Quaternary Fault and Fold Database of the United States

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Black Mountains fault zone, Artists Drive section (Class A) No. 142b

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Compiled in cooperation with the California Geological Survey

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Synopsis	**General:** The Black Mountains fault zone is marked by prominent Holocene and late Pleistocene scarps that are more-or-less coincident with strongly uplifted western margin of the Black Mountains in central Death Valley and their northward continuation as low hills cored by upper Tertiary sedimentary rocks. The fault zone is part of the much longer Death Valley fault system, which extends from Fish Lake Valley (Nevada) in the north, to the Garlock fault [69] in the south. The Black Mountains fault zone is characterized by primarily normal to normal-oblique along its length, and its footwall block is a spectacular example of

active tectonic uplift. The fault zone is somewhat irregular in map plan, strikes roughly north-south (on average). It joins the northwest-striking Northern Death Valley fault zone [141] and the predominately pre-Quaternary Furnace Creek fault zone on the north, and the northwest-striking Southern Death Valley fault zone [143] on the south to form a nearly continuous 300-km-long feature that is one of the most active fault systems in the region. Detailed studies of offset alluvial fans along the Black Mountains suggest normal-dip slip rates of 1-3 mm/yr as recorded by near vertical scarps as much as 10 m high on Holocene alluvium at Willow Wash, east of Mormon Point. Recurrent Holocene movement characterizes the entire fault zone, and some portions may have been active as recently as 200 years ago. Continuous scarps associated with the Black Mountains fault range from 2 to 13 km in length, and although the majority of the range front is fault controlled, active sedimentation has obscured some traces of the fault. Although no trenching studies have been conducted on the fault zone, the entire trace is well mapped, and morphometric studies suggest potentially different times of movement along the fault zone and amount of offsets in a variety of Holocene to late Pleistocene deposits.

Sections: This fault has 4 sections. In general, the Black Mountains fault zone strikes shows little evidence for major steps or potential section or segment boundaries (Machette and others, 2001 #4773). The exceptions are a large embayment in the range north of Mormon Point (Mormon Point Turtleback), a 12-13 km-long gap in terms of scarp continuity north of Natural Bridge (Klinger and Piety, 1996 #3873), and the lack of fault continuity north of Furnace Creek). Very little substantial paleoseismic work has been done to support potential subdivision of this roughly 70-km long fault zone. Various schemes have been proposed, the most recent being two sections for the south half of the fault based on scarp morphometric data (Frankel and others, 2001 #4776), six sections based on topical studies by Knott and others (2001 #4772), and eleven sections based on geometric considerations (Brogan and others, 1991 #298). Knott (1998 #5116) subdivided the range front into six distinct geometric segments based on variations in the mountain front sinuosity, mountain front-piedmont intersection profiles, range crest profile, the strike of the fault, and several other factors. For purposes of estimating the potential magnitude of future earthquakes on the Black Mountains fault zone, Knott (1998 #5116) recombined his six segments into three longer segments with lengths similar to

	the shorter historical ground ruptures reported by Wells and Coppersmith (1994 #546). The most distinct geomorphic boundaries (or anomalies) along the range, Mormon Point and Natural Bridge, separate each of these three longer segments. This is consistent with a 3-part segmentation scheme of the range-front fault based solely on scarp morphology (Klinger and Piety, 1996 #3873)). For this database, we divided the Black Mountains fault zone into three subequal length sections and include the transition zone (modified from Machette and others, 2001 #4773). This subdivision is based primarily on fault trend, structural features (bedrock salients and asperities), fault continuity, location of the fault relative to the range, and apparent recency of movement. From north to south, these are defined as the 1) Mustard Hills transition zone, 2) Artists Drive section, 3) Copper Canyon section, and 4) Smith Mountain section. Each of these are named for prominent geographic features with the section
Name comments	**General:** The Black Mountains fault zone is defined as the zone of Quaternary normal/oblique-slip faults that are more-or-less coincident with the western margin of the Black Mountains in Death Valley (Machette and others, 2001 #4773). It is the third of four fault zones that comprise the much larger Death Valley fault system of Machette and others (2001 #4773). Levi Noble (1926 #1592) first named the normal fault at the base of the Black Mountains escarpment the "Death Valley fault zone," but did not mention other faults or faulted areas to the north or south. Thus, on the basis of first usage, the fault along the front of the Black Mountains should be known as the "Death Valley fault zone" (senso stricto). Noble (1941 #1593) later mapped many of the Quaternary (i.e., post-Funeral Formation) strike-slip faults that continue north and south from the Black Mountains without naming them. Noble and Wright (1954 #1536) and Curry (1954 #1489) continued to use the term Death Valley fault zone, but designated parts of the fault zone as the "Black Mountains frontal fault" and the "Artists Drive fault." Machette and others (2001 #4773) attempted to straighten out the confusing usage of terms, and suggested using the name of the primary geographic feature (i.e., the Black Mountains) that forms the footwall of the fault zone. The northern end of the coherent range-front portion of the fault zone [142b] is considered to be about 1 km north of Furnace Creek, where the Black Mountain fault zone starts to bifurcate into a transition zone [142a] that extends about 10-12 km north of Furnace Creek (Machette and others, 2001 #4771). The southern end of the fault zone [142d] is taken as Ashford Mill (ruins), which is about 3 km east of Shore Line Butte. The portion of the

	fault between Furnace Creek and Ashford Mill coincides with the Death Valley fault of Piety (1995 #915) and Central Death Valley fault of dePolo (1998 #2845). At the latitude of Ashford Mill, the Death Valley fault system changes orientation and sense of slip, from north-trending normal-oblique on the Black Mountains fault zone [142] to southeast-trending, predominately strike-slip on the Southern Death Valley fault zone [143]. **Section:** Derived from section name suggested by Brogan and others (1991 #298). This section coincides with Knott's sections 5 and 6 (in Machette and others, 2001 #4773). In addition, our Artists Drive section includes two of Brogan and others (1991 #298) sections: most of the Golden Canyon (GO), all of the Artists Drive (AD) to the south. Our Artists Drive section [142b] extends from the south end of the Mustard Hills transition zone [142a] about 1 km north of Furnace Creek south to about 3 km north of Natural Bridges, where it the fault zone enters a bedrock salient before emerging as the Copper Canyon section [142c] at Natural Bridges. A large portion of the fault in this section juxtaposes Miocene volcanic and sedimentary rocks of the Artists Drive block against equivalent age rocks on the upthown (Black Mountains) block. **Fault ID:** Refers to the southern part of fault 211 and northern part of fault 248 of Jennings (1994 #2878), fault DV-1F and part of DV-1G of dePolo (1998 #2845), and fault DV of Piety (1995 #915).
County(s) and State(s)	INYO COUNTY, CALIFORNIA
Physiographic province(s)	BASIN AND RANGE
Reliability of location	Good Compiled at 1:100,000 scale. *Comments:* Some of the faults within this section have been mapped at 1:24,000 scale by McAllister (1970 #1572) and Wills (1989 #1693), at 1:62,500 scale by and Brogan and others (1991 #298) (using 1:12,000 scale low sun-angle photos), at 1:96,000 scale by Hunt and Mabey (1966 #1551), and at 1:100,000 scale by Reheis and Noller (1991 #1195). Recently, Machette and others (fig. B2-2, 2001 #4771) produced a detailed geologic map showing faults in the Furnace Creek area, where the Mustard Hills transition zone [142a] and Artists Drive [142b] section meet.

	The traces used herein are adapted from Brogan and others (1991 #298), and Reheis and Noller (1991 #1195) under the general context of Machette and others (fig. B2-2, 2001 #4771) for the northern boundary area of the section. The faults were transferred to a 1:100,000-scale map with topographic base.
Geologic setting	This Death Valley fault system is comprised of major strike-slip fault zones on the north and south, and an intervening (linking) primarily normal fault zone. The fault system is comprised of the Fish Lake Valley fault zone [49], the Northern Death Valley fault zone [141], the Black Mountains fault zone [142], and the Southern Death Valley fault zone [143]. The fault system forms the strongly uplifted eastern margin of Death Valley and the western margin of Fish Lake Valley and marks a highly extended portion of the western Basin and Range Province. Structural studies by Stewart (1983 #1653) and Wernicke and others (1988 #1686) reported >80 km of northwestward extension across the valley, and proposed that much of the adjacent Panamint Range to the west has moved to its present location from atop the Black Mountains since late Miocene time. The Black Mountains fault zone is more-or-less coincident with the uplifted western margin of the Black Mountains and is characterized by primarily normal to oblique-slip along its entire length. The Black Mountains fault zone, which strikes about north, joins the northwest-striking Northern Death Valley fault zone [141] and the predominately pre-Quaternary Furnace Creek fault zone to form a nearly continuous feature that is one of the most active fault systems in the region.. Noble (1926 #1592) described, the Black Mountains fault zone (his Death Valley fault) as irregular in detail, with a zigzag pattern that results from a succession of faults that displace each other and create indented "cusps" along the front of the Black Mountains. Similarly, Hamilton (1988 #593) suggested that the fault is not likely a single steep range-front fault, but is probably "a series of step faults or the downdip continuation of the turtleback faults or a combination of steep and gentle faults." Estimates of vertical displacement on the Black Mountains fault zone range between 2 and 20 km. These estimates are based on a variety of stratigraphic and structural markers of different ages, as discussed by Piety (1995 #915). Fleck (1970 #1514) concluded that most of the vertical displacement on the fault zone probably occurred since about 6 Ma (before deposition of the Furnace

	Creek Formation), although Death Valley may have begun to form before this time. The maximum age for the onset of faulting is assumed by Brogan and others (1991 #298) to be middle Miocene on the basis of K-Ar ages for displaced volcanics believed to be coeval with faulting.
Length (km)	This section is 22 km of a total fault length of 70 km.
Average strike	N25°W (for section) versus N17°W (for whole fault)
Sense of movement	Normal *Comments:* This section has predominately normal movement with suggestions of oblique movement owing to a dextral (right-lateral) component. Wills (1989 #1693) considered the Black Mountains fault zone a "right-oblique fault with the west-side down." Wills (1989 #1693) reasoned that numerous small gullies that cross at about 30? clockwise to the fault south of Breakfast Canyon indicate right-lateral displacement (e.g., tension fractures or Reidel shears along a right-lateral fault). Wills (locality 4 1989 #1693) also noted right-lateral deflection of small drainages along the Artists Drive section east of Desolation Canyon. Slemmons and Brogan (1999 #5115) suggest that the evidence for lateral slip on the Black Mountains fault zone is more persuasive than generally recognized and suggest that the fault is oblique-normal in accord with the pull-apart origin of Death Valley suggested by Burchfiel and Stewart (1966 #1322).
Dip	40°-75° W *Comments:* There are no reported fault dip angles for this section of the Black Mountains fault zone, but are inferring 40?-75? as a general angle (and as reported for the Copper Canyon section [142c] of the fault zone). Noble (1926 #1592) noted that fault planes, where they are exposed in bedrock, are nearly vertical. On the basis of near-vertical fault scarps on alluvial surfaces and a steep fault-line scarp, Miller (1991 #1579) inferred that the Black Mountains fault zone near Badwater (to the north) dips at least 60? W. Drewes (1963 #1501) reported that dips of 40? W. to 55? W. are common on individual fault planes along the fault zone, but that dips of up to 75? SW. were observed southwest of Badwater and near Mormon Point.
Paleoseismology	

studies	
Geomorphic expression	The maximum slope angle reported by Brogan and others (table 4 1991 #298) for scarps on late Holocene surfaces is 57? with a maximum vertical separation of 2.3 m. This scarp is along the Golden Canyon section of Brogan and others (1991 #298), just south of Furnace Creek Wash, and may represent two surface-rupturing events according to Brogan and others (1991 #298). Maximum vertical separations of about 5.0 m and scarp angles of 48?-50? characterize the largest, scarps on older Holocene (2 ka to 10 ka; unit Q1C; table 2) surfaces along this section (table 4, pl. 3 Brogan and others, 1991 #298).
Age of faulted surficial deposits	Wills (1989 #1692) noted that the "fresh scarps are especially well developed near the mouth of Golden Canyon." Brogan and others (1991 #298) speculated that the youngest surface rupture on the Black Mountains fault zone occurred on their Golden Canyon section (immediately south of Furnace Creek Wash) and may be nearly historical. They based this age estimate on the lack of varnish on the youngest disrupted surface, the preservation of scarps that have free faces that "persist only a few hundred to a few thousand years," and on the gradational contact between faulted and unfaulted alluvium (Brogan and others (1991 #298). Hunt and Mabey (1966 #1551) also suggested that the youngest surface rupture on the Black Mountains fault zone occurred on this section (about 2 km south of Furnace Creek Wash between Breakfast Canyon and Golden Canyon) and must be prehistoric (pre late 19th Century) because Indian mesquite storage pits have been constructed in "colluvium that overlaps the scarp" (site 85-56, circle D in Hunt, 1960 #1550). The circular pits were probably built during or after Death Valley III occupation (<2 ka) (Hunt, 1960 #1550). Hunt also concluded that the surface rupture that formed the fault scarp was "sufficiently older than the circles for the [scarp] to have weathered enough to produce the colluvial slope."
Historic earthquake	
Most recent prehistoric deformation	latest Quaternary (<15 ka) *Comments:* Following reconnaissance in the region in the early 1920's, Noble (1926 #1592) noted that the scarps along the Black Mountains fault zone were "fresher than any other scarps of similar magnitude in the West" comparing them to scarps he had

	observed along the Garlock and San Andreas faults. Jennings (1992 #473) portrayed nearly the entire Black Mountains fault zone (between Furnace Creek Wash or Salt Springs and south of Jubilee Pass) as having Holocene (<10 ka) displacement. Wills (1989 #1693) noted that the evidence for Holocene displacement on the fault zone is "abundant." Geologic studies by Hunt and Mabey (1966 #1551) and Brogan and others (1991 #298), as well as archeological age control by Hunt (1960 #1550), all suggest that the most recent surface rupturing on the Artists Drive section of the Black Mountains fault zone only a few hundred to a few thousand years ago. Considering Machette and others (1999 #3874; 2001 #4771) morphometric estimate of 500- to 600-year formation times for less-fresh appearing scarps in the Mustard Hills transition zone, then the very fresh scarps along the Artists Drive section seem to be clearly of late Holocene age, and may have occurred as recently as several hundred years ago, but before the late 19th Century when Death Valley become populated (albeit sparsely) by relatively continuous ranch settlements (Nelson, in Machette and others, 2001 #4433).
Recurrence interval	650-1000 yrs (0-2 k.y.) *Comments:* Piety (1995 #915) states that assuming that three or more surface ruptures have occurred on the Black Mountains fault zone during the late Holocene (<2 ka) as reported by Brogan and others (p. 19, 1991 #298), the maximum recurrence interval for surface-rupturing events is about 650 yr. Brogan and others (1991 #298) concluded this number of events from three distinct scarps that are preserved on late Pleistocene surfaces. They inferred that these scarps represent three separate events on their Artists Drive section. Without dating of specific faulting events, the above calculation of recurrence is somewhat problematic. It seems more likely that if 3 events occurred in 2 k.y., then the average recurrence interval should be >650 years (<3 full recurrence intervals in 2 k.y) to <1000 years (>2 full recurrence intervals in 2 k.y).
Slip-rate category	Between 1.0 and 5.0 mm/yr *Comments:* Piety (1995 #915) attempted to estimate slip rates using the range of maximum vertical separations of 0.15 to 2.3 m in deposits estimated to be 0.2 ka to 2 ka as reported by Brogan and others (table 4, p. 21 1991 #298), which yielded apparent vertical slip rate ranges of 0.08 to 11.5 mm/yr for the late

	Holocene. These rates are unconstrained (open-ended recurrence interval) and based on an extremely wide time frame. Using a range of maximum vertical surface separations of 1.5 to 5 m that is reported by Brogan and others (1991 #298) for older Holocene (2 ka to 10 ka) surfaces, Piety (1995 #915) also calculated an apparent vertical slip rate of 0.15 to 2.5 mm/yr is estimated for DV during the Holocene. The above cited rates are fraught with problems, but the general range in values, apparent recency for movement, and evidence for multiple faulting events in the older (2-10 ka) deposits, all this suggest that rates could be 1-5 mm/yr, as documented on the next fault section [142c] to the south.
Date and Compiler(s)	2001 Michael N. Machette, U.S. Geological Survey, Retired Lucy A. Piety, U.S. Bureau of Reclamation
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