998, HURRICANE FAULT ZONE

Structure number: 998.
Comments:
Structure name: Hurricane fault zone.
Comments: Hecker's (1993) fault number 10-7. Lund and others (2001) and Stenner and others (1999) describe the sections of the fault zone in Utah and Arizona.
Synopsis: Long, generally north-trending Holocene to late Pleistocene fault along the base of the Hurricane Cliffs near the western margin of the Colorado Plateaus. The fault zone shows considerable Cenozoic displacement, which increases northward from Arizona into Utah.
Date of compilation: 7/01.
Compiler and affiliation: Bill D. Black, Greg N. McDonald, and Mike Hylland (Utah Geological Survey), and Suzanne Hecker (U.S. Geological Survey).
State: Utah; Arizona.
County: Washington, Iron; Mohave, Coconino.
1° x 2° sheet: Cedar City, Grand Canyon, Williams.
Province: Basin and Range and Colorado Plateaus.
Geologic setting: From the Utah-Arizona border, the fault trends north, then northeast along the steep and linear Hurricane Cliffs, forming a narrow zone of sub-parallel, en-echelon, west-dipping normal faults that displace generally horizontal Paleozoic through Cenozoic rocks and Quaternary basalt flows down to the west. The fault zone is in a 150-kilometer-wide structural and seismic transition zone between the Basin and Range and Colorado Plateaus provinces. Substantial late Cenozoic displacement on down-to-the-west normal faults in the transition zone (such as the Grand Wash and Toroweap faults in Arizona, and the Hurricane and Washington faults in Utah) has formed a stair-stepped series of plateaus and escarpments down to the west. Stewart and Taylor (1996) document 450 meters of stratigraphic separation in Quaternary basalt displaced by the fault, and a total separation of 2,520 meters across a portion of the Hurricane fault near Anderson Junction. Displacement decreases southward; Pearthree (1998) indicates Cenozoic displacement of only 200-400 meters across the fault zone along most of its length in Arizona. Several swarms of historical seismicity have occurred adjacent to, but cannot be correlated directly with, the north end of the Hurricane fault. The earliest of these swarms (1942) included two approximately magnitude 5 earthquakes (Arabasz and Smith, 1979; Richins and others, 1981). The 1992 magnitude 5.8 St. George earthquake was likely on the Hurricane fault (Pechmann and others, 1995)
Number of sections: 6
Comments: Stewart and Taylor (1996) define two sections in Utah, the Ash Creek and Anderson Junction sections, based on hanging-wall and footwall shortening structures, fault geometry, differences in complexity of faulting, and scarp morphology. Lund and others (2001) propose a third section (Cedar City section) in Utah, at the northern end of the Ash Creek section, based on differences in the timing of surface faulting at two sites along the fault. The boundary between the Cedar City and Ash Creek sections is likely at a pronounced right bend in the fault at Murie Creek just north of Coyote Gulch (Lund and others, 2001). The boundary between the Ash Creek and

Anderson Junction sections is north of Toquerville, where the fault intersects a zone of Sevier-age folds and thrust faults and bends to the northeast (Stewart and Taylor, 1996). The remaining sections (Shivwitz, Whitmore Canyon, and Southern Hurricane sections; Pearthree, 1998) are in Arizona.

Length: End to end (km): 87
Cumulative trace (km): 102

Average strike (azimuth): N16°E

998a, CEDAR CITY SECTION

Section number: 998a.

Section name: Cedar City section.
Comments: Hecker's (1993) fault number 10-7.

Reliability of location: Good.
Comments: Mapped or discussed by Averitt (1962), Anderson and Christenson (1989), and Lund and others (2001). Mapping from Anderson and Christenson (1989).

Sense of movement: N.
Comments:

Dip: No data.
Comments:

Dip direction: W.

Geomorphic expression: The trace of the Cedar City section follows a northeast-trending zone of Sevier-age folds and thrust faults from a pronounced right bend in the fault trace near Murie Creek to Cedar City. The fault displaces deformed Paleozoic and Mesozoic rocks, and undeformed Cenozoic sedimentary rocks and Quaternary basalt down to the west. Small alluvial fans adjacent to the cliffs are probably Holocene in age and appear to be unfaulted. North of the Middleton site (north of Shurtz Creek) and extending to near Cedar City, the fault is buried by a series of late Pleistocene landslide deposits. The landslide deposits do not appear to be faulted.

Age of faulted deposits: Holocene(?).

Paleoseismology studies: None. Trenching was attempted across the scarp at Shurtz Creek, but large boulders prevented exposure of the fault zone (Lund and others, 2001).

Timing of most recent paleoevent: (2) Latest Quaternary (<15 ka).
Comments: Timing of the most recent event on a range-front fault strand at Shurtz Creek, on a 13-meter-high fault scarp first described by Averitt (1962) in coarse bouldery alluvium, is not known, but is likely latest Pleistocene in age. Timing of the most recent event on scarps in older Pleistocene deposits at the Bauer site south of Shurtz Creek and the Middleton site north of Shurtz Creek is also unknown. Unfaulted alluvial-fan deposits at the Middleton site contain charcoal that yielded radiocarbon age estimates that constrain timing of the most recent event to sometime prior to 1,530 years ago; how much prior is uncertain. However, the absence of young fault scarps suggests a considerable period of time since the last surface-faulting earthquake (Lund and others, 2001).

Recurrence interval: No data.
Comments:

Slip rate: Unknown, probably <0.2 mm/yr (<100 ka); (C) 0.2-1 mm/yr (<630 ka).

Comments: Stenner and others (1999) report a minimum slip rate of 0.11 millimeters/year based on scarp profiling (net vertical tectonic displacement of 10.5 m) and a 100 ka surface age of a displaced alluvial surface at Shurtz Creek. Lund and others (2001) indicate a possible age as young as 50 ka for the Shurtz Creek alluvial surface, yielding a slip rate of 0.21 millimeters/year. A basalt flow high on the north wall of Cedar Canyon has been ^{40}Ar-^{39}Ar dated at 0.63 Ma; the calculated rate of stream incision of Coal Creek at the bottom of the canyon provides a proxy for long-term slip on the Cedar City section of 0.53 millimeters/year (Lund and others, 2001).

Length: End to end (km): 13

Cumulative trace (km): 10

Average strike (azimuth): N39°E

998b, ASH CREEK SECTION

Section number: 998b.

Section name: Ash Creek section.

Comments: Hecker's (1993) fault number 10-7.

Reliability of location: Good.

Comments: Mapped or discussed by Averitt (1962), Anderson and Christenson (1989), Stewart and Taylor (1996), Stenner and others (1999), and Lund and others (2001). Mapping from Anderson and Christenson (1989).

Sense of movement: N.

Comments:

Dip: 52-66°W.

Comments: Fault contact between alluvium and bedrock (66°W) and within bedrock (52°W) (Stenner and others, 1999, appendix 1).

Dip direction: W.

Geomorphic expression: The trace of the Ash Creek section follows a northeast-trending zone of Sevier-age folds and thrust faults from north of Toquerville near Anderson Junction to Murie Creek, displacing deformed Paleozoic and Mesozoic rocks, and undeformed Cenozoic sedimentary rocks and Quaternary basalt down to the west. At several locations, the steep range front is formed in relatively nonresistant rocks, and in areas of resistant rocks, sharp knickpoints coincide with the base of the cliffs (Anderson and Christenson, 1989). Small alluvial fans adjacent to the cliffs are probably Holocene in age and appear to be unfaulted. West of the south end of the section and southwest of Pintura, fault scarps as high as 15 meters cross dissected Pine Valley Mountain alluvial-fan surfaces and appear to represent recurrent late Pleistocene(?) antithetic faulting that is mechanically linked to the Hurricane fault. A 3-meter-high scarp in latest Pleistocene or early Holocene alluvial-fan deposits is just south of Murie Creek at the Coyote Gulch site (Stenner and others, 1999). Just north of the scarp at Coyote Gulch, a second scarp is in colluvium at the base of the Hurricane Cliffs. This scarp is 10+ meters high and has a pronounced bevel, indicating multiple surface-faulting events (Stenner and others, 1999). Quaternary basalt flows are displaced more than 360 meters across the fault at the south end of Black Ridge and over 400 meters at the north end of the ridge near Deadmans Hollow.

Age of faulted deposits: Holocene.
Paleoseismology studies: None.
Timing of most recent paleoevent: (2) Latest Quaternary (<15 ka).
Comments: Faulted alluvial-fan deposits at Coyote Gulch contain charcoal that yielded a radiocarbon age estimate that constrains timing of the most recent event to sometime after 1,260 years ago (Lund and others, 2001).
Recurrence interval: No data.
Comments:
Slip rate: (D) <0.2 mm/yr (<50 ka); (C) 0.2-1 mm/yr (<1Ma).
Comments: Displaced basalt flows were geochemically correlated across the fault at North Black Ridge and at the Ash Creek/Anderson Junction section boundary at South Black Ridge; these flows were ^{40}Ar-^{39}Ar-dated at 0.86 Ma and 0.81 Ma, respectively, indicating a long-term slip rate of 0.45-0.55 millimeters/year (Lund and others, 2001).
Length: End to end (km): 32
Cumulative trace (km): 38
Average strike (azimuth): N22°E

998c, ANDERSON JUNCTION SECTION

Section number: 998c.
Section name: Anderson Junction section.
Comments: Hecker's (1993) fault number 10-7.
Reliability of location: Good.
Comments: Mapped or discussed by Anderson and Christenson (1989), Stewart and Taylor (1996), Biek (1998), Stenner and others (1999), and Lund and others (2001). Mapping from Anderson and Christenson (1989).
Sense of movement: N.
Comments: About 3 kilometers south of Hurricane, Stenner and others (1999) observed slickenlines in a bedrock exposure of the fault suggesting a small component of right-lateral motion.
Dip: 70-71°W
Comments: Fault contact between colluvium and bedrock (Stenner and others, 1999, appendix 1).
Dip direction: W.
Geomorphic expression: The Anderson Junction section extends nearly 45 kilometers, from north of Toquerville in Utah to south of Cottonwood Canyon in Arizona, and lies south of the Ash Creek section (998b). The fault trace generally follows a high, north-trending, west-facing escarpment in Paleozoic bedrock. Fault scarps up to 30 meters in height with slopes up to 35 degrees on late Pleistocene colluvium and alluvium mark the fault along the base of the escarpment. Multiple, well-preserved scarps in different-aged units at Cottonwood Canyon document recurrent Quaternary movement. At Cottonwood Canyon, Stenner and others (1999) report 0.6 meters, 5-7 meters, and 18.5-20 meters of displacement in a younger Holocene stream and debris-flow deposit (Q1), an intermediate-age (~20-50 ka) Quaternary stream and debris-flow deposit (Q2), and an older (~70-125 ka) Quaternary alluvial-fan deposit (Q3),

respectively. The amount of most-recent-event displacement is small and is not considered typical of faulting at Cottonwood Canyon, and was likely larger in past events.

Age of faulted deposits: Holocene.

Paleoseismology studies: Stenner and others (1999) excavated two trenches at Cottonwood Canyon in Arizona. They excavated trench Q1 across a low fault scarp less than 1 meter high. The trench exposed 58-60 centimeters of down-to-the-west displacement across a fault zone that is 2 meters wide. Soil development on the units in trench Q1 imply an age of 8,000-15,000 years, probably early Holocene, for the faulted Q1 surface. No carbon or other material suitable for dating was recovered from the trench. Trench Q2 extended across a 5-meter-high scarp formed on the older Q2 surface, 25 meters south of trench Q1. Trench Q2 exposed at least two fault strands in a complex fault zone, across which a minimum net vertical offset of 35-37 centimeters occurred during the most recent surface faulting event. A charcoal sample from scarp-derived colluvium in this trench yielded a radiocarbon age of 870 years, which Stenner and others (1999) interpret as much too young to be representative of the age of the colluvium. The young carbon in older deposits is likely the result of bioturbation.

Timing of most recent paleoevent: (2) Latest Quaternary (<15 ka).

Comments: Stenner and others (1999) estimate the most recent event on the Anderson Junction section probably occurred 5,000-10,000 years ago, based on soil development exposed in trenches at Cottonwood Canyon.

Recurrence interval: No data.

Comments:

Slip rate: (C) 0.2-1 mm/yr.

Comments: Stenner and others (1999) calculate long-term slip rates of 0.1-0.3 millimeters/year in the ~70-125 ka Q3 unit, and 0.1-0.4 millimeters/year in the ~25-50 ka Q2 unit. Displaced basalt flows were geochemically correlated across the fault at the Ash Creek/Anderson Junction section boundary at South Black Ridge, at Pah Tempe Hot Springs, and at Grass Valley, and were ^{40}Ar-^{39}Ar-dated at 0.81 Ma, 0.35 Ma, and 1.0 Ma, respectively. These flows indicate a middle Quaternary slip rate of 0.44-0.45 millimeters/year, slowing to 0.21 millimeters/year sometime before 350,000 years ago (Lund and others, 2001).

Length: End to end (km): 42

Cumulative trace (km): 54

Average strike (azimuth): N10°E

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