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Black Mountains fault zone, Smith Mountain section (Class A) No. 142d

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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:** Name derived from prominent mountains (Smith Mountain) that form the footwall block of this section of the fault zone. This section coincides with Knott's section 1 and 2 (in Machette and others, 2001 #4773) and southern part of Frankel's (2001 #4776) medium-age fault section. In addition, the Smith Mountain section includes three of Brogan and others (1991 #298) sections: Gregory Peak (GP), North Ashford Mills (NM), and the South Ashford Mills (SM). The Smith Mountain section extends from Mormon Point south to Ashford Mills, east of Shoreline Butte. **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:* Faults within this section have been mapped at 1:24,000 scale by Wills (1989 #1693), at 1:62,500 scale by and Brogan and others (1991 #298) (using 1:12,000 scale low sun-angle photos), and at 1:100,000 scale by Reheis and Noller (1991 #1195). The traces used herein are adapted from Brogan and others (1991 #298), and Reheis and Noller (1991 #1195). 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 16 km of a total fault length of 70 km.
Average strike	N23°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." He noted that a drainage about 9 km south of Mormon Point (locality 11, Wills, 1989 #1693) has been right-laterally deflected about 170 m. Brogan (1991 #298) recognized little geomorphic evidence for lateral displacement between Mormon Point and Cinder Hill (their Gregory Peak and North Ashford Mill sections). However, 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). Hill and Troxel (1966 #1539) reported striations that plunge about 30? NW on fault surfaces along this section of the Black Mountains fault zone and interpreted these striations as indicating right-lateral displacement.
Dip	40°-75° W *Comments:* There are no reported fault dip angles for this portion 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. Hill and Troxel (1966 #1539) reported striations that plunge about 30? NW but did not report any associated dips along this section of the Black Mountains fault zone. The mapping of Wright and Troxel (1984 #1700) does not show any fault attitudes for this section.
Paleoseismology studies	
Geomorphic	This section of the fault zone contains classic examples of active

expression	tectonic features, including (but not limited to) fault scarps and grabens, lateral spread features, uplifted lacustrine gravel and tufa, and rockfall-avalanche deposits. Owing to the relative youthfulness of the faulted deposits, most of the scarps only record offsets of several meters. Maximum vertical separations across scarps along the main trace range between 6.6 m and 8.8 m along the North Ashford Mill and Gregory Peak sections, respectively, of Brogan and others (1991 #298). Maximum slope angles for these scarps are 30?-40? (Brogan and others, 1991 #298). In addition to these young small scarps, there is about 200 m of vertical relief across a dissected west-facing compound fault scarp at the Black Mountains range front about 8 km south of Mormon Point (Brogan and others, 1991 #298). Brogan and others (1991 #298) reported roughly en echelon fresh scarps in young alluvium along the southern part of this section. Wills (1989 #1693) confirmed these relations and measured a scarp with a height of 0.6 m and a maximum slope angle of 26?.
Age of faulted surficial deposits	Along this section of the fault, most of the deposits that lie juxtaposed to the fault zone are relatively young (late Pleistocene and Holocene), whereas older deposits are either preserved as uplifted remnants of one more extensive deposits, or are deeply buried by younger debris. These geomorphic relationships have long been recognized as the hallmarks of active tectonic uplift along the front of the Black Mountains, compared with the more passive eastern front of the Panamint Range. However, Pliocene to Pleistocene alluvial and sedimentary deposits are still preserved along this section of the fault zone. Fault scarps on surfaces underlain by interlayered basalt, breccia, and fanglomerate thought by Noble (1941 #1593) to be Pliocene(?) east of Cinder Hill about 13 km south of Mormon Point and just north of Shore Line Butte (Brogan and others, 1991 #298) record about 80 m of vertical relief along the Black Mountains fault zone.
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" and reported a young scarp with a height of 0.6 m and a maximum slope angle of 26?. These morphometric data indicate a late Holocene time for the most recent faulting event along the section, as based on a comparison with other late Holocene fault scarps in the Mustard Hills transition zone [142a] at the northern end of the Black Mountains fault zone (Machette and others, 2001 #4771).
Recurrence interval	
Slip-rate category	Between 1.0 and 5.0 mm/yr *Comments:* (p. 988-989, Noble, 1941 #1593) concluded that northwest-striking fault traces in southern Death Valley between Shore Line Butte (his Shoreline Hill) and Ashford Mill displace (laterally?) Quaternary alluvium commonly not more than 15 m (50 ft), which is much less than the amounts of displacement he noted in the underlying Funeral Formation. However, no displacement data has been reported from dated piercing points along this section of the fault zone. Lacking such data, we can only rely on comparisons with the reported or inferred slip rates on the fault sections to the north ([142c], Copper Canyon section of the Black Mountains fault zone) and south ([143a], Confidence Hills section of the Southern Death Valley fault zone). Since these fault sections are categorized as having 1-5 mm/yr of slip, we infer the same rate for the intervening Smith Mountains section of the Black Mountains fault zone.
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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