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Hebgen fault (Class A) No. 656

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Compiled in cooperation with the Montana Bureau of Mines and Geology

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Synopsis	Even though the largest historic earthquake in Montana, 1959 Hebgen Lake earthquake (Mw7.3), caused surface rupture of this fault, early published data in reports dating from the early 1960s and paleoseismic studies conducted in 2000 are the only investigations addressing the fault.
Name comments	Pardee (1950 #46) noted morphology suggesting a fault-controlled range front along the northeast side of Hebgen Lake but no name was assigned. The earliest use of a name for the fault was probably in the numerous publications that resulted from studies of the 1959 Hebgen Lake earthquake (Myers and Hamilton, 1961 #636; Witkind and others, 1962 #633; Witkind, 1964 #247; Myers and Hamilton, 1964 #250; Witkind and others,

	1964 #629; Witkind, 1969 #468). An earlier publication refers to the fault as Hebgen Lake fault (U.S. Coast and Geodetic Survey, 1959 #630). The Hebgen fault, as defined by 1959 surface rupture, extends from Beaver Creek southeastward to 2.3 km west of Canyon Creek. **Fault ID:** Refers to number 6 (Hebgen fault) of Witkind (1975 #317), number 42 (Hebgen fault) of Johns and others (1982 #259), number 13 (Hebgen fault) of Stickney and Bartholomew (1987 #85), and Hebgen fault of Stickney and Bartholomew (1987 #242; written commun. 1992 #556).
County(s) and State(s)	GALLATIN COUNTY, MONTANA
Physiographic province(s)	NORTHERN ROCKY MOUNTAINS
Reliability of location	Good Compiled at 1:24,000 scale. *Comments:* Location is based on 1:62,500-scale map (Witkind, 1964 #247; Myers and Hamilton, 1964 #250), further constrained by satellite imagery and topography at scale of 1:100,000. Reference satellite imagery is ESRI_Imagery_World_2D with a minimum viewing distance of 1 km.
Geologic setting	High-angle, down-to-the-southwest, range-front normal fault that bounds the northeastern side of main body of Hebgen Lake. Fault generally parallels the strike of the bedrock and has a close spatial relation to the surface trace of the Laramide-age Johnson thrust fault (Witkind, 1964 #247; Myers and Hamilton, 1964 #250). Witkind and others (1964 #629) indicate that Cambrian strata are on both sides of the fault for much of its length suggesting that the total stratigraphic throw is small. Witkind (1964 #247) indicates net cumulative throw is about 305 m.
Length (km)	13 km.
Average strike	N53°W
Sense of movement	Normal *Comments:* Based on slip indicators with rakes of 90? resulting from the Hebgen Lake earthquake (Witkind and others, 1962 #633).

Dip	60°-80° SW *Comments:* Range in dip is from Witkind (1975 #317) and Johns and others (1982 #259). Witkind and others (1964 #629) suggests a dip of 75? SW. Geodetic data suggests fault dips 45? SW (Barrientos and others, 1987 #269).
Paleoseismology studies	Paleoseismic investigations on the Hebgen Fault were conducted in 2000 and again in 2002 at Cabin Creek and Section 31. At site 656-1 at Cabin Creek, two terrace risers at the northwest end of the 1959 surface rupture demonstrate recurrent movement on the fault. The lower terrace is offset 3.1 m (only 1959 offset), whereas the upper terrace is offset 5.3 m. The upper terrace has nearly two times the offset of the lower terrace. A trench, excavated across the fault on the upper terrace, exposed the 1959 colluvial wedge and a penultimate wedge from a presumably earlier Holocene earthquake (Pierce and others, 2000 #7022; 2000 #7023). Site 656-2 at Section 31 site is located near the center of the Hebgen fault. Findings from original trenching (Hecker others, 2000 #7021) suggest the net tectonic vertical displacement of the alluvial-fan surface is 5-6 m; net displacement in the past two events is 2-3 m. A later study revealed a possible third event (Hecker and others, 2002 #7026) since the alluvial fan stabilized about 11-15 ka.
Geomorphic expression	Historical fault scarps are 0.3- to 6-m high (generally 3-m high;Witkind, 1964 #247) and locally superimposed on 3- to 30-m-high prehistoric scarps, monoclinal folds, and linear bedrock outcrops (Witkind, 1964 #247; Myers and Hamilton, 1964 #250; Witkind and others, 1964 #629). Wallace (1980 #657) details significant degradation of scarp at two locations.
Age of faulted surficial deposits	Upper Quaternary (Pinedale and Bull Lake) alluvium (~30%); Precambrian, Cambrian, Devonian, and Mississippian bedrock (~70%) based on mapping shown on plate 5 of USGS Professional Paper 435 (1964).
Historic earthquake	Hebgen Lake earthquake 1959
Most recent	latest Quaternary (<15 ka)

prehistoric deformation	*Comments:* Some early papers that discuss this fault suggest there is no evidence of previous faulting (Witkind, 1975 #317) or provide inconclusive evidence of prior faulting (Myers and Hamilton, 1964 #250); however, more recent morphologic studies by Nash (1984 #343) estimate the age of prehistoric faulting on nearby intrabasin scarps [659] to be 2.8 ?1.0 k.y., which was substantiated by later paleoseimic investigations. Doser (1985 #22) reports a date of 3,250 ?850 yr BP attributed to Nash. Alexander and others (1994 #1252) suggest that the migration of the South Fork of the Madison River meander belt to the east is due to recurrent Holocene faulting. No published data are available for scarps on the Hebgen fault.
Recurrence interval	1.0-13.5 k.y. (<15 ka) *Comments:* Radiocarbon dates and cosmogenic radionuclide dating (26Al, 10Be) of displaced fan and terrace surfaces indicate the intervals between the past three large events are variable: 1-3 ka between 1959 and the penultimate event and 7-13.5 ka between the penultimate and prior surface rupture (van der Woerd and others, 2000 #7025). An earlier study by Wheeler and Krystinik (1992 #608) suggests that these recurrence intervals of 5.4-29.8 k.y. since 0.6-2.0 Ma, which considers the maximum age of the fault zone (including Red Canyon fault) to be 0.6-2.0 m.y., the net cumulative throw of 305 m from Witkind's data (1964 #247), and slip events with displacement similar to 1959 Hebgen Lake earthquake. Ostenaa and Wood (1990 #318) indicate the recurrence interval is less than 10 k.y. for an unspecified time interval.
Slip-rate category	Between 0.2 and 1.0 mm/yr *Comments:* The only known slip rate published for this fault zone is by Doser (1985 #641) whose estimate is 0.8-2.5 mm/yr for an unspecified time interval, but the late Quaternary expression of the fault is not suggestive of a slip rate of this magnitude. A lower long-term (<0.6-2.0 Ma) slip rate is suggested for the entire fault zone, which includes the Red Canyon fault, based on the recurrence-interval data of Wheeler and Krystinik (1992 #608). Data from the various trenching and dating studies suggest that slip rates determined for each known event are variable but fall within the assigned slip-rate category.
Date and	2010

Compiler(s)	Kathleen M. Haller, U.S. Geological Survey
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