This map shows the location and distribution of Quaternary faults, folds, upwarps, and landslides in the central part of the upper Madison Valley and adjacent Madison and Gravelly Ranges in the Cliff Lake 15' quadrangle. The area is situated within the Intermountain Seismic Belt (Smith and Sbar, 1974) and at the east end of the Centennial Tectonic Belt of Stickney and Bartholomew (1987). The northeastern part of the Centennial Tectonic Belt, the Yellowstone-Holocene Fault, is the most seismically active part of the Intermountain Seismic Belt (Stickney and Bartholomew, 1987, p. 1905). The Cliff Lake Quadrangle is located 6 km west of Earthquake Lake which was formed by a massive rock slide that dammed the Madison River during the 1959 Hebgen Lake earthquake, the largest historic earthquake recorded within this seismic belt.

Movement on all faults shown on this map postdates the emplacement of the 1.8-2.0 Ma Huckleberry Ridge Tuff. Faults along the western base of the Madison Range show well-preserved scars along their traces. Faults in the north and east parts of the quadrangle trend mainly northwest. In the east-central part of the quadrangle, east of the Madison River, these faults define a narrow, north-northeast-trending block within the Madison Valley. Uplift of the block, which shows more than 200 m of structural relief in central part, appears to have heaved the wall defined late Pleistocene pediment surface along the west side of the Madison Range. Two major faults are present in the southwestern part of the quadrangle. A large, north-northeast trending fault follows the drainage of the West Fork of the Madison River. The second, a north-trending fault parallel to the west is a major fault of the Gravelly Range. Pre-Pleistocene rocks exposed west of the fault are juxtaposed against poorly consolidated late Tertiary sedimentary deposits which are overlain by the Huckleberry Ridge Tuff.

Landslides in the Cliff Lake Quadrangle range in size from less than 0.1 km² to as large, compound landslides that exceed 5 km². The largest landslides are in the central part of the quadrangle mainly west of the Madison River and its West Fork. These landslides are largely confined to areas underlain by poorly consolidated late Tertiary basin-fill deposits which are overlain by the mechanically rigid, densely welded Huckleberry Ridge Tuff. The landslides, which are currently active, are characterized by hummocky topography, closed and undrained depressions, abundant extensional fractures, and rigid-body rotation of blocks of the Huckleberry Ridge Tuff. Pull-apart depressions adjacent to cliff edges of the Huckleberry Ridge Tuff, as along the Cliff Lake Bench above Cliff and Wade Lakes, and in the vicinity of Triatom Mountain, are common. The depressions often expose roots of trees; soil slope from the depressions tilted trees are common. Currently, mud springs are active at the base of landslides dissected by Quaking Aspen Creek near confluence with the Madison River.

Like Earthquake Lake to the east, Cliff and Wade Lakes, as well as Hidden and Elk Lakes directly south of the quadrangle, are dammed by large landslides. A large slide in the central part of the quadrangle, directly north of Squaw Creek, apparently dammed the Madison River for a brief time; poorly consolidated late Tertiary sedimentary deposits in this slide are present on both sides of the Madison River. Coalescing landslides along the lower reaches of the West Fork appear to have periodically dammed this tributary, causing sediment infilling of the upper stream valley during these times; the gradient of the river along these slides is anomalously gentle, marked by flat floodplains, abundant wetlands, and swampy ground. Smaller landslides appear to have blocked Moose, Squaw, and Poperose Creeks in the recent past.

To determine if landslides in the map area are presently active or have been active in historic times, trees at two sites were cored and their tree-ring record inspected for signs of disturbance. Such signs include bands of narrow tree rings that did not form in response to climate change, and reaction wood, an indicator of tilting. At a site along Cliff Bench Road, three Douglas firs were cored (sites 35 CL on map). The oldest tree at this site had a tree-ring record that extended back to 1837. Although more data needs to be collected from this site, preliminary analysis of bands of narrow tree rings and reaction wood common to more than one tree suggests disturbance five times in the last 130 years: 1865, 1891, 1907, c. 1930, and c. 1943, suggesting a recurrence interval of about 28 years for disturbance (movement).

At a site along Freeway Mountain Road four tilted trees, three Douglas firs and one limber pine, were cored (site 180 PM on map). The oldest tree at this site also had a tree-ring record that extended back to 1837. Although all trees at this site had a tree-ring record that extended back to 1837, one tree contained four very well-defined bands of reaction wood clearly indicating periods of disturbance. Although more data needs to be collected from this site, preliminary analysis suggests disturbance five times in the last 110 years: about 1883 and 1895, clear evidence of movement between 1822 and 1825, about 1942, and about 1960 (probably due to the Hebgen Lake earthquake). The recurrence interval for disturbance (movement) at this site is about 22 years.

During the 1959 Hebgen Lake seismic event, boulders of Huckleberry Ridge Tuff killed two people at the campground developed on the landslide between Cliff and Wade Lakes. Water trees leading from those landslides to the higher Cliff Lake Bench were ruptured by boulders dislodged from the edge of the bench. Extension fractures disrupted the foundation of the main residence of Graeme Place (now the Beaverhead Ranch) along the west fork of the Madison. And both Soap and Quaking Aspen Creek drain landslides along the lower slopes of the Gravelly Range turned white from mud derived from the late Tertiary sedimentary deposits.

REFERENCES CITED


This map is preliminary and has not been reviewed for conformity with U.S. Geological Survey endorsement standards or with the Northern American Stratigraphic Code. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Preliminary Map Showing Quaternary Faults and Landslides in the Cliff Lake 15' Quadrangle, Madison County, Montana

By

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