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Canyon Ferry fault, southern section (Class A) No. 671b

Last Review Date: 2010-12-06

Compiled in cooperation with the Montana Bureau of Mines and Geology

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Synopsis	**General:** Although poorly studied until recently, the fault is shown on several regional neotectonic maps. The heights of scarps on upper Quaternary deposits are reported by Stickney and Bartholomew (1987 #85). The trenching and geomorphic studies of Anderson and LaForge (2003 #6897) and Anderson and others (2005 #6898) have shown the fault is longer and more active than previously thought. **Sections:** This fault has 3 sections. Differentiation of the sections is based on the presence or absence of fault scarps and echelon

	gaps in the fault trace.
Name comments	**General:** Although Pardee (1950 #46) was probably the first to mention this fault as a tectonically young structure (late Cenozoic), it remained unnamed in the literature until Johns and others (1982 #259) referred to it as the Canyon Ferry-Duck Creek fault and the Lower Sixmile Creek fault. Stickney and Bartholomew (1987 #85) were first to document Quaternary movement and refer to it as the Canyon Ferry fault. The fault extends from Oregon Gulch south to near Toston, Mont. (Anderson and others, 2005 #6898; Wong and others, 1999 #7038). **Section:** This section is defined in this compilation as the part of the range-front fault that extends from Hellgate Gulch south to Cottonwood Creek along which Anderson and others (2005 #6898) report evidence of surface faulting in the late Quaternary. They also document clear evidence of recurrent surface faulting between White Gulch south to Little Cottonwood Creek. This section contains the Confederate Gulch scarp (Stickney and Bartholomew, 1987 #85) and the Duck Creek and Gurnett Creek scarps (Stickney and Bartholomew, 1987 #242), all of which are named for local streams. The section also includes the intervening short parts of the fault that are buried by Quaternary deposits. **Fault ID:** Refers to fault 42 (unnamed echelon faults west side of Big Belt Mountains) of Witkind (1975 #317); fault 125 (Canyon Ferry-Duck Creek fault) of Johns and others (1982 #259); fault 18 (Canyon Ferry fault) of Stickney and Bartholomew (1987 #85); Confederate Gulch, Duck Creek and Gurnett Creek scarps of Stickney and Bartholomew (1987 #242); and Confederate Gulch fault of Stickney and Bartholomew (written commun., 1992 #556).
County(s) and State(s)	BROADWATER COUNTY, MONTANA
Physiographic province(s)	NORTHERN ROCKY MOUNTAINS
Reliability of location	Poor Compiled at 1:50,000 scale. *Comments:* Location of the fault trace is from figures 2 and 3 of Anderson and LaForge (2003 #6897) and figure 1 of Anderson and others (2005 #6898), further constrained by satellite imagery

	and topography at scale of 1:50,000. Reference satellite imagery is ESRI_Imagery_World_2D with a minimum viewing distance of 1 km. Location of fault considered poor due to discontinuous scarps and width of line that represents in the fault location on figures even though original base map appears to be at scale of 1:24,000.
Geologic setting	High-angle, down-to-the-southwest, range-front normal fault that bounds the southwestern side of Big Belt Mountains. The fault reportedly has 450–1,200 m of late Cenozoic displacement (Johns and others, 1982 #259). As shown by Witkind (1975 #317), the Canyon Ferry fault extends toward the southeast along the subdued front of the Big Belt Mountains (Pardee, 1950 #46) and would include the Ray Creek and Deep Creek faults of Johns and others (1982 #259). However, this southern extension of the Canyon Ferry fault is not included in this compilation based on the absence of evidence indicating Quaternary movement.
Length (km)	This section is 18 km of a total fault length of 35 km.
Average strike	N25°W (for section) versus N39°W (for whole fault)
Sense of movement	Normal *Comments:* Scarps on Quaternary deposits suggest down-to-the-west offset of alluvial surfaces (Witkind, 1975 #317).
Dip Direction	SW
Paleoseismology studies	Site 671-1 is the G/T Ranch site of Anderson and LaForge (2003 #6897) where a trench was excavated in June 2002. The trench provided the first clear evidence for multiple late Quaternary surface-rupturing earthquakes. The scarp at the site is 13-m high and total dip-slip displacement of approximately 9 m across the fault (Anderson and others, 2005 #6898).
Geomorphic expression	The southern part of the fault forms prominent, but discontinuous fault scarps along base of Big Belt Mountains and on the piedmont east of Canyon Ferry Lake. Single-event scarps are 1- to 3-m high (Anderson and LaForge, 2003 #6897) and are generally located at the abrupt break in slope between steeply dipping bedrock and gently dipping basin fill. Morphology of fault scarps suggests recurrent late Quaternary faulting events (Anderson and LaForge, 2003 #6897). The piedmont scarp at Confederate Gulch is 6 km long, and is 15- to 20-m high on

	middle Quaternary deposits and 1- to 2-m high on upper Quaternary (postBull Lake) alluvium (Stickney and Bartholomew, 1987 #85). Further south, short (2- to 3-km-long) scarps are preserved on both sides of Duck Creek and Gurnett Creek (Stickney and Bartholomew, 1987 #242).
Age of faulted surficial deposits	Upper Quaternary (postBull Lake) alluvium at Confederate Gulch (Stickney and Bartholomew, 1987 #85).
Historic earthquake	
Most recent prehistoric deformation	late Quaternary (<130 ka) *Comments:* The most recent event occurred prior to 13 ka based on infrared stimulated luminescence (IRSL) ages reported in Anderson and LaForge (2003 #6897) and Anderson and others (2005 #6898). The next oldest constraining age that they do not dismiss is 68 ka; thus, this part of the fault is conservatively assigned to the late Quaternary age class. This age assignment is consistent with previous studies by Stickney and Bartholomew (1987 #85) that document that the Confederate Gulch scarp is considered to be older than 15 ka (present on Bull Lake but not Pinedale deposits); the other scarps to the south also are considered to be late Quaternary (Stickney, oral commun., 1993). Early compilations (Witkind, 1975 #317; Johns and others, 1982 #259) only indicated late Cenozoic movement.
Recurrence interval	*Comments:* No recurrence intervals could be determined from the trenching study of Anderson and LaForge (2003 #6897) and Anderson and others (2005 #6898) even though their interpretations include clear evidence for three to four events and possibly additional older events (see fig. 17 in Anderson and LaForge, 2003 #6897). Calculated ages suggest minor stratigraphic reversals, and some of the ages were regarded as too old. They conclude that all the events observed at the site occurred between 68±4 ka and 13±1 ka. Qualitatively, intervals between events range from a few thousand years to over 13 k.y.
Slip-rate category	Between 0.2 and 1.0 mm/yr *Comments:* A low slip-rate category is assigned in this

	compilation based on the average slip rates from the G/T Ranch site of Anderson and LaForge (2003 #6897) and Anderson and others (2005 #6898). However, they provide a number of inter-event, short-term, and long-term slip rates for this fault based on infrared stimulated luminescence (IRSL) ages and offsets from the trench site that range from 0.09 to 0.54 mm/yr (Anderson and LaForge, 2003 #6897; Anderson and others, 2005 #6898) and up to 1 mm/yr (Anderson and others, 2005 #6898). The lowest documented rate is based on about 4 m of vertical offset between 68 ka and 21 ka. This period of low activity was followed by 2–3 events between 21 ka and 13 ka resulting in an additional 5 m of offset. However, no surface faulting events have occurred in the past 13 k.y. The assigned slip rate category is based on post-21 ka slip, which suggests a slip rate of 0.24 mm/yr; although the mean slip rate for entire 68-k.y. record is 0.13 mm/yr (Anderson and others, 2005 #6898).
Date and Compiler(s)	2010 Michael N. Machette, U.S. Geological Survey, Retired Kathleen M. Haller, U.S. Geological Survey
References	#6897 Anderson, L.W., and LaForge, R., 2003, Seismotectonic study for Canyon Ferry Dam, Missouri River Basin Project, Montana: U.S. Bureau of Reclamation Seismotectonic Report 2003-1, 70 p. #6898 Anderson, L.W., Olig, S.S., and Forman, S.L., 2005, Paleoseismic investigation of the Canyon Ferry fault, west-central Montana, *in* Lund, W.R., ed., Proceedings Volume—Basin and Range Province Seismic Hazards Summit II: Utah Geological Survey Miscellaneous Publication 05-2, 17 p. #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. #46 Pardee, J.T., 1950, Late Cenozoic block faulting in western Montana: Geological Society of America Bulletin, v. 61, p. 359-406. #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. #556 Stickney, M.C., and Bartholomew, M.J., 1992 written commun., Preliminary map of late Quaternary faults in western Montana (digital data): Montana Bureau of Mines and Geology (digital version of MBMG Open-File Report 186), 1 pl., scale 1:500,000. #317 Witkind, I.J., 1975, Preliminary map showing known and suspected active faults in western Montana: U.S. Geological Survey Open-File Report 75-285, 36 p. pamphlet, 1 sheet, scale 1:500,000. #7038 Wong, I.G., Olig, S.S., Gorton, A.E., and Naugler, W.E., 1999, Seismotectonic evaluation of the Broadwater Power Project, Toston Dam, Montana: Report prepared for Montana Department of Natural Resources and Conservation, Helena, Mont., 57 p.