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Red Rock fault, Sheep Creeks section (Class A) No. 641c

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Compiled in cooperation with the Montana Bureau of Mines and Geology

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Synopsis	**General:** Trenching at one site on the southern part of the fault, along with clear differences in fault-scarp morphology, geologic relations between faulted and unfaulted deposits, and basin geometry defined by Residual Bouguer gravity data indicate that the three parts of the fault probably have different faulting histories. The northern part, as shown in this compilation by a valleyward echelon step in the fault at its southern end, has been the subject of little study. **Sections:** This fault has 3 sections. Sections are defined by the

	apparent differences in the times of the most recent prehistoric deformation. The two southern sections were first identified by Stickney and Bartholomew (1987 #85). They defined segments from geomorphic data of Johnson (1981 #30) even though Johnson divided this part of the fault into four segments (it is unclear if Johnson meant seismogenic segments). Later studies (Greenwell, 1997 #7035; Harkins and others, 2005 #7034) suggested alternative segment boundaries leading to segments as short as 8-km long (see figure 2 Harkins and others, 2005 #7034). In contrast, Bartholomew and others (2004 #6899) suggest that the two, more active sections of the fault [641b and 641c] rupture together.
Name comments	**General:** The source of the name Red Rock fault is probably from Pardee (1950 #46), who defined the fault as extending from near Clark Canyon Reservoir to southwest of Lima, Montana, along the east flank of the Tendoy Montains. Pardee also referred to this structure as the Lima fault, whereas Scholten and others (1955 #69) used Red Rock fault zone. The fault, as shown in this compilation, extends from about 2 km north of Limekiln Canyon southward to near Birch Creek. Other compilations show only the southern two-thirds of the fault shown in this compilation (Witkind, 1975 #317; Stickney and Bartholomew, 1987 #242). **Section:** Named and defined as the Sheeps Creek section by Stickney and Bartholomew (1987 #85; 1987 #242). It extends from about midway between Big Sheep Creek and Dry Canyon southeastward to southern end of the scarps southwest of Lima, Montana (Haller, 1988 #27). The part of the fault Johnson defined, which most closely coincides with the section described here, includes part from Garr Canyon to Little Sheep Creek and the east-trending part south of Little Sheep Creek. Bartholomew (1989 #294) believed that Timber Butte-Sheep Creeks segment boundary is farther north than Haller's based on a Holocene scarp at Little Water Canyon. Crone and Haller (1991 #186) argue that this young scarp is small and uncharacteristic of older scarps at this site and probably results from a partly ineffective barrier to ruptures at the segment boundary. **Fault ID:** Refers to number 8 (Red Rock fault zone) of Witkind (1975 #317); number 4 (Red Rock fault) of Stickney and Bartholomew (1987 #85); and Timber Butte and Sheep Creeks segments of Red Rock fault in Montana Bureau of Mines and Geology digital database (Stickney, written commun., 1992) and Stickney and Bartholomew (1987 #242).

County(s) and State(s)	BEAVERHEAD COUNTY, MONTANA
Physiographic province(s)	NORTHERN ROCKY MOUNTAINS
Reliability of location	Good Compiled at 1:24,000 scale. *Comments:* Location of fault based on map referenced to 1:24,000 base of Bartholomew and others (2009 #7041) and 1:250,000-scale maps of Haller (1988 #27), original mapping at 1:24,000 scale, further constrained 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. Additional traces at the southern end of the section from M.C. Stickney (written commun., 2011).
Geologic setting	High-angle, down-to-the-northeast, range-front normal fault bounding northeast side of Tendoy Mountains. There is no evidence of young faulting south of mapped trace even though the mountain front extends farther south. The total vertical separation may be 1 km based on gravity data (Johnson, 1981 #313) and displacement?length relations (Harkins and others, 2005 #7034). Hurlow (1995 #1063) also suggests about 1 km of structural relief. However, Bartholomew and others (2009 #7041) state that the Red Rock basin is smaller and very shallow (3,600-m deep) compared to other basins of the northern Basin and Range; in addition, the basin does not contain a thick sequence of Eocene-Miocene sediments.
Length (km)	This section is 15 km of a total fault length of 41 km.
Average strike	N44°W (for section) versus N34°W,N33°W (for whole fault)
Sense of movement	Normal *Comments:* (Witkind, 1975 #317)
Dip Direction	NE
Paleoseismology studies	One trench across a 5-m-high scarp exposed evidence of two postglacial (<12-15 ka) faulting events with the most recent event occurring during the late Holocene. Trench 641-1 excavated by Bartholomew, Stickney, and Wilde in 1986 (Bartholomew and Stickney, 1987 #9; Stickney and others, 1987 #295, Bartholomew

	and others, 2009 #7041), was located approximately 50 m north of Little Sheep Creek access road. As reported by Bartholomew and others (2009 #7041), the trench revealed two colluvial wedges less than l-m-high each. Radiocarbon ages on soils (assumed to be reported as uncalibrated ages) bracket the timing of the younger wedge between 2240+/-150 ka [sic] and 3705+/-260 ka [sic]. However, table 4 correctly identifies the bracketing ages of 2,240 and 3,705 yr.
Geomorphic expression	Section is characterized by nearly continuous, morphologically young fault scarps on alluvium and well preserved, triangular-faceted bedrock spurs (Pardee, 1950 #46; Scholten and others, 1955 #69). Locally multiple-event scarps are as high as 40 m high (Johnson, 1981 #30) and single-event scarps are as high as 6 m high (Haller, 1988 #27). Pardee (1950 #46) recognized that the young fault scarps, which characterize most of the Red Rock fault, are the result of recent movements because of their steep slopes (30?-33?). Scarps heights along the southern 8 km vary from about 1 m to more than 10 m; however, the youngest mapped fan deposits are not faulted (Harkins and others, 2005 #7034).
Age of faulted surficial deposits	Red Rock fault is shown to be located at the contact between bedrock and alluvium (Lonn and others, 2000 #7050).
Historic earthquake	
Most recent prehistoric deformation	latest Quaternary (<15 ka) *Comments:* Bartholomew and others (2009 #7041) indicate that the most recent event is younger than 3705 +/-260 yr and older than 2240+/-150 yr. Scarps along this segment also are estimated to be Holocene in age based on their morphology (Haller, 1988 #27). In contrast, Witkind (1975 #317) suggested historic movement along this part of the fault.
Recurrence interval	10 k.y. (<13 ka) *Comments:* Bartholomew and others (2009 #7041) indicate that the most recent event is younger than 3705 +/-260 yr and the penultimate event occurred shortly after the deposition of the underlying late-glacial outwash exposed in the trench, which

	suggests an elapse time of about 10 k.y.
Slip-rate category	Between 0.2 and 1.0 mm/yr *Comments:* Harkins and others (2005 #7034) show slip rates based on the offset from the most recent event and acknowledge that they represent maximum rates as shown on figure 9. The slip rates presented are an order of magnitude larger than the suggested rate based on the single trench site on the fault and probably is the basis of the 1.5 mm/yr slip rate reported by Majerowicz and others (2007 #7036). In contrast, Ostenaa and Wood (1990 #318), based on trenching of Stickney and Bartholomew, suggest that slip during the most recent event was about 2.5 m, and the recurrence interval between the past two events was 5-15 k.y., which yields a slip rate that would fall within the assigned slip-rate category. Bartholomew and others (1999 #7141) indicate the trenching data points to a slip rate of about 11.3 cm/1000 yr (0.11 mm/yr) considering 2.6 m of displacement in the past 23 k.y. The range of slip rates for Big Sheep Creek scarps presented by Harkins and others (2005 #7034) are similar to the rate that Ostenaa and Wood suggest.
Date and Compiler(s)	2011 Kathleen M. Haller, U.S. Geological Survey
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