schuster (1994 #5566), and Tabor and others (1982 #7408).
Geologic setting	The Frenchman Hills are in the northeastern 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). The south-dipping Frenchman Hills and Lind Coulee faults are thrust faults that cut the north limbs of the Frenchman Hills anticline and Lind Coulee flexure, which are the principal folds of the Frenchman Hills anticlinal uplift. This uplift forms one of the many anticlinal ridges that comprise the Yakima fold belt in south-central Washington. The Frenchman Hills and Lind Coulee faults show evidence for Quaternary faulting events, but the folds and other faults of the Frenchman Hills uplift are only known to deform rocks of the Columbia River Basalt Group (Miocene).

Length (km)	This section is 91 km of a total fault length of 123 km.
Average strike	N82°W (for section) versus N83°W (for whole fault)
Sense of movement	Anticline, Thrust *Comments:* The Frenchman Hills anticline is a slightly asymmetric anticline that has a short steeply dipping north limb (dips as much as 60°) and a long, gently sloping south limb (Grolier and Bingham, 1971 #5542). The anticline has a slightly undulating crest and is associated with other east-trending folds, such as the anticline and syncline pair called the Lind Coulee flexure that is present along the east end of the Frenchman Hills. The Frenchman Hills fault is a south-dipping thrust (Mège and Reidel, 2001 #7407).The north vergence of the Frenchman Hills anticline may reflect its formation and tightening during movement along the underlying, north-directed, south-dipping Frenchman Hills and Lind Coulee faults (West and Shaffer, 1988 #5549; Shaffer and West, 1989 #5551).
Dip	18–34° S *Comments:* The asymmetry (north vergence) of the Frenchman Hills anticline (Grolier and Bingham, 1971 #5542) suggests that its axial plane dips steeply to the south. Mège and Reidel (2001 #7407) report a mean fault dip of 18–34° for the Frenchman Hills thrust fault based on a combination of field measurements and accessible seismic profiles.
Paleoseismology studies	Detailed studies of the Lind Coulee fault [561b] have been conducted and are discussed in that section.
Geomorphic expression	The slightly arcuate, east-trending ridge-like form of the Frenchman Hills is the principal geomorphic expression of the Frenchman Hills anticline and related easterly trending folds. Miocene volcanic rocks, which form the core of the Frenchman Hills, are obviously deformed in the Frenchman Hills anticline (Reidel and Fecht, 1994 #5565; Schuster and others, 1997 #3760). Deformation of Quaternary units in these folds has not been reported. Information about the geomorphic expression of the faults included in this section of the Frenchman Hills structures has not been reported.
Age of faulted surficial deposits	Miocene volcanic rocks are obviously folded in the Frenchman Hills anticline and related folds (Grolier and Bingham, 1971 #5542; West and Shaffer, 1988 #5549; Reidel and Fecht, 1994 #5565; Schuster and others, 1997 #3760). West and Shaffer (1988 #5549), Shaffer and West (1989

	#5551), and Geomatrix Consultants (1990 #5550) discuss evidence for deformation of Quaternary units along the Frenchman Hills and Lind Coulee faults [561a,561b] that cut the north flanks of the Frenchman Hills anticline and Lind Coulee flexure. Folding of Quaternary units, related to growth or tightening of the Frenchman Hills anticline and related folds of the Frenchman Hills, has not been documented or described. No evidence of deformation of Quaternary units along the faults included in this section of the Frenchman Hills structures has been reported, however, Quaternary deposits are sparse to absent along many of these faults (Reidel and Fecht, 1994 #5565; Schuster and others, 1997 #3760).
Historic earthquake	
Most recent prehistoric deformation	undifferentiated Quaternary (<1.6 Ma) *Comments:* West and Shaffer (1988 #5549), Shaffer and West (1989 #5551), and Geomatrix Consultants (1990 #5550) discuss evidence for Quaternary deformation of Quaternary units along the Frenchman Hills and Lind Coulee faults [561a, 561b] that cut the north flanks of the Frenchman Hills anticline and Lind Coulee flexure. Quaternary growth or tightening of other ridge-anticline features of the Yakima fold belt, related to movement along underlying thrust faults, has been inferred from the following local and regional relations: (1) correlation of uplift rates of Miocene volcanic rocks (Reidel, 1984 #5545); (2) the north-south orientation of the principle stress direction and active seismicity of the region (Reidel and others, 1994 #3539); and (3) interpretations of geometric relations of the folds relative to normal or strike-slip faults that show Quaternary offsets (Campbell and Bentley, 1981 #3513).
Recurrence interval	*Comments:* Piety and others (1990 #3733) used uplift rates calculated from 13.5 Ma volcanic rocks to estimate recurrence intervals of 1,120–61,100 years based on uplift per events of 0.02–1.0 m along an inferred principle fault underlying the Frenchman Hills anticlinal uplift.
Slip-rate category	Less than 0.2 mm/yr *Comments:* Slip or uplift data derived from Quaternary deposits are not available for the Frenchman Hills anticline and related folds, nor for the faults included in this section of the Frenchman Hills structures. Some data is available on uplift rates of Miocene volcanic rocks across the Frenchman Hills anticline and related folds. Coppersmith and others (2014 #7402) report the average relief across the anticline is 155 m with a

	maximum of 180 m. Piety and others (1990 #3733) report 221 m of uplift of 13.5 Ma volcanic rocks, which yields an uplift rate of 0.02 mm/yr. Geomatrix Consultants Inc. (1995 #3593) used uplift of 200 m and horizontal offset of 300 m of 10.5–16.0 Ma volcanic rocks along estimated fault dips of 30°, 45°, and 60° to estimate slip rates of 0.008–0.067 for a presumed principle fault underlying the Frenchman Hills. These estimates for long-term uplift and slip rates suggest that if the folds have been active in the Quaternary their rate of growth or tightening probably is <0.2 mm/yr. The apparent lack of scarps along faults included in this section of the Frenchman Hills structures also suggests relatively low rates for possible Quaternary slip along these faults.
Date and Compiler(s)	2016 David J. Lidke, U.S. Geological Survey Kathleen M. Haller, U.S. Geological Survey
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