U.S. DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

CLIFF LAKE QUADRANGLE

MONTANA-MADISON CO.

15 MINUTE SERIES (TOPOGRAPHIC)

OPEN-FILE REPORT

94-198

EXPLANATION

LANDSLIDE DEPOSITS

FAULT--approximately located, dotted where concealed by landslides, queried where questionable; ball and bar on downthrown side

FOLD

Anticline or upwarp

Monocline

● 186 FM SAMPLE LOCALITY OF TREE RING DATA

DISCUSSION

This map shows the location and distribution of Quaternary faults, folds, upwarps, and landslides in that 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 easternmost part of the Centennial Tectonic Belt, the Yellowstone-Hebgen Lake segment, is the most seismically active part of the Intermountain Seismic Belt (Stickney and Bartholomew, 1987, p. 1605). 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 postdate the emplacement of the 1.8-2.0 Ma Huckleberry Ridge Tuff. Faults along the western base of the Madison Range show well preserved scarps 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, northwest-trending block within the Madison Valley. Uplift of the block, which shows more than 200 m of structural relief in its central part, appears to have bowed the well 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 largely concealed northeast-trending fault follows the drainage of the West Fork of the Madison River. The second, a north-trending fault farther to the west is a major fault of the Gravelly Range; Precambrian 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 that 0.1 km^2 to large, compound landslides that exceed 5 km^2. 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 recurrently 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 Flatiron Mountain, are common. These depressions often expose roots of trees; downslope from the depressions tilted trees are common. Currently, mud springs are active at the toes of landslides dissected by Quaking Aspen Creek near its 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 above these slides is anamolously gentle, marked by wide, flat floodplains, abundant wetlands, and swampy ground. Smaller landslides appear to have blocked Moose, Squaw, and Papoose 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 tilted Douglas firs were cored (site 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, $\leq$ 1930, and $\leq$ 1943, suggesting a recurrence interval of about 26 years for disturbance (movement).

At a site along Freezeout Mountain Road four tilted trees, three Douglas firs and one limber pine, were cored (site 186 FM 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 showed some signs of disturbance, one tree contained four very well-defined bands of reaction wood clearly indicating periods of disturbance. Although more data should 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 1922 and 1925, 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 lines leading from these lakes 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 Grahams Place (now the Beaverhead Ranch) along the West Fork of the Madison. And both Soap and Quaking Aspen Creeks that drain landslides along the lower slopes of the Gravelly Range turned white from mud derived from the late Tertiary sedimentary deposits.

REFERENCES CITED

Smith, R.B., and Sbar, M.L., 1974, Contemporary tectonics and seismicity of the western United States with emphasis on the Intermountain Seismic Belt: Geological Society of America Bulletin, v. 85, p. 1205-1218.

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

Stereo compilation by Fairchild Aerial Surveys, Inc. for the Bureau of Reclamation

Field examination and publication by the Geological Survey as part of the Department of the Interior program for the development of the Missouri River Basin

Control by USGS, USC&GS and Fairchild Aerial Surveys, Inc.

Topography from aerial photographs by stereoplanigraph methods. Aerial photographs taken 1947. Field check 1950

Polyconic projection. 1927 North American Datum

10,000-foot grid based on Montana coordinate system, south zone

Dashed land lines indicate approximate locations

Land lines unsurveyed in T. 9 S.-R. 1 W., T. 11 S.-R. 1 W., T. 12 S.-R. 1 W., and T. 10 S.-R. 2 E.

Unchecked elevations are shown in brown

1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue

UTM GRID AND 1950 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:62500

CONTOUR INTERVAL 40 FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929

Geology mapped in 1992 and 1993

INTERIOR GEOLOGICAL SURVEY, RESTON, VIRGINIA 1994

MONTANA

QUADRANGLE LOCATION

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

By

J. Michael O'Neill, Thomas H. LeRoy, and Paul E. Carrara

1994