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Helendale-South Lockhart fault zone, Helendale section (Class A) No. 110b

Last Review Date: 2002-04-06

citation for this record: **Bryant, W.A., and Perry, S., compilers, 2002, Fault number 110b, Helendale-South Lockhart fault zone, Helendale section, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, https://earthquakes.usgs.gov/hazards/qfaults, accessed 12/14/2020 02:19 PM.**

Synopsis	**General:** Major Holocene active dextral strike-slip fault zone located in the Central Mojave Desert. Fault zone is divided into sections for this compilation and includes: the South Lockhart, Helendale, and Northern San Bernardino Mountains sections. Detailed reconnaissance level geologic and geomorphic mapping of the fault zone includes Dibblee (1958 #6627; 1960 #6628; 1960 #6629; 1960 #6630; 1964 #1343; 1967 #1345; 1967 #6614; 1968 #6631), Page and Moyle (1960 #6637), Morton and others (1980 #6636), Manson (1986 #6635), Bryant (1986 #6611; 1987 #6626), and Bryan (1995 #6625). Holocene slip rate has not been determined for the Helendale fault. Clark and others (1984 #2876) reported a long term (Miocene) slip rate of about 1 mm/yr, based on 1–2 km dextrally offset pluton boundary (Miller and Morton,

	1980 #6618). Onset of displacement is poorly constrained between 2 Ma and 20 Ma. Petersen and Wesnousky (1994 #6024) reported a preferred slip rate of 0.8 ? 0.7 mm/yr based on 3 km dextral offset of petrologically distinct pluton reported by Dokka (1983 #6632) and Dokka and Travis (1990 #3188) and assumed initiation of offset between 2 Ma and 20 Ma. Bryan (1995 #6625) excavated three trenches (sites 110-1 and 110-2, herein) across traces of the Helendale fault in the Lucerne Valley and exposed evidence of as many as three earthquakes since about 16.5 ka. Most recent paleoevent occurred post 2.3 ka, based on calibrated 14C age of offset alluvium reported by Bryan (1995 #6625), perhaps within the last 1–2 ka. **Sections:** This fault has 3 sections. There is insufficient data to designate seismogenic segments. Wesnousky (1986 #5305) proposed three segments for the Helendale fault (from north to south: Helendale A, B, and C) and considered the South Lockhart a separate fault. Page and Moyle (1960 #6637) inferred that the South Lockhart fault was the northern-most extension of the Helendale fault. Petersen and others (1996 #4860) combined the Helendale fault zone north of the San Bernardino Mountains and the South Lockhart fault. This compilation will delineate 3 sections: The South Lockhart section, which incorporates the South Lockhart fault; the Helendale section, which includes the principal active traces of the Helendale fault zone; and the Northern San Bernardino Mountains section, which includes the Helendale and North Branch Helendale faults south of the North Frontal thrust system [109].
Name comments	**General:** Helendale fault first mapped by Vaughn (1922 #5801) and named by Bowen (1954 #6624). South Lockhart fault first mapped and named by Dibblee (1958 #6627; 1968 #6631). **Section:** Section name is proposed in this compilation. Northern San Bernardino Mountains sections extends from near the mouth of Cushenbury Canyon southeast when it intersects with the Pipes Canyon fault of Dibblee (1967 #1345) and consists of the Helendale fault (southeast extension) of Jennings (1994 #2878) and an eastern trace Dibblee (1967 #1345; 1967 #6614) referred to as the North Helendale fault. The intersection of the Helendale-South Lockhart fault zone and North Frontal thrust system [109] is complex and there are differing interpretations as to whether the Helendale-South Lockhart fault zone is a through-going dextral strike slip fault or if north-vergent reverse displacement along the North Frontal thrust system [109] is dominant (Dibblee,

	1964 #1343; Hollenbaugh, 1968 #6634; Sadler, 1982 #6619; Bryant, 1986 #6611; Miller, 1987 #6617). Miller (1987 #6617) and Bryant (1986 #6611) mapped strands of the North Frontal thrust system as continuous across the strike of the Helendale fault [110b]. **Fault ID:** Refers to numbers 365 (South Lockhart fault), 382 (Helendale fault), and 413 (Helendale fault (southeast extension)) of Jennings (1994 #2878) and number 42 (Helendale fault) of Ziony and others (1985 #5931).
County(s) and State(s)	SAN BERNARDINO COUNTY, CALIFORNIA
Physiographic province(s)	BASIN AND RANGE
Reliability of location	Good Compiled at 1:62,500 scale. *Comments:* Locations based on digital revisions to Jennings (1994 #2878) using original mapping by Dibblee (1960 #6629; 1960 #6630; 1964 #1343) at 1:62,500; mapping by Morton and others (1980 #6636), Manson (1986 #6635), and Bryan (1995 #6625) at 1:24,000.
Geologic setting	Major Holocene active dextral strike slip fault zone located in the central Mojave Desert. The northwest-striking Helendale-South Lockhart fault zone is the westernmost of a series of sub-parallel dextral strike-slip faults in the central Mojave Desert and is part of the eastern California shear zone (Dokka and Travis, 1990 #3188). The Helendale-South Lockhart fault zone extends from its presumed junction with the Lockhart fault zone [111] about 10 km northwest of Highway 395 along the South Lockhart fault [110a] south-southeast to about 15 km northwest of Highway 15 where the South Lockhart fault may form a large right step-over to the Helendale fault. The Helendale fault bounds the southwest side of the Sidewinder Mountains, through the Lucerne Valley and into the northern San Bernardino Mountains. The complex junction between the Helendale-South Lockhart fault zone and North Frontal thrust system [109] is poorly understood. Some have mapped the Helendale fault [110b] as through-going into the San Bernardino Mountains, offsetting the North Frontal thrust system [109] (e.g. Dibblee, 1964 #1343; Hollenbaugh, 1968 #6634), while others map the North Frontal thrust system [109] as

	continuous across the Helendale fault [110b] (e.g. Bryant, 1986 #6611; Miller, 1987 #6617). Cumulative dextral displacement across the Helendale-South Lockhart fault zone may total 3 km, based on an offset 75 Ma pluton (Dokka and Travis, 1990 #3188). Miller and Morton (1980 #6618) argue that this offset pluton is dextrally offset only about 1 to 2 km. Garfunkel (1974 #6633) estimated that 10 to 15 km of dextral offset has occurred along the fault zone, based on locations of Paleozoic marine sedimentary rocks north and east of Victorville.
Length (km)	This section is 63 km of a total fault length of 135 km.
Average strike	N39°W
Sense of movement	Right lateral *Comments:* Fault exhibits well-defined geomorphic evidence of dextral strike-slip displacement (Morton and others, 1980 #6636; Manson, 1986 #6635; Bryan, 1995 #6625). Miller and Morton (1980 #6618) reported a dextrally offset pluton contact. Amount of dextral displacement is not well constrained. Dokka and Travis (1990 #3188) suggest up to 3 km of dextral offset, but Miller and Morton (1980 #6618) stated that outer contacts of the pluton have not been mapped in detail and the inferred extent of the pluton precludes a dextral offset of more than 1–2 km.
Dip Direction	V *Comments:* Trench exposures reported in Bryan (1995 #6625) indicate near vertical dip.
Paleoseismology studies	Sites 110-1 and 110-2 by Bryan (1995 #6625) involved the excavation of three fault-parallel trenches in the Lucerne Valley area in order to determine the nature and age of displacement along the southern part of the Helendale section. At the Waverly Road site (110-1) two trenches exposed evidence of latest Pleistocene and Holocene displacement. At the Rabbit Spring site (111-2), one fault-perpendicular trench across a linear scarp exposed warped and fissured Holocene lacustrine and overlying alluvial deposits.
Geomorphic expression	Helendale fault delineated by geomorphic features indicative of Holocene dextral offset such as linear scarps in late Pleistocene and Holocene alluvium, aligned springs, sidehill benches,

	truncated spurs, linear valleys, shutter ridges, dextrally deflected drainages and ridges (Manson, 1986 #6635; Bryant, 1987 #6626; Bryan, 1995 #6625).
Age of faulted surficial deposits	Fault offsets Mesozoic crystalline basement rocks, Pleistocene alluvium, and, locally, Holocene alluvium (Dibblee, 1960 #6629; 1960 #6630; 1964 #1343). Bryan (1995 #6625) exposed evidence of faulted latest Pleistocene and Holocene alluvial deposits. Calibrated radiocarbon ages indicate that most recent surface-rupturing event post-dates 2.3 ka alluvium
Historic earthquake	
Most recent prehistoric deformation	latest Quaternary (<15 ka) *Comments:* Timing of the most recent paleoevent is not well constrained. Bryan (1995 #6625) reported that the most recent event on the Helendale fault in the Lucerne Valley area (his event 3) is less than 2.3 ka, based on calibrated 14C age of 2,330+28, -189 yrs BP of detrital charcoal found in plastically deformed alluvium exposed at the Rabbit Spring site. This age is a maximum and Bryan (1995 #6625) reported that paleoevent could be as young as 1–2 ka. Bryan recognized two earlier events at the Waverly Road site: his event 2 is based on re-sheared pedogenic carbonate lining of fissure fills 14C dated at about 9.2 ka (assuming carbonate in equilibrium with atmosphere at time of deposition). Bryan reported that age of displacement probably between 7 and 11 ka. Bryan's event 1 is poorly constrained between his alluvial units 2 and 3. Unit 2 has MRT 14C date of about 16.5 ka.
Recurrence interval	
Slip-rate category	Between 0.2 and 1.0 mm/yr *Comments:* Holocene slip rate has not been determined for the Helendale fault. Clark and others (1984 #2876) reported a long term (Miocene) slip rate of about 1 mm/yr, based on 1–2 km dextrally offset pluton boundary (Miller and Morton, 1980 #6618). Onset of displacement is poorly constrained between 2 Ma and 20 Ma. Petersen and Wesnousky (1994 #6024) reported a preferred slip rate of 0.8?0.7 mm/yr based on 3 km dextral offset of petrologically distinct pluton reported by Dokka (1983 #6632)

	and Dokka and Travis (1990 #3188) and assumed initiation of offset between 2 Ma and 20 Ma. Slip rate assigned by Petersen and others (1996 #4860) for probabilistic seismic hazard assessment for the State of California was 0.6 mm/yr (with minimum and maximum assigned slip rates of 0.2 mm/yr and 1.0 mm/yr, respectively.
Date and Compiler(s)	2002 William A. Bryant, California Geological Survey Sue Perry, Southern California Earthquake Center/U.S. Geological Survey
References	#6624 Bowen, O.B., Jr., 1954, Geology and mineral deposits of Barstow quadrangle, San Bernardino County, California: California Division of Mines Bulletin 165, 208 p., 8 pls., scale 1:125,000. #6625 Bryan, K.A., 1995, Comparison of brittle vs. ductile surface deformation in an Alquist-Priolo earthquake fault zone-Example from the Helendale fault, San Bernardino County, California: San Diego, Calif., San Diego State University, unpublished M.S. thesis, 64 p., 3 pls. #6611 Bryant, W.A., 1986, Eastern North Frontal fault zone and related faults, southwestern San Bernardino County: California Division of Mines and Geology Fault Evaluation Report FER-182, microfiche copy in California Division of Mines and Geology Open-File Report 90-14, 20 p., scale 1:24,000. #6626 Bryant, W.A., 1987, Recently active traces of the Blackwater, Harper, Lockhart and related faults near Barstow, San Bernardino County: California Division of Mines and Geology Fault Evaluation Report FER-189, microfiche copy in California Division of Mines and Geology Open-File Report 90-14, 17 p., scale 1:24,000. #2876 Clark, M.M., Harms, K.H., Lienkaemper, J.J., Harwood, D.S., Lajoie, K.R., Matti, J.C., Perkins, J.A., Rymer, M.J., Sarna-Wojcicki, A.M., Sharp, R.V., Sims, J.D., Tinsley, J.C., III, and Ziony, J.I., 1984, Preliminary slip rate table and map of late Quaternary faults of California: U.S. Geological Survey Open-File Report 84-106, 12 p., 5 plates, scale 1:1,000,000. #6627 Dibblee, T.W., Jr., 1958, Geologic map of the Boron quadrangle, Kern and San Bernardino Counties, California: U.S.

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#6631 Dibblee, T.W., Jr., 1968, Geology of the Fremont Peak and Opal Mountains quadrangles, California: California Division of Mines and Geology Bulletin 188, scale 1:62,500.

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