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Quaternary Fault and Fold Database of the United States

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South Granite Mountains fault system, Green Mountains section (Class A) No. 779b

Last Review Date: 1999-05-17

citation for this record: **Machette, M.N., compiler, 1999, Fault number 779b, South Granite Mountains fault system, Green Mountains section, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, https://earthquakes.usgs.gov/hazards/qfaults, accessed 12/14/2020 03:16 PM.**

Synopsis	**General:** This 125-km-long, west-northwest trending, north-dipping fault system is located along the north margin of a low chain of anomalous west-northwest-trending mountain ranges within the Wyoming Basin province of central Wyoming. Two episodes of movement have been documented on the fault system. The first was near the end of the Eocene when the Granite Mountains (to the north) were uplifted at least 3 km, and during the Pliocene to Quaternary when the fault system was reactivated in the opposite sense (down-to-the-north) resulting in subsidence of the previously uplifted Precambrian-cored Sweetwater Arch. Part of this subsidence was accommodated by the Split Rock syncline [778], which lies north of the South Granite Mountains fault system. There has been a thorough reconnaissance of the fault system and detailed paleoseismic investigations at two locations along its middle portion. This study revealed clear

	evidence for Quaternary deformation on the three central faults (sections) of the system, but Quaternary deformation has not been proven for the distal sections (Class B structures). Pleistocene to Holocene displacement was found in the Green Mountain and Ferris Mountains areas, and minor Quaternary displacement was found in the Muddy Gap area. However, all five sections are considered to be of potential Quaternary age because of the prevalence of lineaments, springs, alignment of vegetation and fault scarps. Trenching has shown that a displacement of about 0.5 m (net vertical) is typical of the average surface-rupturing event on the Ferris Mountains section of the fault system. In addition, using reported average to maximum displacement ratios for historic faulting events, they proposed that the active (late Quaternary) sections of the South Granite Mountains fault system might have a maximum surface faulting event of 1–1.5 m displacement. **Sections:** This fault has 5 sections. Geomatrix Consultants (1988 #2980) defined five segments (herein considered as sections) for the South Granite Mountains fault system. From west to east, these are the Crooks Mountain [779a], Green Mountains [779b], Muddy Gap [779c], Ferris Mountains [779d] and Seminoe Mountains [779e] sections. Quaternary movement (Class A structures) has been documented in the Green Mountain area, along the Ferris Mountains, and in the Muddy Gap area. As such, only these three sections are described in detail; the Crooks Mountain (779a) and Seminoe Mountains [779e] sections are considered to be of Class B (potential Quaternary) structures, pending further investigations.
Name comments	**General:** Named for its location south of the Granite Mountains. However, the fault is in fact much closer to the mountain chain formed by the Green, Ferris, and Seminoe Mountains, which it borders on their north sides. The fault system is defined by Geomatrix Consultants (1988 #2980) as having five sections; the western end of the system is near Alkali Creek on the western end of the Crook Mountains and the eastern end is at Saylor Creek, north of Horseshoe Ridge at the eastern end of the Seminoe Mountains. **Section:** Named for the fault's proximity to the Green Mountains. This section of the fault extends west-northwest for roughly 23 km along the north margin of the Green Mountains from Crooks Creek on the west to Willow Creek on the east (Geomatrix Consultants, 1988 #2980). This section coincides with the Green

	Mountains block, which includes the Owl Hills on the north, Whiskey Peak on the east, and Sheep Mountains on the west. **Fault ID:** Referred to as normal fault 3 on figure 2-1 of Geomatrix Consultants (1988 #2973) and fault 242 of Witkind (1975 #819).
County(s) and State(s)	FREMONT COUNTY, WYOMING
Physiographic province(s)	WYOMING BASIN
Reliability of location	Poor Compiled at 1:250,000 scale. *Comments:* Trace based on map of entire fault system (fig. 3-1) at about 1:330,000 scale by Geomatrix Consultants (1988 #2980) with modifications based on Geomatrix Consultants (1988 #2980) 1:250,000 scale map (plate 2). This trace is a generalization from Love and others (1979 #3470) and Love and Christiansen (1985 #2287). For this database, the trace was transferred to a 1:250,000-scale map with topographic base. The fault is also shown in generalized fashion at 1:500,000 scale by Witkind (1975 #819) and Geomatrix Consultants (1988 #2980), and at 1:1,000,000 scale by Case and others (1997 #3449). Detailed maps of the fault section are included in fig. 3-15 (1:100,000 scale) by Geomatrix Consultants (1988 #2980) and in Jaworowski's thesis (1985 #3452) at 1:24,000 scale.
Geologic setting	The South Granite Mountains fault system trends west-northwest along the northern flanks a chain of low mountain ranges comprised of Crooks Mountain (on the west), the Green Mountains, Ferris Mountains, and Seminoe Mountains (on the east). The fault system forms the southern margin of the Sweetwater Arch, a west-northwest-trending asymmetric Laramide-age anticline consisting of a steeply dipping southern limb and a gently dipping northern limb (Love, 1970 #3445). The central to western portion of the arch is comprised of Precambrian granitic knobs that protrude above Miocene to Pliocene sediment. The southern limb is comprised of the South Granite Mountains. After being buried by conglomerate in the Eocene, the arch started to subside via structural downwarping along the Split Mountain syncline and by normal displacement along the North and South Granite Mountain fault systems. Subsidence continued

	into the Pliocene, but Quaternary movement has only been documented on portions of the South Granite Mountains fault system. The system's east-west orientation and normal sense of movement are consistent with the north-south extensional stress regime proposed for the Wyoming foreland by Zoback and Zoback (1980 #176)(1980).
Length (km)	This section is 24 km of a total fault length of 133 km.
Average strike	N79°W (for section) versus N72°W (for whole fault)
Sense of movement	Normal *Comments:* Down to the north in Pliocene to Quaternary time; in Eocene, movement was in opposite (down-to-the-south) sense (Love, 1970 #3445). Love (1970 #3445) suggested a minimum post-Miocene displacement of 650 m for the fault system.
Dip Direction	N *Comments:* Appears to dip steeply (Love, 1970 #3445).
Paleoseismology studies	Site 779-1 Grieves' Ranch area. A single exploratory trench (GR-1) was excavated across the fault scarp on unit Q6g, about 50-60 m west of Copper Creek near Grieves' Ranch. At this site, the surface of Q6g is about 5 m above the creek on the uplifted block, and about 2 m above the creek on the downthrown (northern) block. Unit Q6g is the youngest faulted deposit at Grieves' Ranch: it forms a 150- to 200-m-wide terrace (ancient floodplain) on both sides of the creek. Topographic profiling indicated a scarp height of about 6.6 m on Q6g that is associated with about 4.1 m of vertical surface offset. The maximum scarp-slope angle is only 8°, which is relatively gentle for a 4-m-high (multiple-event) scarp. Trench GR-1 penetrated the surface of unit Q6g, which is composed of fine- and coarse-grain fluvial deposits that fill a channel over sheared bedrock. Charcoal from about 1.8 m depth in the trench yielded an age of 29.3 ka, which supports Geomatrix Consultants (1988 #2980) estimate of a 15–40 ka (Pinedale) for unit Q6g. There was no evidence of deformation of the fluvial or overlying fine-grained deposits, but the vertical to overturned attitude of the sheared bedrock suggested faulting of the basal surficial deposits. Geomatrix Consultants (1988 #2980) suggested that the younger, scarp-forming fault is down slope from trench GR-1, which seems to be a reasonable inference. However, this

	proposed fault has not been confirmed. Thus, the trench did not reveal any direct evidence for the timing or amounts of individual faulting events at this site.
Geomorphic expression	The western (10-km-long) part of the section does not have fault scarps or lineaments indicative of Quaternary faulting, but is included in the section because it is a part of the larger Green Mountains structural block. However, the eastern part of the section is characterized by fault-related features such as scarps, topographic saddles, springs and vegetation lines (Jaworowski, 1985 #3452). Along this eastern part of the fault (18 km), two study areas were studied in detail by Geomatrix Consultants (1988 #2980). (A) West Cottonwood Creek to Copper Creek. In this area, the range bounding fault is defined by aligned springs and vegetation lineaments, and small discontinuous scarps at several locations. A remnant of a high-level (middle Pleistocene) piedmont gravel is displaced by two faults that have minor offset (about 1 m of net vertical). Younger (late Quaternary) surfaces that cross the trace of the range-front fault are not displaced. At McIntosh Ranch, about 5 km north of the range front fault (Owl Hills), there are scarps on late Quaternary and older surfaces. These scarps are present for a distance of about 3 km, to the east and west the ranch (along Middle Cottonwood Creek). The scarps are typically 1–2 m high, form en echelon traces and a graben, but were not profiled by Geomatrix Consultants (1988 #2980) for morphometric analysis. (B) Copper Creek to Willow Creek. This area includes the easternmost evidence for faulting in the Green Mountains section. Numerous short, subparallel lineaments here are defined by aligned springs, vegetation lines and fault scarps. At the eastern end of the section, the fault seems to splay into multiple (five ?) scarps that are preserved on mudflow deposits: vertical displacements for these scarps is less than 1 m. A prominent fault scarp is preserved on five different-aged stream terraces at Grieves' Ranch, in the vicinity of Copper Creek. The scarps range from 26 m in height on the oldest (Q2g) profiled surface, to 6.6 m in height on the youngest (Q6g) deformed surface. All of these scarps, including the smallest (4.1 m offset) are the product of multiple, late to middle Pleistocene faulting events. This site was chosen by Geomatrix Consultants (1988 #2980) for detailed investigation using surficial mapping, topographic profiling, and

	excavation and analysis of five soil pits and one exploratory trench.
Age of faulted surficial deposits	Although undated, Geomatrix Consultants (1988 #2980) made a six-fold subdivision of surficial units at the two study areas. Unit Q1g is the oldest and is faulted an undetermined amount. Units Q2g (older) through Q6g (youngest) are faulted from 20.5–4.1 m, showing a predictable increase in displacement with relative age. On the basis of soil development, assumptions that the terraces are related to early or late phases of glacial cycles (Jaworowski, 1985 #3452), and comparisons with dated sequences elsewhere in the Rocky Mountains province, Geomatrix Consultants (1988 #2980) made the following age estimates for the three younger faulted units: Q4g, >190 ka (pre-Bull Lake); Q5g, 90–190 ka (Bull Lake); and Q6g, 15–40 ka (Pinedale). Ages estimates (other than relative) were not made for the older units (Q1g, Q2g, and Q3g) owing to erosion or lack of exposure.
Historic earthquake	
Most recent prehistoric deformation	latest Quaternary (<15 ka) *Comments:* Although not explicitly stated by Geomatrix Consultants (1988 #2980), we believe that the Grieves' Ranch study suggested that the most recent faulting event occurred in the latest Pleistocene. Clearly, deposits that are 15–40 ka (and at the trench, <29.3 ka) are faulted, and the associated scarp has about 4 m of net vertical offset. If this offset occurred in 2 or more events, if seems reasonable to infer that the most recent event was <15 ka, which is the younger age estimate for the Q6g surface. Although considered to be late Quaternary (<130 ka) by Geomatrix Consultants (1988 #2980), we characterize the most recent event as latest Pleistocene or Holocene for this database.
Recurrence interval	*Comments:* There are no data on the number or amount of past displacements on the Green Mountain section. However, Geomatrix Consultants (1988 #2980) calculated recurrence intervals of 4.5– >12 k.y. for a Ms6.5–6.75 earthquake using a moment-rate approach.
Slip-rate category	Less than 0.2 mm/yr

	Comments: Geomatrix Consultants (1988 #2980) calculated vertical dispacement rates based on displacements and estimated ages of surfaces in the Grieves Ranch study area, although there are no data on the number or amount of individual displacement events on the Green Mountain section. Their rates range from a minimum slip rate of 0.05–0.15 mm/yr to a maximum slip rate of 0.11–0.35 mm/yr (assumes pure normal dip slip on a 60° fault plane). They concluded that the average slip rate on the section is probably 0.1–0.2 mm/yr. These rates are slightly more than those calculated for the Ferris Mountains section [779d].
Date and Compiler(s)	1999 Michael N. Machette, U.S. Geological Survey, Retired
References	#3449 Case, J.C., Larsen, L.L., Boyd, C.S., and Cannia, J.C., 1997, Earthquake epicenters and suspected active faults with surficial expression in Wyoming: Geological Survey of Wyoming Preliminary Hazards Report 97-1, 1 sheet, scale 1:1,000,000. #2973 Geomatrix Consultants, Inc., 1988, Northwestern Wind River Basin seismotectonic evaluation: Technical report to U.S. Department of Interior, Bureau of Reclamation, Denver, under Contract 6-CS-81-07310, 116 p., 3 pls. #2980 Geomatrix Consultants, Inc., 1988, Wyoming Basin geomorphic province seismotectonic evaluation: Technical report to U.S. Department of Interior, Bureau of Reclamation, Denver, under Contract 6-CS-81-07310, 167 p., 2 pls. #3452 Jaworowski, C.C., 1985, Geomorphic mapping and trend analysis of Quaternary deposits with implications for late Quaternary faulting, central Wyoming: Laramie, Wyoming, University of Wyoming, Masters, 109 p. #3445 Love, J.D., 1970, Cenozoic geology of the Granite Mountain area, central Wyoming: U.S. Geological Survey Professional Paper 495-C, 154 p., 10 pls. #2287 Love, J.D., and Christiansen, A.C., 1985, Geologic map of Wyoming: State Geologic Map, 3 sheets, scale 1:500,000. #3470 Love, J.D., Christiansen, A.C., Earle, J.L., and Jones, R.W., 1979, Preliminary geologic map of the Casper 1° x 2° quadrangle central Wyoming: U.S. Geological Survey Open-File Report 79-961, 13 p., 1 pl., scale 1:250,000.

	#819 Witkind, I.J., 1975, Preliminary map showing known and suspected active faults in Wyoming: U.S. Geological Survey Open-File Report 75-279, 35 p. pamphlet, 1 sheet, scale 1:500,000. #176 Zoback, M.L., and Zoback, M., 1980, State of stress in the conterminous United States: Journal of Geophysical Research, v. 85, no. B11, p. 6113-6156.