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Southern Death Valley fault zone, Nobel Hills section (Class A) No. 143b

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Compiled in cooperation with the California Geological Survey

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Synopsis	**General:** The Southern Death Valley fault zone (SDV) is comprised of dextral-slip faults that extend southeast from Cinder Hill and Shoreline Butte, both of which shows clear evidence of right-lateral offset. The SDV is the southern of four fault zones that comprise the much longer Death Valley fault system. From north to south, these include the north-trending Fish Lake fault zone [49] in western Nevada and easternmost California, the northwest-trending Northern Death Valley fault zone [141], the north-trending Black Mountains fault zone [142], and the Southern Death Valley fault zone [143]. It has been long proposed

that right-lateral displacement on the northwest-striking SDV [143] and NDV [141] fault zoned has resulted in tension that caused the two sides of Death Valley to pull apart along the north-trending Black Mountains fault zone [142], thus forming the deep trough of the present Death Valley. The SDV is distinguished from the Black Mountains fault zone by its more northwesterly trend (about N 40? W) and almost pure dextral sense of slip. Neogene movement on the SDV has offset upper Cenozoic to Quaternary volcanic and sedimentary deposits throughout southern Death Valley (its namesake). Estimates of the total right-lateral displacement on the SDV range between 8 km (in Quaternary sediment) and about 50 km (in old rocks). These estimates are based on a variety of stratigraphic and structural markers of different ages. The SDV can be traced southeast to nearly the Garlock fault zone [69], where it is truncated, bent and has had young reverse slip on some of its strands. An offset continuation of the SDV may extend as far south to the Bristol and Old Dad Mountains, although it is unclear whether or not there is Quaternary movement along this portion of the fault zone. Much of the SDV is characterized by very linear right-lateral fault traces with abundant evidence for Holocene surface ruptures. The Confidence Hills are sandwiched between two strands of the SDV, which has resulted in strong deformation and folding of the sediments. South of the Confidence Hills, the SDV begins to splay out into several strands as it approaches the Garlock fault zone. Holocene activity on two main strands appears to die out near the north end of the Noble Hills, but several additional traces with Quaternary displacement extend to within a few kilometers of the Garlock fault zone.

Sections: This fault has 2 sections. Owing to changes in fault position, complexity, and evidence for young movement, we have subdivided the Southern Death Valley fault zone into two sections. The northern (Confidence Hills) section extends from the north margin of Cinder Hill to the south end of the Confidence Hills (ca. N 35?50') as suggested by Wright and Troxel (1984 #1700). The southern (Nobel Hills) section continues south from the Confidence Hills through and along the Nobel Hills to the northern margin of the Avawatz Mountains and its junction with the Garlock fault zone [69]. This point is roughly coincident with the boundaries between T. 18/17 N. and R. 5/6 E. The fault zone may continue further south to the Soda Mountains as suggested by Brady (1988 #1452), where evidence for young movement on the fault appears to be buried beneath sediment of Silver Lake

	playa. However, there does not appear to be abundant evidence for Quaternary movement along this extension of the fault, and thus this portion of the SDV is not included herein.
Name comments	**General:** The Southern Death Valley fault zone (SDV) is defined as the zone of Quaternary dextral slip faults first recognized by Noble (1941 #1593) that extends southeast from Cinder Hill and Shoreline Butte to the Garlock fault zone [69] on the northern margin of the Avawatz Mountains (Machette and others, 2001 #4773). The SDV is more-or-less coincident with the axis of southern Death Valley, though which the Amargosa River enters Death Valley. The SDV has been referred to as the Confidence Hills fault zone by Drewes (1963 #1501) and Hunt and Mabey (1966 #1551), but more commonly was included with the Death Valley fault zone (Jennings and others, 1962 #498; Stewart, 1967 #1652; Wright and Troxel, 1967 #1698; Davis, 1977 #1491; Brady, 1986 #1450; Hart and others, 1989 #1532; Wills, 1989 #1693). It is the southern (fourth) of four fault zones that comprise the much larger Death Valley fault system (Machette and others, 2001 #4773). The northern end of the SDV is considered to be at Cinder Cone (about 3 km northwest of Shoreline Butte), where the fault system changes from normal and oblique-slip on the north-trending Black Mountains fault zone [143] to predominately strike slip along a S 40? E trend. The southern end of the SDV is poorly defined and mapped. Quaternary movement is clearly expressed to as far south as its intersection with the Garlock fault [69] (Butler, 1984 #1464; Brady, 1986 #1451), but the fault zone may extend considerably farther, perhaps to the Bristol and Old Dad Mountains (Brady, 1988 #1452). **Section:** The Nobel Hills (southern) section extends from north of Cinder Hill (west of the southern section of the Black Mountains fault zone [142d]) to the south end of the Confidence Hills (ca. N 35? 52' 30"N) as suggested by Wright and Troxel (1984 #1700). The portion of the fault has long been known as the Confidence Hills fault zone (Wright and Troxel, 1984 #1700), but is herein considered to be the northern part of the longer Southern Death Valley fault zone (Machette and others, 2001 #4773). Butler (1984 #1464) subdivided subparallel traces of the Southern Death Valley fault zone between the Confidence Hills and the southern Owlshead Mountains into a western fault subzone along the eastern side of the Owlshead Mountains and an eastern fault subzone within southern Death Valley. Brogan and others (pl. 4, 1991 #298) suggested that their South Ashford Mill section and

	possibly their Gregory Peak and North Ashford Mill sections may be part of the SDV, but they recognized little geomorphic evidence for lateral displacement along this part of the fault. Thus, their sections are included in the Black Mountain fault zone [142] for his database. **Fault ID:** Refers to southern part of fault 248 of Jennings (1992 #473), fault DV-1G by dePolo (1998 #2845), and fault SDV of Piety (1995 #915).
County(s) and State(s)	INYO COUNTY, CALIFORNIA SAN BERNARDINO COUNTY, CALIFORNIA
Physiographic province(s)	BASIN AND RANGE
Reliability of location	Good Compiled at 1:100,000 scale. *Comments:* Location of most active fault traces along the Nobel Hills section were depicted on 1:24,000-scale topographic maps by Wills (1989 #1693). His traces are based on inspection of 1:12,000 scale low-sun-angle photographs, and 1:20,000 and 1:24,000 scale vertical aerial photographs, as well as reconnaissance geologic mapping and limited field checking. These fault traces were transferred by inspection to a 1:100,000 scale base map by the compiler. In addition, the fault studies have been supported by reconnaissance geologic mapping by Brady (1986 #1450) and detailed geologic mapping by Troxel (1986 #1678).
Geologic setting	The Southern Death Valley fault zone (SDV) is the southern of four fault zones that comprise the much longer Death Valley fault system. From north to south, these include the north-trending Fish Lake fault zone [49] in western Nevada and easternmost California, the northwest-trending Northern Death Valley fault zone [141], the north-trending Black Mountains fault zone [142], and the Southern Death Valley fault zone [143]. The SDV is the dextral-slip fault zone that extends from Cinder Hill and Shoreline Butte, both of which shows clear evidence of right-lateral offset, southeast to the Confidence Hills. At Shoreline Butte, the Death Valley fault system changes strike from north on the Black Mountains fault zone [142] to southeast on the Southern Death Valley fault zone [143] and the predominate slip direction becomes dextral rather than normal

oblique. Along the majority of its trace, older alluvium is faulted against strongly deformed and uplifted Pliocene to Pleistocene lacustrine deposits (Troxel and Butler, 1986 #2376; Wills, 1989 #1693). South of the Confidence Hills, much of the trace of the SDV is obscured by young (Holocene) alluvium, and the fault trace becomes discontinuous south to around the junction of State Highway 127 (from the Harry Wade Monument to Ashford Mills), and the road west to Owl Hole Springs, on the north margin of the Nobel Hills (Noble Hills section [143b]).

According to different authors (and interpretations), the length of the Southern Death Valley fault zone ranges between about 50 km and greater than 300 km. The fault zone is about 3 to 6.5 km (2 to 4 miles) wide in southern Death Valley between the Owlshead and Avawatz Mountains (Noble and Wright, 1954 #1536). It is nearly 2.5 km wide in the northern Avawatz Mountains and extends at least 20 km south of the Avawatz Mountains beneath Quaternary sediment in Silver Lake Valley to the southern Halloran Hills (Brady, 1986 #1450; 1986 #1451), which would make the total length of fault zone would be about 85 km.

Neogene movement on the SDV has offset upper Cenozoic to Quaternary volcanic and sedimentary deposits throughout southern Death Valley (its namesake). Estimates of the total right-lateral displacement on the SDV range between 8 and 20 km (in Quaternary to Pliocene sediment) to about 50 km (in old rocks). These estimates are based on a variety of stratigraphic and structural markers of different ages. Brady (1986 #1451) concluded, on the basis of structural and sedimentological evidence, that the minimum right-lateral displacement across the SDV during the Pliocene and Pleistocene is 20 km. He also concluded that the amount of deformation increases from northwest in the Confidence Hills to southeast along the Noble Hills where the greatest displacement is on the eastern traces of the SDV (Brady, 1986 #1451). Brady [, 1986 #1451) reported that clasts in a granite-bearing conglomerate on the eastern side of the Noble Hills were derived from the Owlshead Mountains, 8 km to the northwest. The conglomerate was moved to its present position by right-lateral displacement on the SDV, so that 8 km is the minimum amount of right-lateral displacement on an eastern trace of SDV at Denning Spring Wash in the Noble Hills since the clasts were deposited (Quaternary?).

In summary, there seems to be a general consensus for 8 to 20 km

	of Pliocene to Pleistocene strata along this and the southern section of the SDV. However, there is little firm data on ages of piercing points along the fault zone.
Length (km)	This section is 34 km of a total fault length of 50 km.
Average strike	N43°W (for section) versus N43°W (for whole fault)
Sense of movement	Right lateral *Comments:* The Southern Death Valley fault zone is distinguished from the Black Mountains fault zone [142] by its more northwest trend (nearly N 50? W) and almost pure dextral sense of slip. Displacement on the SDV has been predominantly right-lateral (Hill and Troxel, 1966 #1539). Wills (locality 16, 1989 #1693) noted that a drainage along a trace the southern section of the has been displaced right-laterally 1.2 m in each of two surface ruptures. Directly east of this locality on another trace of the SDV, Wills (locality 17, 1989 #1693) reported 27 m of right-lateral deflection of an entrenched (i.e., young) drainage and 3 m of right-lateral displacement of a smaller drainage. In addition, the apparent sense of normal movement on the fault alternates along strike, suggesting that the lateral component of slip is predominant.
Dip	90° V *Comments:* The dip is inferred to be vertical or near vertical on the basis of the fault's straight trace (Burchfiel and Stewart, 1966 #1322; Butler, 1984 #1464). However, as the SDV approaches the Garlock fault zone [69] its traces appear to be bent and have a component of young reverse movement (Butler and others, 1988 #1468).
Paleoseismology studies	
Geomorphic expression	Much of the Southern Death Valley fault zone (SDV) is characterized by very linear right-lateral fault traces that have evidence for Holocene and late Pleistocene surface ruptures. South of the Confidence Hills, the SDV begins to splay out into several strands as it approaches the Garlock fault zone [69] (Machette and others, 2001 #4773). Wills (1989 #1693) reported that the SDV along the northeastern side of the Noble Hills is expressed as scarps and tonal lineaments on young alluvial

	surfaces, indicating some Holocene displacement on this part of the fault. Holocene activity on two main strands appears to die out near the northern end of the Noble Hills (Brady, 1986 #1450; Wills, 1989 #1693). Several additional traces with Quaternary displacement extend to within a few kilometers of the Garlock fault zone.
Age of faulted surficial deposits	Brady (1986 #1451) reported that the SDV along the Noble Hills consists of six main branches along which Cenozoic sediments have been tectonically juxtaposed against crystalline basement rocks. Displacement on these branches has formed and uplifted the Noble Hills, with the youngest displacement on the eastern branches (Brady, 1986 #1451). However, because Brady (1986 #1450) thought that the age of Death Valley is constrained by the age of the Furnace Creek Formation, which was suggested by Hunt and Mabey (1966 #1551) to have a maximum age of 5 Ma, he speculated that initial displacement on the SDV occurred about 5 Ma.
Historic earthquake	
Most recent prehistoric deformation	latest Quaternary (<15 ka) *Comments:* Jennings (1992 #473) portrayed displacement on some traces as Holocene (<10 ka) as indicated by sag ponds, uneroded scarps, displaced stream channels, and shutter ridges, some of which are on surfaces thought to be Holocene. Hart (table 1, 1989 #1532) described SDV as "moderately to well defined by side-hill troughs, benches, and right-laterally deflected drainages." Displacement on other traces are shown by Jennings (1992 #473) as late Quaternary (<700 ka) or Quaternary (<1.6 Ma). Holocene activity on two main strands appears to die out near the north end of the Noble Hills (Brady, 1986 #1450; Wills, 1989 #1693), which suggests that this section is not as active as the Confidence Hills section [143a] to the north. However, Brady (1986 #1450) reported that the eastern branch of SDV between Pipeline Wash and Cave Spring Wash in the northern Avawatz Mountain cuts Quaternary alluvial-fan deposits (his Qf2 unit with an estimated age of early Holocene to late Pleistocene, 8 ka to 15.5 ka) and is expressed as a series of right-stepping shutter ridges. Although, Brady (1986 #1450) recognized that this displacement could be as young as 8 ka, he speculated that most of the displacement in this area occurred between 1 Ma and 2 Ma. Noble (1941 #1593) (p. 960) reported that alluvial-fan deposits east of Sheep Creek

	Spring at the base of the northeastern side of the Avawatz Mountains are displaced by "recent faults." Brady (1986 #1451) noted that the Pleistocene (>15.5 ka) alluvial fans (his Qf1 unit) on the eastern and northern sides of the Avawatz Mountains have been deformed and uplifted, as well as deeply dissected. The fans have also prograded northward, partially burying the Saddleback and Ibex Hills and deflecting the course of the Amargosa River. He attributed these characteristics to uplift of the Avawatz Mountains that occurred during and shortly after deposition of the alluvial fans. Brady (1986 #1451) reported that SDV along the Noble Hills consists of six main branches along which Cenozoic sediments have been tectonically juxtaposed against crystalline basement rocks. Displacement on these branches has formed the Noble Hills, with the youngest displacement on the eastern branches (Brady, 1986 #1451). Because Brady (1986 #1450) thought that the age of Death Valley is constrained by the age of the Furnace Creek Formation, which is suggested by Hunt and Mabey (1966 #1551) to have a maximum age of 5 Ma, he speculated that initial displacement on SDV occurred about 5 Ma.
Recurrence interval	
Slip-rate category	Between 1.0 and 5.0 mm/yr *Comments:* Holocene activity on two main strands appears to die out near the north end of the Noble Hills (Wills, 1989 #1693), which suggests that this section is not as active as the Confidence Hills section [143a]. Using the observations by Brady (1986 #1451) that early Holocene to late Pleistocene (8 ka to 15.5 ka) alluvial-fan deposits are displaced laterally <0.5 km, a maximum apparent lateral slip rate of 32 to 63 mm/yr can be estimated for SDV in the Noble Hills. Brady (1986 #1451) estimated that late Pleistocene-early Holocene alluvial-fan deposits (unit Qf2, 8 ka to 15.5 ka; table 1) near Pipeline Wash in the Noble Hills in the northern Avawatz Mountains have a cumulative lateral displacement of <0.5 km on western traces of the SDV. This estimate is based on the inference that "dioritic" clasts included in the deposits were probably derived from the eastern Avawatz Mountains. Using the observations by Brady (1986 #1451), Piety (1995 #915) calculated that early Holocene to late Pleistocene (8 ka to 15.5 ka) alluvial-fan deposits are displaced laterally <0.5 km, which yields a maximum apparent lateral slip rate of 32 to 63 mm/yr for SDV in the Noble Hills. This rate, which almost an

	order of magnitude greater than the maximum rates recorded elsewhere along the Death Valley fault system (and greater than the San Andreas fault zone [1]) seems wrought with potential errors, and should not be used. Wills (locality 16, 1989 #1693) noted that a drainage along a trace the southern section of the SDV (the eastern subzone of Burchfiel (1966 #1322) and Butler (1984 #1464) has been displaced right-laterally 1.2 m in each of two surface ruptures. Directly east of this locality on another trace of the SDV, Wills (locality 17, 1989 #1693) reported 27 m of right-lateral deflection of an entrenched (i.e., young) drainage and 3 m of right-lateral displacement of a smaller drainage. So, although there have been a number of measurements of Quaternary and younger offset along the SDV (and its individual strands), there are no definitive age/offset data to compute a slip rate. However, with the present of clear Holocene activity and consideration of slip rates on the Black Mountain fault zone [142] to the north, we categorize the SDV as having a tentative lateral slip rate of 1-5 mm/yr.
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