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Southern Death Valley fault zone, Confidence Hills section (Class A) No. 143a

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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 Confidence Hills (northern) 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. 41991 #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 this 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
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 Confidence 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 geologic mapping at a scale of 1:24,000 (Burchfiel and Stewart, 1966 #1322; Wills, 1989 #1693; Gomez and others, 1992 #2392).
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 18 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 (N 40? W) and almost pure dextral sense of slip. Noble (1954 #1536) interpreted displaced streams as indicating right-lateral displacement. Troxel and Butler (1986 #2376) (p. 25) reported that the two strands of SDV that bound the Confidence Hills appear to be left-stepping, right-lateral faults and concluded that the folds in the Confidence Hills are a result of transpression between these two strands. However, Pluhar and others (1992 #1599) found, on the basis of paleomagnetic data, that the lake sediments that compose the Confidence Hills have not undergone net tectonic rotation as might be expected. Wills (1989 #1693) suggested that SDV has a minor vertical component of displacement, but documented clearly predominant dextral slip. Displacement on the western subzone of the SDV of Burchfiel and Stewart (1966 #1322) between the Confidence Hills and the southern Owlshead Mountains has been predominantly right-lateral strike-slip, whereas displacement on the eastern subzone has been both lateral (dextral) and vertical.
Dip	35°-90° NE *Comments:* Dips vary between 35? to 65? to the east and northeast in natural exposures on the western subzone of Burchfiel and Stewart (1966 #1322). However, on the basis of the fault's straight trace the dip is inferred to be vertical or near vertical on the eastern subzone of Burchfiel and Stewart (1966 #1322).
Paleoseismology studies	
Geomorphic expression	Much of the Southern Death Valley fault zone (SDV) is characterized by very linear right-lateral fault traces with abundant evidence for Holocene or late Quaternary surface

	rupture. Cinder Hill and Shoreline Butte at the north end of the SDV, both of which show clear evidence of right lateral, offset (Wright and Troxel, 1984 #1700). Wills (1989 #1693) reported fault scarps and a side-hill trough on the basalt of Shore Line Butte that are "considerably sharper and "fresher" than adjacent Pleistocene shorelines and may truncate those shorelines." These geomorphic features align with scarps on late Pleistocene alluvial surfaces south of Shoreline Butte (Wills, 1989 #1693), indicating lateral continuity to the southeast. However, discontinuous strands of the SDV that extend through Shoreline Butte north to Cinder Hill, west of the junction of the SDV [143] and Black Mountains [142] fault zones, apparently were not active during the most recent movement of the SDV evidenced farther south, in the Confidence Hills. The highly deformed sedimentary rocks of the Confidence Hills are sandwiched by localized compression between two strands of the Southern Death Valley fault zone. Wills (1989 #1693) reported that a scarp at the southern end of the Confidence Hills is 1.8 m high and has a maximum slope angle of 28?. 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 11989 #1532) described the SDV as "moderately to well defined by side-hill troughs, benches, and right-laterally deflected drainages."
Age of faulted surficial deposits	Wright and Troxel (1984 #1700) portrayed the SDV across Shore Line Butte and in the northern Confidence Hills as displacing Quaternary gravel (their Qg1 deposits, deeply dissected and slightly deformed) but not Qg2 deposits (moderately dissected, undeformed). The Qg1 gravels were probably deposited between <1.5 Ma and >0.69 Ma, because the Qg1 gravels abut a basalt tentatively correlated with the basalt on Shore Line Butte (1.5 Ma) and because tephra from the eruption forming Cinder Hill (0.69 Ma) overlies the eroded surface of the Qg1 gravels. Wright and Troxel (1984 #1700) also showed the SDV in this area as displacing older deposits, Pliocene and Pleistocene Funeral Formation (their QTfc and QTfs units) and the volcanic rocks at Shore Line Butte and Cinder Hill. The map by Wright and Troxel (1984 #1700) shows traces of the SDV in this area as concealed by younger Quaternary gravels (their Qg3 unit), which are undeformed and relatively undissected. North-northwest-striking fault traces north of the Amargosa River are portrayed by Wright and Troxel (1984 #1700) as displacing the Qg3 gravels. Quaternary displacement on the northern end of the eastern

	subzone of Burchfiel and Stewart (1966 #1322) and Butler (1984 #1464) is recorded by uplifted and tilted basalt flows on Shore Line Butte and by right-lateral displacement of Cinder Hill about 3 km north of Shore Line Butte (Noble, 1941 #1593; Burchfiel and Stewart, 1966 #1322; Hill and Troxel, 1966 #1539). The basalt flows on Shore Line Butte have been radiometrically dated at 1.5 Ma (K-Ar whole rock), whereas the andesite that forms Cinder Hill yielded a date of 0.69 Ma (K-Ar whole rock) (Wright and Troxel, 1984 #1700). These rocks have been the subject of continued dating, and seemingly have become progressively younger as dating techniques improve. The Cinder Hill basalt has a new Ar-Ar date of about 300 ka (Larry Snee, U.S. Geological Survey, written commun. to Ren Thompson, 1999). Noble (1941 #1593) 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 #1450) reported that the eastern branch of the SDV between Pipeline Wash and Cave Spring Wash in the northern Avawatz Mountain cuts late Quaternary alluvial-fan deposits (his Qf2 unit; estimated 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 latest Quaternary, he speculated that most of the displacement in this area occurred between 1 Ma and 2 Ma. Folding and faulting of the lake beds that compose the Confidence Hills indicate substantial Quaternary displacement on the SDV because these lake beds are thought to be 2 Ma (Troxel, 1986 #1678), 1.5 Ma (Wright and Troxel, 1984 #1700), or younger (Troxel and Butler, 1986 #2376). Detailed work utilizing paleomagnetics and tephrochronology led Gomez and others (1992 #2392) to conclude that these lake sediments were deposited between at least 2.2 Ma and <1.5 Ma.
Historic earthquake	
Most recent prehistoric deformation	latest Quaternary (<15 ka) *Comments:* Wills (1989 #1693) interpreted a maximum scarp-slope angle of 28? on a 1.8-m-high scarp preserved on an alluvial surface at the southern end of the Confidence Hills as suggesting Holocene displacement on the SDV. 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. On the northern part of the section, evidence of late Quaternary displacement is more common. Thus, the youngest displacement on at least part of the SDV may be Holocene, whereas others traces may be older (latest to late Pleistocene).
Recurrence interval	
Slip-rate category	Between 1.0 and 5.0 mm/yr *Comments:* Noble (1941 #1593) noted right-lateral displacement of "several hundred feet" (i.e., 60-100? m) on a fault trace that parallels the Confidence Hills anticline along the crest of the Confidence Hills. This amount of displacement was interpreted from northeastward-draining stream channels that are sharply deflected in a right-lateral direction where they cross the fault (Noble, 1941 #1593). Noble (1941 #1593) noted vertical as well as right-lateral displacement on this trace, but had no age date to compute slip rates. Burchfiel and Stewart (1966 #1322) noted that right-lateral displacement across two fault traces at the northern end of their eastern subzone has been "on the order of a few hundred meters." This displacement estimate is from a small cinder cone called Cinder Hill by Wright and Troxel (1984 #1700), who noted that the conical structure has been displaced by these traces (p. 9, Wright and Troxel, 1984 #1700). Butler (1984 #1464) estimated about 200 m of right-lateral displacement of Cinder Hill. Butler (1984 #1464) also reported a maximum lateral displacement of "on the order of several hundred meters" for their eastern subzone and a maximum vertical displacement of about 100 m for this subzone. Wills (1989 #1693) reported that a drainage (probably late Pleistocene?) along the southwestern side of the Confidence Hills adjacent to Contact Canyon in the Owlshead Mountains (western subzone of Burchfiel and Stewart, 1966 #1322; Butler, 1984 #1464) has been displaced right-laterally about 360 m. Wills (1989 #1693) also noted that a smaller drainage at this same locality is displaced right-laterally 30 m. Butler (1984 #1464) concluded that the average (long-term) apparent right-lateral slip rate on the western subzone of the SDV adjacent to the Owlshead Mountains is about 2 to 3 mm/yr based on 20 to 35 km of displacement that he thought occurred between about 10 Ma and 1 Ma. Butler (1984 #1464) inferred an average apparent right-lateral slip rate on the eastern subzone of the SDV of about 0.3 mm/yr based on his estimate of a maximum lateral

	displacement of 200 m at Cinder Hill, which has been dated at about 700 ka. More recently, Cinder Hill basalt has been redated at around 300 ka, which results in a long-term average horizontal slip rate of 0.7 mm/yr. However, these data are for the northernmost end of the SDV, and thus may represent a minimum slip rate value. 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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