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Quaternary Fault and Fold Database of the United States

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Madison fault, Madison Canyon section (Class A) No. 655b

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Compiled in cooperation with the Idaho Geological Survey and the Montana Bureau of Mines and Geology

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Synopsis	**General:** Detailed mapping and reconnaissance studies of the morphology of scarps along the fault are the primary source of data for this fault; segmentation models have been proposed based on these data. However, no detailed trenching has been conducted. Short parts of the fault ruptured during the 1959 Hebgen Lake earthquake resulting in displacements of less than 1 m. The southern part of the fault seems to have higher rates of activity than the northern part, where extension appears to be partitioned on sub-parallel faults at the surface.

	Sections: This fault has 3 sections. Several reports discuss the right-stepping echelon nature of this fault as evidence of separate tectonic blocks with Pardee (1950 #46) being the earliest, and later discussed by Shelden (1960 #478). Young (1985 #690) describes 12 segments along the northern 10-12 km of the fault, but each is defined by parts of the fault having a similar strike. Johns and others (1982 #259) and Schneider (1985 #319) defined three segments; the latter discussed the northern two in detail. These previously published boundaries roughly coincide with the section boundaries shown here. Ruleman and Lageson (2002 #7030) indicate that the fault is composed of five segments. The sections shown in this compilation are nearly coincident with the parts of the fault defined by Johns and others (1982 #259); they do not distinguish any difference in timing of paleoearthquakes and assign a single age (Holocene) to the whole fault based on the short ruptures from the 1959 Hebgen Lake earthquake south of Madison Canyon (Witkind, 1964 #247; Myers and Hamilton, 1964 #250). Available data suggest that the timing of the most-recent faulting event does differ along strike.
Name comments	**General:** Pardee (1950 #46) is an early reference to this fault and referred to it as the Madison Range fault. Most of the early literature followed this nomenclature; however, the name "Madison fault" is commonly used now. The fault is also shown on a map as the "Madison Valley fault" (U.S. Coast and Geodetic Survey, 1959 #630). The fault extends from north of Saint Joe Creek southwestward to Garner Canyon. Witkind and others (1964 #629) described the fault as extending farther south to near Big Springs, but they did not show it as such on their map. Young (1985 #690) shows this fault extending farther north (at least another 2 km) to the edge of her map and states that its trace may coincide with the Madison River near the Madison Powerhouse. **Section:** Bartholomew and Stickney (1987 #85; 1987 #242) refer to this part of the fault as Madison Canyon segment. Schneider (1985 #319) also discussed and defined segments of the Madison fault based on morphologic studies, but no names were assigned. The section, as defined in this compilation, extends from about 2 km south of Corral Creek southward to the headwaters of Mile Creek. Mathieson (1983 #1065) shows a scarp at the southern end that extends about 140 m southwest of Mile Creek, forming a 50? change in trend, which extends into the mountain block at west edge of a Pinedale moraine. Furthermore, Mathieson believes that the strand that trends up Mile Creek accommodated earlier

	Holocene movement than that on the valleyward strand shown on her map. The section is longer than middle segment of Schneider, which extends from Indian Creek to Madison Canyon. This compilation does not show a fault in the area between Indian Creek and Corral Creek where no scarps are mapped (Hadley, 1969 #572) but includes 9 km of scarps south of Madison Canyon and the extension up Mile Creek. Part of this section ruptured during the 1959 Hebgen Lake earthquake. The section, as defined here, roughly coincides with unnamed segment defined by Lundstrom (1986 #457) who suggests that the northern boundary is between Wolf and Corral Creeks and southern boundary is at Mile Creek where the continuity of the range-front scarp ends. **Fault ID:** Refers to fault number 5 (Madison Range fault) of Witkind (1975 #317); fault numbers 45 (Madison Range fault-southern segment), 46 (Madison Range fault-middle segment), and 47 (Madison Range fault-northern segment) of Johns and others (1982 #259); fault number 11 (Madison fault) of Stickney and Bartholomew (1987 #85); Jack Creek, Cedar Creek, Burger Creek, Bear Creek, and Indian Creek scarps and Madison Canyon segment of the Madison fault of Stickney and Bartholomew (1987 #242); and Jordan Creek, Jack Creek, Cedar Creek, Burger Creek, Bear Creek, Indian Creek, Madison Canyon, and Northern Henrys Lake segments of the Madison fault of Stickney and Bartholomew (written commun., 1992 #556).
County(s) and State(s)	FREMONT COUNTY, IDAHO MADISON COUNTY, MONTANA
Physiographic province(s)	NORTHERN ROCKY MOUNTAINS
Reliability of location	Good Compiled at 1:24,000 scale. *Comments:* Location of fault is from Ruleman (2002 #5311), further constrained by satellite imagery and topography at scale of 1:24,000. Reference satellite imagery is ESRI_Imagery_World_2D with a minimum viewing distance of 1 km.
Geologic setting	The Madison fault is a high-angle, down-to-the-west, range-front normal fault bounding the western side of Madison Range. Maximum depth to basement in northern Madison Valley is about 2.1 km, in central Madison Valley the depth may exceed 4.5 km,

	and in southern Madison Valley about 1.2 km (Schofield, 1981 #314; Rasmussen and Fields, 1985 #481). Maximum total throw is probably more than 8 km according to Locke and Schneider (1990 #253).
Length (km)	This section is 50 km of a total fault length of 98 km.
Average strike	N26°W (for section) versus N20°W,N26°W (for whole fault)
Sense of movement	Normal *Comments:* (Witkind, 1975 #317). Mathieson (1983 #1065) did not recognize any significant component of horizontal movement.
Dip	60° W *Comments:* Dip of slickensided surface at the third canyon south of Sheep Creek (Mathieson, 1983 #1065). Dip is inferred to be steep or possibly vertical (Johns and others, 1982 #259). Rasmussen and Fields (1985 #481) suggest fault is listric and soles into a Laramide thrust based on seismic data; however, Alexander and Leeder (1990 #458) state that the characteristics of surface deformation of fluvial terraces at the mouth of the Madison River are inconsistent with listric faulting.
Paleoseismology studies	
Geomorphic expression	Fault is expressed as nearly continuous, high (locally >35 m) scarps on alluvium with steep (30?-45?, with mode around 35?) maximum slope angles (Gary, 1980 #695; Schneider, 1985 #319). Lundstrom (1986 #457) indicates most scarps are 7- to 14-m high and cluster into two groups that are about 7-m and 11-m high. A short (about 3-km-long) part of this section ruptured during the 1959 Hebgen Lake earthquake, with vertical offsets less than 1 m (Myers and Hamilton, 1964 #250). One continuous scarp, about 0.1-km long, is centered on Sheep Creek, the other about 2.4-km long is north of Little Mile Creek. Doser (1985 #22) states that it is difficult to determine if the historical movement was related to tectonic movement along the fault or some other mechanism such as settlement. Wallace (1980 #657) reoccupied two sites photographed in 1959 and describes the post-1959 scarp degradation. Locally, nick points in streams crossing the fault are only a few tens of meters from the scarp (Gary, 1980 #695).

	Ruleman (2002 #5133) measured 103 scarp profiles along this part of the Madison fault, which to date provides the most extensive data available. Ruleman describes the presence of single-event scarps on early- to mid-Holocene deposits along the southern part of this section with offsets of 2.2-4.0 m; the scarps along the northern part of the section have 2.2-6.5 m of displacement on early- to mid-Holocene deposits, and that "Pinedale lateral moraines have vertical surface offsets as great as 12.0 m."
Age of faulted surficial deposits	Upper Quaternary alluvium and colluvium, glacial till, and landslide deposits, nearly all are <40 ka. Gary (1980 #695) shows that scarps are on some late Pleistocene (Pinedale) moraines but not all. Much of the length of the fault coincides with the bedrock-alluvium contact.
Historic earthquake	
Most recent prehistoric deformation	latest Quaternary (<15 ka) *Comments:* Based on diffusion-equation modeling of scarp-morphology data, Lundstrom (1986 #457) estimates the timing of the most recent event to be 4 ka. A late Holocene age is also suggested by Schneider (1985 #319), whose best estimate is 3-5 ka, and Ruleman and Lageson (2002 #7030) suggest 1-5 ka. Leveling data indicate fluvial terraces at mouth of Madison River have been tilted in the past few hundred years (Alexander and Leeder, 1990 #458). Mathieson (1983 #1065) also recognized the most recent movement to be Holocene but also points out that prominent prehistoric facets (bevels) are absent on the scarp. Furthermore, Mathieson suggests this is due to high degradation rates rather that absence of young movement to be the cause. A more recent study combining scarp morphology and geologic mapping (Ruleman, 2002 #5133) documents the presence of single-event scarps on early- to mid-Holocene deposits.
Recurrence interval	10-25 k.y. (<2 Ma) *Comments:* Evidence of multiple-late Quaternary faulting events is clearly characterized by large scarps on deposits related to the last glacial cycle and smaller scarps on Holocene deposits (Ruleman, 2002 #5133; Ruleman and Lageson, 2002 #7030). Lundstrom (1986 #457) determined this recurrence interval based

	on assuming a nearly constant rate of tilting (0.05 mrad/yr) of the valley floor across a 5.5-km-wide valley, with displacements of 3-7 m per event, and the 7-m-high scarps are presumed to be the result of one to two events and constrain the amounts of offset per event. Mathieson (1983 #1065) indicates that the average recurrence interval could be as long as 7.5-10 k.y. during the past 15-30 k.y., if displacements were 3 m per event, or as short as 1.9-3.8 k.y. during the same interval, if displacements were 1 m per event. Schneider (1985 #319) speculates the recurrence interval may be 1-2 k.y. Ritter and others (1995 #882) suggest a recurrence interval of less than 1 k.y., but the basis for this estimate is not clear.
Slip-rate category	Between 0.2 and 1.0 mm/yr *Comments:* Ruleman and Lageson (2002 #7030) document long-term average tectonic rates ranging from 0.18-0.6 mm/yr, which are based on measured offset of deposits of known-age and morphometric analyses (Ms, Vf ratios and faceted spur reconnaissance analyses, data from Ruleman, 2002 #5133). Lundstrom (1986 #457) reports a similar range of slip rates (0.15-0.4 mm/yr) based on 6- to 8-m offsets of deposits thought to be 20-40 ka for this part of the fault. Lundstrom also indicates that the rate of valley floor tilting has been 0.05 mrad/yr for the past 2 Ma based on tilting of Huckleberry Ridge Tuff (2 Ma) and a similar (0.046 mrad/yr) corrected rate based on tilting of upper Pleistocene (150-ka Bull Lake) deposits. Mathieson (1983 #1065) indicated that slip on this part of the Madison fault might be episodic, and determined a 0.2-0.6 mm/yr slip rate for post-Pinedale slip (<11-20 ka), with 0.3-0.4 mm/yr being a preferred rate. Slip rate during the Sangamon interglacial might be about one order of magnitude less, and a late Quaternary rate may be about 0.1 mm/yr. In another publication, Mathieson (1983 #764) documented a slip rate of 0.4-0.7 mm/yr for the past 30 k.y. based on a 11-m-high scarp on Pinedale or younger debris-flow deposits. Furthermore, Mathieson also cites previous investigators that show a similar (0.5 mm/yr) slip rate for post-Huckleberry Ridge Tuff displacement. Vertical displacement of the 2-Ma Huckleberry Ridge Tuff is 800-900 m (Pierce and Morgan, 1992 #539), which suggests a Quaternary slip rate of about 0.4 mm/yr. Schneider (1985 #319) suggests that this section of fault appears to have been more active and have a higher late Quaternary slip rate than section to the north. Comparison of 1923 second-order and 1960 first-order leveling data indicate uplift rate of 2 to greater than 5 mm/yr in this area, with the higher rates to the

	south (Reilinger and others, 1977 #479). Collectively, the data supports the assigned slip rate category.
Date and Compiler(s)	2010 Kathleen M. Haller, U.S. Geological Survey
References	#458 Alexander, J., and Leeder, M.R., 1990, Geomorphology and surface tilting in an active extensional basin, SW Montana, U.S.A.: Journal of the Geological Society, London, v. 147, p. 461-467. #22 Doser, D.I., 1985, Source parameters and faulting processes of the 1959 Hebgen Lake, Montana, earthquake sequence: Journal of Geophysical Research, v. 90, no. B6, p. 4537-4555. #695 Gary, S.D., 1980, Quaternary geology and geophysics of the upper Madison Valley, Madison County, Montana: Missoula, University of Montana, unpublished M.S. thesis, 76 p., 2 pls. #572 Hadley, J.B., 1969, Geologic map of the Cameron quadrangle, Madison County, Montana: U.S. Geological Survey Geologic quadrangle Map GQ-813, 1 sheet, scale 1:62,500. #259 Johns, W.M., Straw, W.T., Bergantino, R.N., Dresser, H.W., Hendrix, T.E., McClernan, H.G., Palmquist, J.C., and Schmidt, C.J., 1982, Neotectonic features of southern Montana east of 112°30' west longitude: Montana Bureau of Mines and Geology Open-File Report 91, 79 p., 2 sheets. #253 Locke, W.W., and Schneider, N.P., 1990, General geology and geomorphology of the Madison Range and Valley, southwest Montana, *in* Hall, R.D., ed., Quaternary geology of the western Madison Range, Madison Valley, Tobacco Root range, and Jefferson valley: Rocky Mountain Cell, Friends of the Pleistocene, August 15-19, 1990, Guidebook, p. 1-23. #457 Lundstrom, S.C., 1986, Soil stratigraphy and scarp morphology studies applied to the Quaternary geology of the southern Madison Valley, Montana: Arcata, California, Humboldt State University, unpublished M.S. thesis, 53 p., 1 pl., scale 1:24,000. #1065 Mathieson, E.L., 1983, Late Quaternary activity of the Madison Range fault along its 1959 rupture trace, Madison County, Montana: Stanford, California, Stanford University,

unpublished M.S. thesis, 169 p., 4 pls.

#764 Mathieson, E.L., 1983, Post-Pinedale displacement rate on the Madison Range fault along its 1959 rupture trace, Madison County, Montana: Geological Society of America Abstracts with Programs, v. 15, p. 376-377.

#250 Myers, W.B., and Hamilton, W., 1964, Deformation accompanying the Hebgen Lake earthquake of August 17, 1959, *in* The Hebgen Lake, Montana, earthquake of August 17, 1959: U.S. Geological Survey Professional Paper 435-I, p. 55-98.

#569 O'Neill, J.M. , "1992, in prep.", Geologic map of the Granite Mountain quadrangle, Madison County, Montana: U.S. Geological Survey Geologic quadrangle Map, 1 sheet, scale 1:24,000.

#570 O'Neill, J.M. , "1992, in prep.", Geologic map of the Squaw Creek quadrangle, Madison County, Montana: U.S. Geological Survey Geologic quadrangle Map, 1 sheet, scale 1:24,000.

#46 Pardee, J.T., 1950, Late Cenozoic block faulting in western Montana: Geological Society of America Bulletin, v. 61, p. 359-406.

#539 Pierce, K.L., and Morgan, L.A., 1992, The track of the Yellowstone hot spot—Volcanism, faulting, and uplift, *in* Link, P.K., Kuntz, M.A., and Platt, L.B., eds., Regional geology of eastern Idaho and western Wyoming: Geological Society of America Memoir 179, p. 1-53, 1 pl.

#481 Rasmussen, D.L., and Fields, R.W., 1985, Cenozoic structure and depositional history, Jefferson and Madison intermontane basins, southwestern Montana, *in* Beaver, P.C., ed., Geology and mineral resources of the Tobacco Root Mountains and adjacent region: Tobacco Root Geological Society, 10th Annual Field Conference, August 7-10, 1985, p. 14.

#479 Reilinger, R.E., Citron, G.P., and Brown, L.D., 1977, Recent vertical crustal movements from precise leveling data in southwestern Montana, western Yellowstone National Park, and the Snake River Plain: Journal of Geophysical Research, v. 82, p. 5349-5359.

#882 Ritter, J.B., Miller, J.R., Enzel, Y., and Wells, S.G., 1995, Reconciling the roles of tectonism and climate in Quaternary alluvial fan evolution: Geology, v. 23, p. 245-248.

#7030 Ruleman, C.A., and Lageson, D.R., 2002, Late Quaternary tectonic activity along the Madison fault zone, Southwest Montana: Geological Society of America Abstracts with Programs, v. 34, no. 4, p. 12.

#5133 Ruleman, C.A., III, 2002, Quaternary tectonic activity within the northern arm of the Yellowstone tectonic parabola and associated seismic hazards, southwest Montana: Bozeman, Montana State University, unpublished M.S. thesis, 158 p.

#319 Schneider, N.P., 1985, Morphology of the Madison Range fault scarp, southwest Montana—Implications for fault history and segmentation: Oxford, Ohio, Miami University, unpublished M.S. thesis, 131 p.

#314 Schofield, J.D., 1981, Structure of the Centennial and Madison Valleys based on gravitational interpretation, *in* Tucker, T.E., ed., Guidebook to southwest Montana: Montana Geological Society, 1981 Field Conference and Symposium, p. 275-283.

#478 Shelden, A.W., 1960, Cenozoic faults and related geomorphic features in the Madison Valley, Montana, *in* Campau, D.E., and Anisgard, H.W., eds., West Yellowstone—Earthquake area: Billings Geological Society, 11th Annual Field Conference, September 7-10, 1960, p. 178-184.

#242 Stickney, M.C., and Bartholomew, M.J., 1987, Preliminary map of late Quaternary faults in western Montana: Montana Bureau of Mines and Geology Open-File Report 186, 1 pl., scale 1:500,000.

#85 Stickney, M.C., and Bartholomew, M.J., 1987, Seismicity and late Quaternary faulting of the northern Basin and Range province, Montana and Idaho: Bulletin of the Seismological Society of America, v. 77, p. 1602-1625.

#690 Young, S.L.-W., 1985, Structural history of the Jordan Creek area northern Madison Range, Madison County, Montana: Austin, University of Texas at Austin, unpublished M.S. thesis, 113 p., 2 pls.