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Dixie Valley fault zone, 1954 earthquake section (Class A) No. 1687b

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Synopsis	**General:** The Dixie Valley fault is a range-front structure that bounds the east side of the Stillwater Range. The Stillwater Range has been uplifted several kilometers relative to the bounding basins since basin-and-range faulting began (<13 Ma), and the southern part of range was tilted 40° to 90° east during early Miocene extensional faulting. This long, continuous, well-defined to spectacularly expressed fault zone is divided into two sections. The southern section ruptured in the 1954 earthquake, and the northern one did not. The 1954 Dixie Valley earthquake produced spectacular surface ruptures (up to 2.8 m high) along the southern part of the fault zone. The northern part of the fault zone has been referred to as the "Stillwater seismic gap" because it is located between coseismic surface ruptures of the 1915 Pleasant Valley earthquake to the north and 1954 Disie Valley earthquake to the south. In addition to geophysical studies, including seismic

	refraction, aeromagnetics and gravity surveys, and reconnaissance and detailed photogeologic mapping of the fault zone, detailed mapping and measurement of the 1954 ruptures, scarp morphology, and 5 trench at 4 sites are the sources of data. **Sections:** This fault has 2 sections. The pattern of 1954 surface faulting and general movement history provide a basis for subdividing the Dixie Valley fault zone into a southern section (1954 section), which ruptured in the 1954 earthquake and a northern section (Stillwater seismic gap section) that did not rupture. The Stillwater seismic gap section, which overlaps north end of 1954 scarps, extends along and near front of Stillwater Range from about Hare Canyon northward to mouth of White Rock Canyon, and discontinuously northeast to the area east of McKinney Pass.
Name comments	**General:** Refers to faults mapped by Slemmons (1968, unpublished Reno 1:250,000-scale map), Willden and Speed (1974 #3645), Bell (1984 #105), Wallace and Whitney (1984 #167), Bell and Katzer (1987 #205), Greene and others (1991 #3487), Caskey (1996 #2437), Caskey and others (1996 #2439), Dohrenwend and Moring, (1991 #282), and Dohrenwend and others (1992 #283). The fault extends along east side of Stillwater Range and in western Dixie Valley from La Plata Canyon, in northern part of Fairview Valley, northward to The Bend and continues northeastward across mouth of White Rock Canyon, to about 2 km north of the mouth of Man Canyon where one trace bends sharply east and separates into echelon northeast-striking traces and another steps west, where it forms discontinuous northeast-striking fault scarps that continue north to the area east of McKinney Pass (the topographic divide between the Stillwater and East Ranges). Slemmons (1957 #154) is an early reference to the Dixie Valley fault zone name. **Section:** Refers to faults mapped by Slemmons (1957 #154, Slemmons, 1968, unpublished Reno 1:250,000-scale map), Bell (1984 #105), Wallace and Whitney (1984 #167), Bell and Katzer (1987 #205), Greene and others (1991 #3487), John (1993 #3712; 1995 #3713), Caskey (1996 #2437), and Caskey and others (1996 #2439) that extend southward along eastern side of Stillwater Range and through western Dixie Valley to south end of the 1954-rupture zone and including a series of paleoscarps along strike to the south in northern Fairview Valley. **Fault ID:** Refers to fault number R29 (Dixie Valley fault zone) of

	dePolo (1998 #2845).
County(s) and State(s)	CHURCHILL COUNTY, NEVADA
Physiographic province(s)	BASIN AND RANGE
Reliability of location	Good Compiled at 1:100,000 scale. *Comments:* Fault locations are generally based on 1:48,000-scale map of Caskey (1996 #243, reproduced in Caskey, 1996 #2439). Mapping based on detailed photogeologic analysis of 1:10,000- to 1:12,000-scale vertical, low-sun-angle aerial photography, transferred by inspection to 1:24,000-scale mylar orthophotos and directly to 1:24,000-scale topographic maps, that were then reduced to 1:48,000-scale; mapping also based on detailed field mapping and hundreds of measurements of fault offsets along fault zone. Selected fault locations are based on 1:250,000-scale map of Bell (1981 #2875; 1984 #105); mapping is from photogeologic analysis of 1:40,000-scale low sun-angle aerial photography, supplemented with 1:12,000-scale aerial photography of selected areas, several low-altitude aerial reconnaissance flights, and field reconnaissance of major structural and stratigraphic relationships.
Geologic setting	This long, continuous, well-defined to spectacularly expressed fault zone has: (1) range-front faults bounding east front of Stillwater Range from near Elevenmile Canyon north to The Bend, east for several kilometers along northern margin of The Bend, and continues nearly continuously from about Hare Canyon northeastward to mouth of White Rock Canyon; (2) subparallel piedmont faults are widely distributed in western Dixie Valley, particularly in The Bend as much as 5 to 6 km east of range front, on piedmont slope between East Lee Canyon and about Cain Spring Canyon, on alluvial fan of Elevenmile Wash, and bounding and in uplifted pediment on Quaternary-Tertiary alluvium at westward step in range front at about La Plata Canyon; and (3) short intermontane faults on range-front escarpment between about Rough Creek Canyon north to James Canyon (Slemmons, 1968, unpublished Reno 11:48,000-scale map of Caskey (1996 #243t; Bell, 1984 #105; Bell and Katzer, 1987 #205; Greene and others, 1991 #3487; Caskey, 1996 #2437; Caskey and others, 1996 #2439). Dixie Valley is an asymmetric

	graben-in-graben bounded on west by the range-front fault zone and traversed in its western part by the piedmont fault zone, each have as much as 1500 to 1800 m of late Cenozoic (approximately 15 Ma) vertical offset (Burke, 1967 #2432; Herring, 1967 #3711; Meister, 1967 #3715; Thompson and Burke, 1973 #164; Bell, 1981 #2875; Anderson and others, 1983 #2852; Schaefer, 1983 #3716). The Stillwater Range has been uplifted several kilometers relative to the basin beneath Dixie Valley and Carson Sink since basin-and-range faulting began (<13 Ma), and southern part of range was tilted 40° to 90° east during early Miocene extensional faulting (John, 1995 #3713). In its north-most part, one splay of the fault zone steps left and continues discontinuously along the Stillwater Range to its north end and a second splay bends sharply east and separates into echelon northeast-striking traces, forming the boundary between Dixie Valley and the Sou Hills. The 1954 Dixie Valley earthquake produced spectacular surface ruptures along fault zone from east of La Plata Canyon to east of Mississippi Canyon (Bell, 1984 #105; Caskey, 1996 #2437; Caskey and others, 1996 #2439). The rupture pattern of the 1954 Fairview Peak-Dixie Valley earthquakes suggests that this fault zone may be related to the Louderback Mountains fault [1689], Gold King fault [1691], West Gate fault [1692], and Fairview Peak fault zone [1690]; the general pattern of young faulting suggests fault zone is also related to the Sand Springs Range fault [1685] to the south (Bell and Ramelli, 1999 #4330).
Length (km)	This section is 57 km of a total fault length of 105 km.
Average strike	N18°E (for section) versus N21°E (for whole fault)
Sense of movement	Normal *Comments:* The fault zone is predominantly normal (Slemmons, 1957 #154; Meister, 1967 #3715; Bell, 1981 #2875; Schaefer, 1983 #3716; Wallace and Whitney, 1984 #167; Bell and Katzer, 1987 #205; John, 1995 #3713; Caskey, 1996 #2437; Caskey and others, 1996 #2439), even though the faults locally exhibit evidence of either right-lateral or left-lateral offsets (*e.g.*, Slemmons, 1957 #154; Caskey, 1996 #2437).
Dip	<30° to 80° E. *Comments:* Bell and Katzer (1987 #205) reported generally steep dips (60–70° E.) for the range-front faults. Caskey (1996 #2437) and Caskey and others (1996 #2439) reported several dip

	measurements made along range-front faults: north of mouth of Hare Canyon, fault exposed in excavation dips of 55°E and steepens to 80° E. near the surface (presumably in alluvial deposits) and, to the north, an exhumed bedrock fault surface dips 38° E.; south of the mouth of James Canyon, relation of fault trace to range-front topography suggests that the fault may dip <30° E.; at mouth of East Job Canyon, fault in alluvium is well exposed in channel bank dipping 45°–50° E.; at mouth of Little Box Canyon, 1954 rupture appears to cut alluvium along an approximately 32° E.-dipping fault. Slemmons (1957 #154) also noted that the fault tends to dip steeper in alluvial deposits relative to underlying fault in bedrock, which he reported ordinarily dipped 55° to 75° (unspecified locations). Seismic reflection, seismicity, and geodetic studies suggest that the faults bounding the Stillwater Mountains are high-angle and planar to depths of 14 km or more (Anderson and others, 1983 #2852; Vetter and Ryall, 1983 #3244).
Paleoseismology studies	Bell and Katzer (1987 #205) excavated five backhoe trenches at four location across the more continuous faults in the piedmont zone of The Bend area; faults at all four sites were ruptured in 1954. Soil-profile development, tephrachronology, and surficial geology were used to infer a sequence of three surface-faulting events; a pre-Holocene event, a middle to late Holocene event, and the 1954 event; the pre-1954 event is not recognized along the range-front zone (Bell and Katzer, 1987 #205). Site 1687-1 in northern piedmont zone: Bell and Katzer (1987 #205) excavated a backhoe trench (their trench 3) across a 3-m-high scarp marking main piedmont fault that continues north and bounds east front of Stillwater Range. Trench exposed late Quaternary alluvial fan and beach gravel, form below highstand of pluvial Lake Dixie (<12 ka), displaced by two shear zones, one of which had 1954 movement that added about 60 cm to height of the paleoscarp. The 1954 event ruptured a cambic soil (>1–2 ka) that underlies face of the paleoscarp and has formed in colluvium derived from that scarp, providing evidence for at least one pre-1954 scarp-forming event (Bell and Katzer, 1987 #205). Sites 1687-2 and 1687-3 near Dixie Valley Road, approximately 2.3 km north of Settlement Road: Bell and Katzer (1987 #205) excavated two exploratory trenches (their trench 2), about 15 m apart, across an approximately 1-m-high subdued scarp on young basin-fill deposits that presumably postdate highstand of Lake

Dixie (<12 ka). Although this low lying area experienced liquefaction in 1954, the scarp is inferred to be tectonic in origin because it is subparallel to faults higher on piedmont slope marked by compound scarps (i.e., a primary tectonic geomorphic feature) and is continuous for nearly 3 km. Unfortunately stratigraphic relations were unclear in these trenches, so young faulting could not be confirmed or precluded. However, a layer of Turupah Flat ash (~1.5 ka) was exposed buried by eolian sand and draped over the scarplet, suggesting that the pre-1954 event occurred before about 1.5 ka (Bell and Katzer, 1987 #205).

Site 1687-4. East Job Canyon: Bell and Katzer (1987 #205) excavated an exploratory trench (their trench 1) across a large, east-facing scarp marking main piedmont fault, which bounds a broad graben traversing middle alluvial fan of East Job Canyon. This trench exposed older alluvial-fan deposits, multiple packages of scarp-derived colluvium, and buried soils that indicate two paleoevents prior to the 1954 event along this piedmont fault; older alluvial-fan deposits are vertically displaced about 7.6 m down to the east. A pre-Holocene time for the oldest paleoevent is indicated by a well-developed argillic soil on upper part of paleoscarp. The penultimate event is represented by scarp colluvium with a cambic soil indicative of a Holocene age, up to nearly a 1 m thick against the fault. 1954 event produced about 1/3 m vertical offset and is marked by a discontinuous free face (Bell and Katzer, 1987 #205).

Site 1687-5. Willow Canyon: Bell and Katzer (1987 #205) excavated an exploratory trench (their trench 4) that exposed young alluvial-fan deposits displaced nearly 3 m along a prominent piedmont fault traversing alluvial fan of Willow Canyon. Pre-1954 event was represented by scarp colluvium exhibiting a cambic soil, suggesting a Holocene time of greater than 1 to 2 ka for the penultimate event.

Site 1687-6. La Plata Canyon: A sixth trench was excavated in 1999 by Bell and Ramelli across a 7-m-high scarp on Holocene deposits near mouth of La Plata Canyon, south of the 1954 rupture zone. The trench exposed Holocene alluvial-fan deposits vertically separated 5 m across a 2- to 3-m wide zone of high-angle faults, a sequence of four colluvial-wedge deposits in hanging wall, and minor fissure-fill deposits. The colluvial wedges suggest 4 paleoearthquakes have occurred on the fault in past 10 to 12 ka. The three oldest wedges are separated from the

	youngest wedge by a weak soil, possibly suggesting clustering of events in the early Holocene. The most-recent event is associated with a 50- to 100-cm scarp on late Holocene deposits containing a weak (A-C to weak Bw) soil, possibly suggesting it occurred within the past several hundred several years; however this event may be related to a surface-rupturing event along the Sand Springs fault (1685) to the south.
Geomorphic expression	Section consists predominately of historical scarps that prominently mark range-front faults bounding eastern front of Stillwater Range and distributed scarps on subparallel to left-stepping echelon piedmont and intra basin faults in western Dixie Valley (Slemmons, 1957 #154; Bell, 1981 #2875; 1984 #105; Wallace and Whitney, 1984 #167; Bell and Katzer, 1987 #205; John, 1995 #3713; Caskey, 1996 #2437; Caskey and others, 1996 #2439). Bell and Katzer (1987 #205) referred to these as the "range-front" and "piedmont" fault zone, respectively. The 1954 scarps are nearly continuous, and commonly ruptured preexisting scarps, along range-front fault zone from east of mouth of Mississippi Canyon southeast to east of Wood Canyon, where fault continues into western part of Dixie Valley as an intra basin fault along east margin of the piedmont fault zone. The 1954 scarps commonly bound extensive narrow graben in upper piedmont-slope deposits adjacent to sinuous range front in The Bend area, nearly continuously from near mouth of Silver Hill Canyon southward to near mouth of East Lee Canyon, and along a short section of range front at Slaughter Canyon to north of Elevenmile Canyon Valley (Slemmons, 1957 #154; Bell, 1981 #2875; 1984 #105; Wallace and Whitney, 1984 #167; Bell and Katzer, 1987 #205; 1990 #111; Caskey, 1996 #2437; Caskey and others, 1996 #2439). The 1954 scarps adjacent to range front locally exhibit right- or left-stepping echelon patterns, coincide with compound paleoscarps, are marked by discontinuous free faces, and represent as much as 2.8 m, near Coyote Canyon, and 2.5 m, near IXL Canyon, of vertical separation (Bell and Katzer, 1987 #205; Caskey, 1996 #2437; Caskey and others, 1996 #2439). One of the earliest reports of "aseismic afterslip" was reported Slemmons (1957 #154 , Figs. 2 and 3), who stated that a scarp about 100 m north of Mud Spring (near mouth of Willow Canyon) increased in height by nearly a meter between 5 and 10 February, 1955, almost two months after the December 16, 1954, earthquake. Although, lateral offsets occurred along locally very sinuous range front (e.g., range-front salient between Coyote and Sheep Canyons), 1954 motion was predominantly normal-dip slip

	(e.g., Slemmons, 1957 #154; Bell, 1981 #2875; Caskey, 1996 #2437). In addition, range-front faults are expressed as eastern front of Stillwater Range which exhibits small and up to 146-m-high basal fault facets (up to about 145 m), wineglass canyons, and uplifted stream terraces (dePolo, 1998 #2845; dePolo and Anderson, 2000 #4471). Wallace and Whitney (1984 #167) estimated that Holocene scarps occur along 28 to 30 percent of the 1954-rupture zone, mostly along piedmont faults and that only a very few paleoscarps occur at the range front. In The Bend area, 1954 vertical displacements, generally less than 0.5 m, were superimposed on mostly Holocene scarps (representing 1 to 2 m of vertical displacement) and locally on large multiple-event scarps on late Pleistocene piedmont-slope deposits marking piedmont and intra basin faults (Caskey, 1996 #2437). Bell and Katzer (1990 #111) reported 15 to 18 m vertical offset of mid Pleistocene alluvial-fan deposits (200–500 ka based on soil development) at range-front fault and an additional 21 to 23 m offset of the same deposits across the subparallel piedmont zone, based on borehole data. Evidence of 1954 faulting also includes stream knickpoints at and near range front, scarps along antithetic piedmont faults that locally pond and have resulted in stream-gradient modifications, and liquefaction features in low lying areas that include commonly scalloped-shaped scarps and fissures, sand boils, mud and silt volcanoes, and sinkholes (Bell and Katzer, 1987 #205; Caskey, 1996 #2437). Some minor 1954 surface breaks reported by Slemmons (1957 #154) are no longer visible (e.g., Caskey, 1996 #2437). This section also includes a series of paleoscarps on piedmont slope and along east front of Stillwater Range from between about East Lee Canyon and Slaughter Canyon and from mouth of Elevenmile Canyon to northern Fairview Valley, southeast of mouth of La Plata Canyon. These Holocene to late Pleistocene scarps (Caskey, 1999, written commun.) are as much as 6 m high and have slope angles up to approximately 24°; small (<10 cm) 1954 breaks occurred locally at base of several of these scarps (Wallace and Whitney, 1984 #167; Caskey, 1996 #2437).
Age of faulted surficial deposits	Holocene; late Pleistocene; middle to late Quaternary. There is general agreement that Holocene, as young as post-Mazama (6845±50 yr), and late Pleistocene piedmont-slope deposits are faulted in this section, primarily along piedmont and intra basin faults in The Bend area (e.g., Slemmons, 1957 #154; Bell and Katzer, 1987 #205; 1990 #111; Caskey, 1996 #2437). Bell and Katzer (1987 #205) reported that older colluvial deposits are

	commonly faulted at range front, and that middle to late Quaternary alluvial-fan deposits (about 200 ka to 400500 ka) are apparently offset 15–18 m at range front, with about 3 m of offset occurring in 1954, and are offset 21 to 23 m in piedmont fault zone, with less than a meter occurred in 1954. Wallace and Whitney (1984 #167) reported Holocene scarps on piedmont faults and much older scarps at range front in The Bend area.
Historic earthquake	Dixie Valley earthquake 1954
Most recent prehistoric deformation	latest Quaternary (<15 ka) *Comments:* Trench studies by Bell and Katzer (1987 #205; 1990 #111) provide evidence for a Holocene time on the piedmont zone, between 6.8 ka and 1.5 ka, of the most recent paleoevent (their Bend event), which agrees well with mapping by Bell (1984 #105), Wallace and Whitney (1984 #167), Caskey (1996 #2437), Caskey and others (1996 #2439). Pearthree and others (1986 #2564) implied that the most recent paleoevent on this section occurred between 2 and 6 ka and that it also ruptured the adjacent section to the north. However, a late Pleistocene time for the range-front fault zone was reported by Bell and Katzer (1990 #2439); their IXL event. An event perhaps in the past several hundred several years at La Plata Canyon is apparently related to a surface-rupturing event along the Sand Springs fault [1685] to the south, rather than an event on this section (Bell and Ramelli, 1999, personal commun.).
Recurrence interval	>3.4 ka (<12 ka); 15–50 ka (<200 ka) *Comments:* Bell and Katzer (1987 #205) reported a Holocene recurrence interval for the piedmont zone may be as short as 3.4 ka based on two events post-Mazama ash (6845±50 yr) at site 1687b-2 (Bell and Katzer, 1987 #205). However, the mid to late Quaternary recurrence intervals may be as much as an order of magnitude longer; 15–50 ka based on analysis of displaced surficial deposits and deposits encountered in exploratory boreholes and trenches.
Slip-rate category	Between 0.2 and 1.0 mm/yr *Comments:* A variety of vertical displacement rates have been calculated or estimated for locations along this fault, all of which suggest that the vertical displacement rate that best characterizes the fault is less than 0.5 mm/yr. Bell and Katzer (1990 #111)

	reported a Holocene vertical slip rate of 0.2–0.5 mm/yr, with the higher rate based on 6 m of total offset of shoreline deposits (~12 ka). Bell and Katzer (1987 #205) estimated a mid to late Quaternary vertical slip rate of 0.02 mm/yr for both the range-front and piedmont zones. The Holocene rate for piedmont zone alone is 0.1 mm/yr (Bell and Katzer, 1987 #205). dePolo (1998 #2845) and dePolo and Anderson (2000 #4471) arrived at an estimated slip rate of 0.14 mm/yr (0.07–0.23 mm/yr) for entire zone, based on Bell and Katzer's (1990 #205) estimated age of a mid Pleistocene alluvial fan (200–500 ka) and by adding Bell and Katzer's 15–18 m and 21–23 m vertical offsets of older alluvial-fan deposits across the range-front and piedmont fault zones, respectively; and assuming a shallowly dipping fault (25–50°) as suggested by Caskey and others (1996 #2439). Wallace and Whitney (1984 #167) estimated a late Cenozoic vertical rate for the Dixie Valley fault (northern section ?) of 0.27–0.34 mm/yr based on apparent offset of a 10.4–12.9 Ma volcanic unit that is at an elevation of 2200 m in Stillwater Range and correlative unit is thought to be about 1280 m below sea level near center of Dixie Valley based on seismic-reflection data.
Date and Compiler(s)	1999 Thomas L. Sawyer, Piedmont Geosciences, Inc. R. Ernest Anderson, U.S. Geological Survey, Emeritus
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