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Pyramid Lake fault zone (Class A) No. 1669

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Synopsis	The Pyramid Lake fault zone is a northwest trending right-lateral strike-slip fault located in the northern Walker Lane that is expressed as northwest-striking down-to-the-northeast and -southwest intra basin faults extending from about 15 km south of Fernley northwest to near southern margin of Pyramid Lake. The fault also includes the northwest- to northeast-trending intermontane lineaments and small faults in eastern Virginia Range near south end of zone and a north-northeast trending zone of faults that diverges from main zone near Nixon and extends into southern part of Winnemucca Dry Lake basin. Surface faulting is manifested by the presence of springs, vegetation and tonal lineaments, tufa deposits, uphill-facing scarps, linear bedrock and alluvial ridges, and closed depressions. The Pyramid Lake fault zone is almost entirely below the highstand of Lake Lahontan, which reached its pluvial maximum at about 15 ka followed by rapid lowering in the early Holocene. The right-

	lateral Pyramid Lake fault zone may be structurally related to the left-lateral Olinghouse fault zone [1668] as they appear to merge near White Horse Canyon on east side of Pah Rah Range. Trench investigations have been completed as well as detailed evaluation of offset pluvial features at additional sites, which result in latest Pleistocene horizontal displacement rates but no inter-event rates.
Name comments	Refers to faults mapped by Russell (1885 #3549), Slemmons (1968, unpublished Reno 1:250,000-scale quadrangle), Bonham (1969 #2999), Bell and Slemmons (1979 #104), Anderson and Hawkins (1984 #2404), Bell (1984 #105; 1984 #107), Greene and others (1991 #3487), and Yount and others (1993 #1608) on east side of Pah Rah and Virginia Ranges. The Pyramid Lake fault was apparently named by Bell and Slemmons (1979 #104); this compilation includes Nixon fault zone of dePolo (1998 #2845). The fault was divided into two sections based on geomorphic and structural observations (Bell and Slemmons, 1979 #104; Anderson and Hawkins, 1984 #2404; Briggs and Wesnousky, 2004 #7697); however, both sections are characterized by the same age and slip-rate categories used in this compilation. Further division of the fault at this time is not warranted. **Fault ID:** Refers to fault R15B (Pyramid Lake fault zone) and R17 (Nixon fault zone) of dePolo (1998 #2845).
County(s) and State(s)	STOREY COUNTY, NEVADA LYON COUNTY, NEVADA WASHOE COUNTY, NEVADA
Physiographic province(s)	BASIN AND RANGE
Reliability of location	Good Compiled at 1:24,000 scale. *Comments:* Fault locations are based on 1:24,000-scale maps of Bell and others (2005 #7364, 2005 #7365 augmented by mapping shown in figures 3–5 in Briggs and Wesnousky (2004 #7697).
Geologic setting	This long, nearly continuous dextral zone consists of: (1) northwest-striking down-to-the-northeast and -southwest intra basin faults extending from about 15 km south of Fernley northwest to near southern margin of Pyramid Lake; (2) northwest- to northeast-trending intermontane lineaments and small faults in eastern Virginia Range near south end of zone; and

	(3) a north-northeast trending zone of faults that diverges from main zone near Nixon and extends into southern part of Winnemucca Dry Lake basin (Slemmons, 1968, unpublished Reno 1:250,000-scale quadrangle, Bonham, 1969 #2999; Bell and Slemmons, 1979 #104; Bell, 1984 #105; 1984 #107; Anderson and Hawkins, 1984 #2404; Greene and others, 1991 #3487). The right-lateral Pyramid Lake fault zone may be structurally related to the left-lateral Olinghouse fault zone [1668], because they appear to merge near White Horse Canyon on east side of Pah Rah Range (Sanders and Slemmons, 1996 #1229). A highly conjectural estimate of 32 km of cumulative right-lateral offset on the fault zone is based on apparent offset of northern outcrop limit of a group of Cenozoic tuffs (Bonham, 1969 #2999).
Length (km)	45 km.
Average strike	N13°W
Sense of movement	Right lateral, Normal *Comments:* Onshore right-lateral sense of movement reported by Bonham, (1969 #2999), Bell and Slemmons (1979 #104) Bell (1981 #2875, 1984 #107;) Anderson and Hawkins (1984 #2404), Yount and others (1993 #1608). Marine shallow seismic-reflection suggests the fault, at least locally, dips to the east and exhibits oblique motion along the west shore of the lake. CHIRP images do not show any large strike-slip fault entering the southern end of the lake; however, the location of the Pyramid Lake fault is indicated by the sharp linear nature of the southwestern shoreline along the panhandle (Eisses and others, 2015 #7366). Bell and others suggest that the part of the fault near Wadsworth and in the Nixon quadrangle exhibits predominantly normal displacement. Profiles within the panhandle of the lake show southwestward-dipping stratigraphy.
Dip Direction	NE; SW
Paleoseismology studies	Anderson and Hawkins (1984 #2404) excavated three trenches across central part of Pyramid Lake fault zone. Their study suggests repeated Holocene displacements of alluvial, eolian, and lacustrine deposits. Site 1669-1: One trench was excavated across a 5-m-high southwest-facing scarp with a maximum slope angle of 20° near southern end of an 800-m-long shutter ridge. The trench exposed

alluvial fan gravel deposits, lacustrine silt and sand, eolian silt (loess), and colluvium and slope wash deposits. All units except the overlying colluvium and slope wash deposits have been faulted. Anderson and Hawkins (1984 #2404) reported at least three, probably four, and possibly five Holocene faulting events based on structural and stratigraphic relations exposed in the trench. The earliest faulting event occurred after 9855±380 yr, but before deposition of Mazama tephra (6,845±50 14C yr, Bacon, 1983 #3787). The two most recent events are reported to have occurred at about 2 ka and within last several hundred years. Two additional events (at 3–4 ka and 5–6 ka) are inferred from juxtaposition of disparate stratigraphic units and from correlation with trenches 1669-2.

Site 1669-2: Two trenches were excavated across a small graben and associated sag pond. One was excavated immediately adjacent to the southwest end of the other because of caving problems. The trenches exposed a faulted sequence of alluvial fan deposits of probable Holocene age with intercalated pods, lenses, and beds of Mazama tephra (6,845±50 14C yr, Bacon, 1983 #3787). Anderson and Hawkins (1984 #2404) reported at least three and possibly four post-Mazama faulting events based on faulting and folding of Mazama tephra layer, scarp-derived colluvial wedge, correlation with the trench at site 1669-1, complex juxtaposition of stratigraphic units, and faulting of an alluvial fan unit with a moderately-developed soil. This sequence was overlain by unfaulted colluvium that is probably only a few hundred years old based on similarities with modern wash deposits. Anderson and Hawkins (1984 #2404) suggested that the most recent coseismic surface rupture on this part of the fault zone may have occurred within last few hundred years based on stratigraphic and structural relations exposed in the trenches.

Briggs and Wesnousky (2004 #7697) document findings from three lateral-offset sites and three trench sites; figures 3, 4, and 5 show additional displacement data that are not described. In general, post Lahontan (<15.5 ka) horizontal displacement rates are less than 1 mm/yr except at site 1669-6 where the resulting horizontal displacement rate is reported to be 2.6±0.3 mm/yr.

Site 1669-3. Site A of Briggs and Wesnousky (2004 #7697) is located where a broad abandoned stream channel is displaced by two fault strands expressed as a graben. Right-lateral offset of 12–15 m was recognized across eastern fault strand; no offset was reported across the other fault scarp. The resulting minimum horizontal displacement rate is 0.7–1.0 mm/yr.

Site 1669-4. Two trenches were excavated near Secret Canyon (Briggs and Wesnousky, 2004 #7697). The exposure in the south trench contained a unit containing faulted Mazama ash (7627±150 cal yr BP) displaced by two events; one or possibly two additional earthquakes occurred between the lowering of Lake Lahonton and the deposition of the ash (7.6–15.5 ka). The timing of the third oldest earthquake (between 7,627±150 cal yr BP and 8,980±260 cal. yr B.P.) is constrained by relations in the North trench.

Site 1669-5. Site B of Briggs and Wesnousky (2004 #7697) is located near the Truckee River 0.5 km north of Gardella Canyon. On the basis of topographic mapping, vertical air photo reconstruction, and field measurements of the channel thalweg, channel margin, and ridge crest offsets total right-lateral displacement of 35–43 m is reported.

Site 1669-6.A trench excavated in the Truckee River floodplain exposed lacustrine clayey silts overlain by thinly laminated lacustrine silts and fine sands mantled by thick, extensively bioturbated eolian sands and silts; all radiocarbon samples yielded Holocene ages. Movement was interpreted to be post-Lahontan resulting in a minimum horizontal displacement rate of 2.6±0.3 mm/yr. Another trench excavated across the unfaulted low terrace of the recently active Truckee River floodplain in Wadsworth. The stratigraphically inverted AMS radiocarbon ages group between 2,245±95 cal yr BP to 1,705±175 cal yr BP is probably the result of reworking of upstream deposits.

Site 1669-7. Site C of Briggs and Wesnousky (2004 #7697) is located about 2 km south of Fernley where a shallow channel formed in post-Lake Lahontan alluvium is offset 13–15 m in a right-lateral sense. The resulting minimum horizontal displacement rate is 0.8–1.0 mm/yr.

Angster and others (2016 #7362) report displacement derived from digital elevation models developed from structure-from-motion processing of low-altitude aerial photography at seven locations along the fault. Combined with paleolake-level chronology (Reheis and others, 2014 #7368) and ages that includes the brief high-stand at about 13,070±60 14C BP (Adams and Wesnousky, 1998 #5841) or the calibrated age of 15,475±720 cal yr BP (reported in Briggs and Wesnousky, 2004 #7697).

Horizontal displacement rates from this study range from 0.5±0.2 to 1.9±0.7 mm/yr. The sites are all north of Site B of Briggs and Wesnousky (2004 #7697) and are restricted to about 15 km long part of the fault. They are sequentially numbered in the original study from northwest to southeast; they are similarly represented as sites 1669-8 through 1669-16 herein.

Site 1669-8. Site 1 of Angster and others (2016 #7362) is located in the northern end of the fault about 4 km south of the modern shoreline; faulting has resulted in an uphill-facing fault scarp across a fan that postdates the late Pleistocene transgression of Lake Lahontan (10,820±35 yr BP). Correlating a beheaded drainage channel on the northeast side of the fault with a similar channel on the other side of the fault results in right lateral offset of 17±2 m and a minimum horizontal displacement rate of 1.6±0.2 mm/yr. They disregard a channel that would suggest 60 m of offset as implausible.

Site 1669-9. Site 2 of Angster and others (2016 #7362) is located about 1 km southeast of Site 1; similarly, faulting is expressed as a single linear uphill facing scarp up to 1.5 m high on lacustrine deposits. Correlating offset channels results in right lateral offset of 16±6 m; The large uncertainty is due to the broad and muted channel morphology at the site. The resulting minimum horizontal displacement rate is 0.9±0.4 mm/yr.

Site 1669-10. Site 3 of Angster and others (2016 #7362) is located about 0.75 km southeast of site 2, where the fault offsets a broad constructional shoreline ridge. The crest of the ridge is offset 15±10 m and the ridge formed between Sehoo highstand (15.5 ka) and the transgressional maximum (10.8 ka), yielding a range of horizontal displacement rates of 1.0±0.6 mm/yr to 1.4±0.9 mm/yr.

Site 1669-11. Site 4 of Angster and others (2016 #7362) is located about 2 km southeast of Site 3; surface rupture is expressed as two subparallel scarps that form a graben. At this site they estimate 14±2 m of right-lateral offset, similar to the offset reported by Briggs and Wesnousky (2004 #7697, site A) of 12–15 m and an additional 3±1 m offset across the southwestern strand of the fault. The reported minimum horizontal displacement rate is 1.1±0.2 mm/yr.

Site 1669-12. Site 5 of Angster and others (2016 #7362) is located at the southern end of a 1-km-long linear northwest-trending wave-washed bedrock-cored ridge where the fault intersects and

	displaces two broad but distinct shoreline ridges. The crest of the northwestern ridge is offset in a right lateral sense 21±8 m, and the pronounced southeastern ridgeline is offset 20±5 m. Horizontal displacement rates from these relations range from 1.4±0.5 mm/yr to 1.9±0.7 mm/yr. Site 1669-13. Site 6 of Angster and others (2016 #7362) is located approximately midway between Site 5 and Site 7 where arcuate constructional shoreline ridges intersect the 1-m-high uphill-facing fault scarp at a high angle. The break in slope on the northwest face of this shoreline ridge is right-laterally offset 19±9 m; the shoreline is just below the Sehoo highstand, which results in a minimum horizontal displacement rate of 1.2±0.6 mm/yr. Site 1669-14. Site 7 of Angster and others (2016 #7362) is located at the southern end of a linear bedrock-cored ridge where the southeast-facing shoreline escarpment is offset 8±3 m across the fault zone. The horizontal displacement rate estimate is 0.5±0.2 mm/yr; however, numerous fault traces exist at the latitude of this site and the stated estimate probably does no capture the entire near-field displacement.
Geomorphic expression	Intrabasin faults are expressed by sag ponds, echelon left-stepping fault scarps, elongate depressions and troughs, offset stream channels, vegetation lineaments, linear gullies, transcurrent buckles (folds), and rhombohedral and wedge-shaped enclosed depressions. Intermontane structures at south end of zone are likely expressed by topographic lineaments. The northeast-striking faults at north end of zone are expressed by west-facing fault scarps on latest Pleistocene lacustrine deposits (Bell and Slemmons, 1979 #104; Bell, 1981 #2875; 1984 #105, Anderson, 1984 #2404).
Age of faulted surficial deposits	Holocene; late Pleistocene; Quaternary; Tertiary. Bell and Slemmons (1979 #104) and Anderson and Hawkins (1984 #2404) reported faulted Holocene and late Pleistocene sediments; mapping of Bonham (1969 #2999) shows faulted Quaternary-Tertiary gravels along this zone; and mapping of Greene and others (1991 #3487) shows faults displacing Tertiary bedrock.
Historic earthquake	
Most recent prehistoric	latest Quaternary (<15 ka)

deformation	*Comments:* The early investigation of the fault by Anderson and Hawkins (1984 #2404) showed convincing stratigraphic evidence exposed in trenches for several post-Mazama (about 7.6 ka) faulting events. Similar timing for the most recent event is indicated by Bell (1984 #105), Slemmons (1968, unpublished Reno 1:250,000-scale quadrangle), and Dohrenwend and others (1996 #2846). According to Briggs and Wesnousky (2004 #7697) the timing of the most recent surface rupture is bracketed by charcoal ages of 810±100 cal yr BP and 1,705±175 cal yr BP where the minimum bounding age is the historic highstand (A.D. 1870–1890); furthermore, there is no compelling evidence to conclude that the large 1845 or 1852 earthquake occurred on the Pyramid Lake fault.
Recurrence interval	*Comments:* Anderson and Hawkins (1984 #2404) reported the possibility of as many as five surface-faulting events in about the last 7500 yr. Briggs and Wesnousky (2004 #7697) combine the chronologies from their three trenches and conclude there have been four surface-rupturing earthquake in the past 15.5 k.y., and two occurred in the past 7.6 k.y. They propose an average recurrence interval of 2,910–3,080 yr by using horizontal displacement rate derived from Site B; individual recurrence intervals are not directly constrained by radiometric dating.
Slip-rate category	Between 1.0 and 5.0 mm/yr *Comments:* Offset measurements at the seven locations reported by Angster and others (2016 #7362) range from 8 to 21 m and yield horizontal rates of 0.5–1.9 mm/yr. The uncertainties in some cases are large and conclusions of the study suggest that 1.3±0.4 mm/yr is an appropriate estimate of average rate of horizontal displacement. Earlier studies propose displacement rates of 2.1–2.5 mm/yr (Briggs and Wesnousky, 2004 #7697), 0.4–1.1 mm/yr (dePolo and others (1997 #1367), and a late Cenozoic displacement rate of 0.7 mm/yr (E.J. Bell in Bell, 1984 #107, p. 409).
Date and Compiler(s)	2016 Kathleen M. Haller, U.S. Geological Survey Kenneth Adams, Piedmont Geosciences, Inc.
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