

**GEOLOGIC MAP OF THE
CENTRAL MADISON VALLEY (ENNIS AREA)
SOUTHWESTERN MONTANA**

MBMG Open File Report 543

2007

Karl S. Kellogg¹, Chester A. Ruleman¹, and Susan M. Vuke²

¹ U.S. Geological Survey

² Montana Bureau of Mines and Geology

This report has been reviewed for conformity with Montana Bureau of Mines and Geology technical and editorial standards.

Partial support has been provided by the STATEMAP component of the National Cooperative Geology Mapping Program of the U.S. Geological Survey under contract Number 05HQAG0093.

GEOLOGY OF THE CENTRAL MADISON VALLEY (ENNIS AREA)

Introduction

The geologic map of Cenozoic deposits of the central Madison Valley is one of a series of 1:50,000-scale intermontane valley maps prepared by the Montana Bureau of Mines and Geology as part of the U.S. Geological Survey STATEMAP program (Fig. 1). The western Montana valley maps were individually proposed by the STATEMAP Advisory Board primarily because they are areas where development is occurring or is anticipated. The maps emphasize the geology of the Cenozoic deposits. The central Madison Valley map adjoins a 1:50,000-scale geologic map to the north, of the lower Jefferson Valley (Vuke, 2006).

The Central Madison Valley map is based on a series of 1:24,000-scale geologic maps by Karl S. Kellogg (1992, 1993a, 1993b, 1994, and 1995) and part of a 1:100,000-scale geologic map of the Ennis 30' x 60' quadrangle by Karl S. Kellogg and Van S. Williams (2000) that incorporates much new mapping with previous mapping in the area. In addition, the Central Madison Valley map includes subsequent mapping by Chester S. Ruleman (2002) on the east side of the Madison valley. Susan M. Vuke (Montana Bureau of Mines and Geology) compiled the Central Madison Valley map with minor modifications to the maps by Kellogg and Ruleman.

The central Madison Valley is part of an elongate north-south-trending structural basin, the Madison Basin, that developed as a result of horizontal extension following Laramide thrusting. Gravity and seismic data indicate that the basin (pre-Cenozoic surface) is asymmetric in the subsurface. The deep axis of the basin is parallel to the steep east-bounding mountain front and lies east of the geographic axis of the valley. The valley becomes progressively deeper to the south within the map area, to a depth of 4,500 meters (14,750 feet) or more south of Ennis (Rasmussen and Fields, 1985).

East side of basin

Gravity and seismic data indicate that the basin is bounded on the east side by a large, steep, west-dipping fault zone (Rasmussen and Fields, 1985), the Madison Range fault system of Pardee (1950). The faults of this system along the range front and the east side of the valley fill are interpreted as listric-normal, and many of the listric normal faults developed along fault planes of pre-existing, east-directed Laramide thrust faults (Kellogg and others, 1995). Movement has occurred along the central part of the Madison Range fault system during the last 130,000 years (Stickney and others, 2000; Ruleman, 2002). South of the map area the fault system moved during historic time (Stickney and others, 2000), including movement on the Hebgen Lake fault that produced the dramatic and devastating magnitude 7.3 earthquake in 1959 (Witkind, 1960; Doser, 1985).

An east-west composite seismic line near Jack Creek (Fig. 2) shows Tertiary sediment of the central Madison Valley dipping gently eastward and thickening toward the mountain front, indicating that the valley-bounding normal faults are Cenozoic growth faults. The basin fill along this seismic line is as much as 2.0 km (1.24 mi) thick (Kellogg and others, 1995).

Numerous small faults, many of which are antithetic to the overall down-to-the-west movement, cut the deeper Tertiary strata and diminish in throw upward (Rasmussen and Fields, 1985).

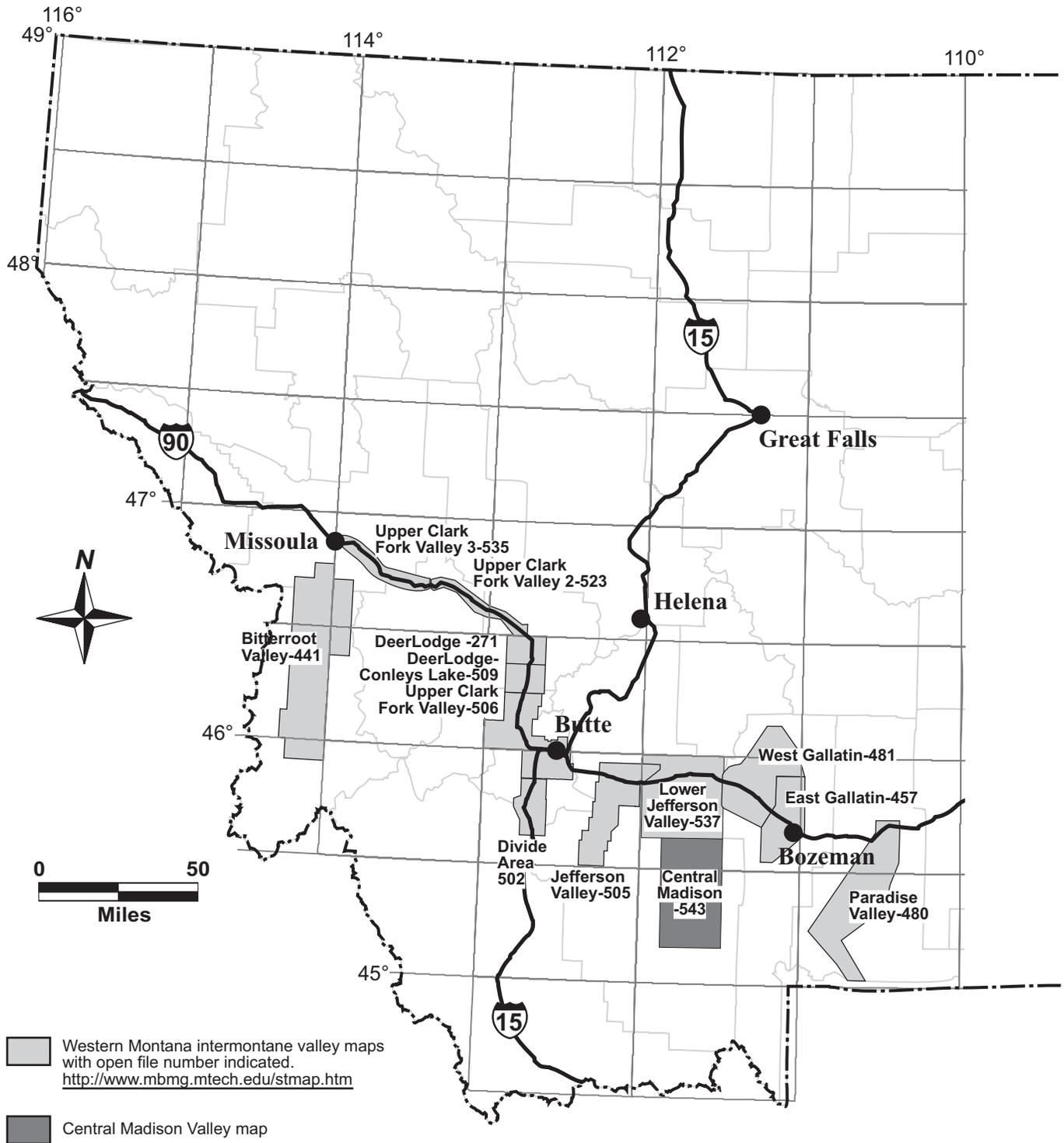


Figure 1. Location of Western Montana intermontane valley maps prepared by the Montana Bureau of Mines and Geology as part of the U.S. Geological Survey STATEMAP program.

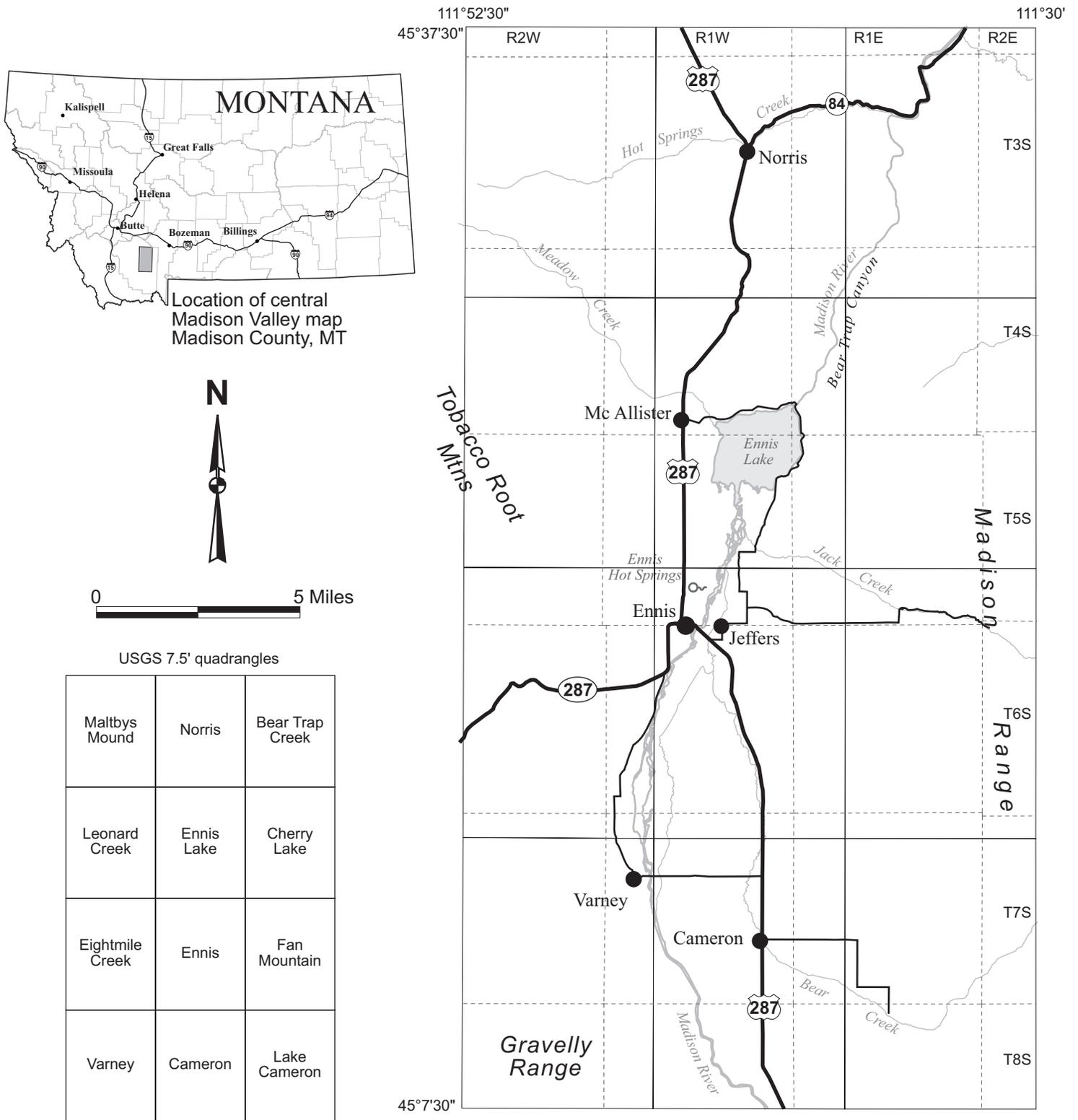


Figure 2. Location of the central Madison Valley map and index of 7.5' quadrangles.

North end of basin

The north end of the basin is bounded by the post-Laramide North Meadow Creek normal fault and an inferred normal fault about 0.5 km to the south, the South Meadow Creek fault, both of which probably developed concurrently with the Madison Range fault system. The North Meadow Creek fault lies approximately along the trace of the northwest-striking Laramide Spanish Peaks reverse fault, a reactivated Precambrian basement fault. However, the Spanish Peaks fault dips north whereas the North Meadow Creek fault dips south, indicating a complex fault zone architecture and reactivation history. The northwest-striking North Meadow Creek fault joins the north-striking Madison Range fault system to form the northeast corner of the Madison Basin (Schmidt and Garihan, 1985). North of the North Meadow Creek and Spanish Peaks faults, Cenozoic deposits are relatively sparse, and the Madison River flows through Bear Trap Canyon (Fig. 2), a gorge cut through Archean crystalline rocks. A geologic map by Peale (1896) shows a distinct jog in the Madison River where it crosses the North Meadow Creek fault (Young, 1985), within an area, now concealed by Ennis Lake. Movement along the North Meadow Creek and Spanish Creek faults has resulted in the juxtaposition of soft valley-fill sediment to the south and hard crystalline rocks to the north. Although this abrupt constriction of the Madison Valley created a seemingly ideal place for the Ennis Lake dam, the probable Quaternary displacement that has occurred along the North Meadow Creek fault suggests the potential for seismic hazard to the dam.

West side of basin

Gravity and seismic data indicate that the west side of the central Madison valley is bounded by east-dipping faults of considerably smaller magnitude than the Madison Range fault system (Rasmussen and Fields, 1985). Gravity surveys, seismic-refraction profiles, and additional electrical soundings were obtained in the Ennis Hot Springs vicinity at the west margin of the valley (Leonard and Wood, 1988). Results indicate that the springs overlie the eastern edge of a buried block of fractured crystalline rock bounded on the east and northeast by subsurface fault scarps. The north-striking fault beneath the hot springs is not a range-front-fault of major displacement such as those of the Madison Range fault system on the east side of the valley. Instead, the west side of the valley may be bounded by a series of north-striking step faults of relatively small displacement, downthrown to the east (Leonard and Wood, 1988).

**CENTRAL MADISON VALLEY
SOUTHWESTERN MONTANA**

EXPLANATION OF MAP UNITS

Quaternary sediment

- Qal** **Alluvium of modern channels (Holocene)**—Unconsolidated silt- to boulder-size clasts, moderately sorted to well-sorted in modern river and stream channels. Larger clasts are moderately rounded to well rounded, reworked from higher-energy fluvial episodes of the mid- to late Pleistocene. Thickness about 200 ft (61 m) based on GWIC* logs at various locations along the length of the Madison River in the map area. Northeast of Ennis Lake in a gorge through the Norris Hills, the Madison River rests on as much as 100 feet (30 m) of gravel (Paul and Lyons, 1960). Thickness of deposits of tributaries to the Madison River is limited to cut-and-fill channels inset into late Pleistocene deposits no greater than 3 to 5 m (1 to 2 ft), including silt and sand of overbank deposits.
- Qpa** **Paludal deposit (Holocene)**—Sand, silt, and organic matter deposited in swamp environment.
- Qalo** **Older alluvium and flood-plain deposits (Holocene and Pleistocene)**—Gravel, sand, silt, and clay, and organic matter deposited in broad, open stream valleys and in confined ephemeral stream channels immediately adjacent to alluvium of modern channels (Qal). A lithologic log from a well at Ennis Hot Springs (Fig. 2) at the westernmost part of the valley indicates about 5 m (16 ft) of Qalo overlying about 150 m (492 ft) of basin-fill deposits (unit QTen) above Archean crystalline rock (Leonard and Wood, 1988).
- Qta** **Talus deposit (Holocene and late Pleistocene?)**—Angular and subangular rock fragments at base of steep valley walls or cliffs that are as large as 10 m (33 ft) in diameter but generally less than 2 m (7 ft) in diameter. Locally includes minor alluvial deposits and rock-glacier deposits. Maximum thickness greater than 20 m (66 ft).
- Qrg** **Rock glacier deposit (Holocene and late Pleistocene?)**—Hummocky, lobate deposit of angular boulders having a frontal slope near the angle of repose; locally active. In places, grades into and includes some talus deposits (unit Qta). As much as about 20 m (66 ft) thick.
- Qac** **Alluvium, colluvium, and loess (Holocene and late Pleistocene)**—Unconsolidated to slightly indurated, mostly massive, dark-brown to light-gray-brown deposits that mantle gently to moderately sloping surfaces; locally includes eolian deposits at surface; intermixed with colluvium by downslope movement. Colluvium contains cobbles and pebbles derived from weathering of bedrock; loess is very fine grained sand, silt, and minor clay. Unit commonly contains poorly to moderately developed soil profile in upper part. Includes alluvium in small channels and sheetwash on steeper hillsides. Unmapped in many areas, particularly where deposit is thin and forms discontinuous veneer. Maximum thickness probably less than 10 m (33 ft).

*GWIC refers to the Montana Bureau of Mines and Geology Groundwater Information Center
<http://mbmgGWIC.mtech.edu/>

Qls **Landslide deposit (Holocene and late Pleistocene)**—Ranges from chaotically oriented debris to almost-intact slump blocks of bedrock. Cretaceous sedimentary rocks (Ks) are particularly susceptible to landslide development. Landslide deposits labeled **Qls (Tfet)** between Wigwam and Moran Creeks (Fig. 1) in the southwestern part of the map are composed of pale-gray to white rhyolitic air-fall ash, tuffaceous sandstone, and sparse gravel lenses, deposits that are highly unstable and prone to landslide development.

Qc **Colluvium (Holocene and late Pleistocene)**—Locally derived mixture of poorly sorted, angular clasts, as large as boulders, in a sand or finer-grained matrix. Includes some areas underlain by till. Common J-shaped tree trunks on steeper slopes record active soil creep. Mostly of late Pleistocene age (K.L. Pierce, oral communication, 1990).

Qafc₂
Qafc₁

Cedar Creek alluvial fan deposits (Holocene and Pleistocene)—Moderately well sorted cobble and boulder gravel that forms a prominent alluvial fan at mouth of Cedar Creek in Madison Valley. Clasts rounded to sub-rounded. Surface is characterized by braided stream pattern. Locally mantled by loess less than 1 m (3 ft) thick. Unit divided into deposits that correlate in time with the Pinedale mountain glaciation about 14-20 ka when most fan deposition occurred (unit Qafc₂), and deposits that correlate with the Bull Lake mountain glaciation about 100-140 ka (unit Qafc₁). Qafc₂ is inset into and topographically lower than Qafc₁, which is characterized by smooth, extensive surfaces that grade to the Cameron surface, which is underlain by unit Qgrc. Minor proximal fan development during Holocene time is included in Qafc₂. Modern channel of Cedar Creek incised about 10 m (31 ft) into Qafc₂ deposits near mouth of creek, indicating that proximal fan deposits are presently eroding. Qafc shown separately from Qaf because of its prominent size and detailed studies (Ritter and others, 1990). Thickness of fan deposit, as shown on GWIC* well logs as much as 445 ft (136 m) on the south edge of the fan, and 360 ft (110 m) on the north edge. Central part of the fan may be as much as 500 ft (154 m) thick.

Qaf₃
Qaf₂
Qaf₁

Alluvial fan deposits (Holocene to Pleistocene)—Moderately well sorted pebble- to boulder-size gravel in fan-shaped deposits at base of mountain fronts. Includes piedmont-slope deposits and debris-flow deposits. Unit is divided into Holocene deposits (Qaf₃); deposits that correlate with Pinedale mountain glaciation, about 14-20 ka (Qaf₂); and deposits that correlate with the Bull Lake mountain glaciation about 100-140 ka (Qaf₁). Qaf₃ is restricted to the mountain-piedmont junction along ephemeral drainage channels and is characterized by fresh, steep alluvial fan deposits that lack substantial soil development. Qaf₂ is inset into Qaf₁ which is characterized by smooth, subdued, **Qaf₂** extensive surfaces that grade to the Cameron surface, which is underlain by unit Qgrc. Thickness of fan deposit between 200 and 350 ft (61 and 107 m) on several GWIC* well logs through alluvial fan deposits south of the Cedar Creek alluvial fan, and as much as 390 ft (148 m) through alluvial fan deposits north of the Cedar Creek alluvial fan.

Qat **Alluvial terrace deposit of Madison River (Pleistocene)**—Moderately sorted, moderately rounded to well-rounded sand and gravel in linear deposits adjacent to and higher than modern flood plain of Madison River but lower than adjacent Qgr deposits. Mapped where separated from higher gravel (Qgr) by intermittent linear exposures of unit QTbf, and where separated from lower gravel (Qalo) by intermittent exposures of Tertiary units. Mantled by less than 2 m (7 ft) of loess at most places, although loess on many higher

surfaces is thick enough to support cultivation. Scarp symbol on map indicates abrupt change to different terrace levels within the unit. Equivalent to intermediate terraces of Paul and Lyons (1960). Deposits mostly less than 10 m (33 ft) thick.

- Qgt** **Glacial till (Pleistocene)**—Unsorted, unstratified, unconsolidated, subangular to subrounded boulders in an unsorted matrix as fine as silt. Most till deposited during Pinedale (about 14-20 ka) and Bull Lake (about 100-140 ka) mountain glaciations. Pinedale-age till preserved in hummocky deposits that contain numerous closed depressions and have a thin or non-existent soil profile; deposits of Bull Lake-age till have more rounded topography, are more dissected, and generally exhibit a well-developed soil profile. As much as about 50 m (164 ft) thick.
- Qdf** **Debris-flow deposit (Pleistocene)**—Very poorly sorted, unstratified deposit that contains angular to subrounded boulders as much as 2 m (7 ft) in diameter. May include some deposits of glacial till and small alluvial fans, although braided stream pattern typical of alluvial fans not well developed. Maximum thickness greater than 10 m (33 ft).
- Qgr** **Gravel deposits, undivided (Pleistocene)**—Moderately sorted, moderately rounded to well-rounded, poorly bedded sand and gravel. Although terrace scarps are not apparent, unit probably includes terrace gravel of the Madison River on the west side of the valley. In part may be equivalent in time and position to unit Qgrc. Gravel deposits along Jack Creek (Figure 2) are cut by multiple erosional scarps (Bearizi, 1987). Scarp symbol on the map indicates abrupt change from one terrace level to another. Thickness of gravel deposits in Meadow Creek and North Meadow Creek area west and northwest of McAllister is as much as 325 ft (99 m), but generally less than 150 ft (46 m) based on GWIC* well logs. Gravel in those areas is underlain by Archean metamorphic rocks.
- Qgrc** **Gravel of Cameron Bench (Pleistocene)**—Moderately sorted, moderately rounded to well-rounded sand and gravel, topographically higher than Qat. Deposited during Bull Lake glaciation (about 140-100 ka) (Schneider and Ritter, 1987). Mantled by less than 2 m (66 ft) of loess in most places.

Quaternary and/or Tertiary sediment and sedimentary rocks

- QTb1s** **Limestone of Blaine Springs (Pleistocene or Pliocene)**—(Description from Hadley, 1969a and b) Light brownish-gray to yellowish-gray, locally vuggy, well-bedded, fine-grained limestone locally overlain by bedded tuffaceous sand and silt (Hadley, 1969a and b). Represents a warm-spring deposit that contains Pleistocene freshwater gastropods (Montagne, 1960). (May be Pliocene based on current Cenozoic time scale.) The shell material of the gastropods is original, not at all recrystallized, and completely distinct from the enclosing matrix. Exposed thickness 20 m (66 ft).
- QTbf** **Basin-fill deposits (Pleistocene and Pliocene?)**—Interbedded, moderately sorted, poorly consolidated to unconsolidated, well-bedded to massive silt, sand, and well-rounded cobbles that are exposed on slopes adjacent to, and below terraces in Madison Valley. Exposed deposits are interpreted to be no older than Pliocene. Mapped as basin-fill deposit by Kellogg and Williams (2000) that represents the uppermost, exposed part of a deposit that is as thick as about 16,000 ft (about 4900 m) and as old as Eocene at the base (Rasmussen and Fields, 1983).
- QTnm** **Sandstone bed of North Meadow Creek (Pleistocene or Pliocene?)**—Light-tan to white,

carbonate-cemented, pebbly sandstone and sandy, pebbly limestone. Matrix-supported clasts as large as 4 cm (1/2 inch) make up as much as 30 percent of the rock and consist of subrounded to moderately well rounded quartz and Archean gneiss; largest clasts commonly are amphibolite. Forms ledges at approximately constant stratigraphic level within upper part of QTbf north of Ennis Lake. Thickness at least 20 m.

Tertiary sediment and sedimentary rocks

- Tls** **Landslide deposit (Pliocene or Miocene)**—Chaotically oriented angular blocks of Archean gneiss and rhyodacite flow rocks that are as large as 30 m north of Ennis Lake (in and near SW ¼ Sec 23, T4S, R1W). Ancient post-landslide hydrothermal activity is suggested by blocks that contain hematitic and jasperitic vein fillings as wide as 2 cm and by argillic alteration and bleaching of gneiss. Significant erosion and dissection of deposit suggest Tertiary age.
- Tbtc** **Diamicton of Beartrap Creek (Pliocene or upper Miocene)**—Diamicton with subangular to subrounded clasts of Archean gneiss and Paleozoic rocks as large as 2 m (7 ft) in mostly unconsolidated sandy matrix. Deposits are greatly dissected and underlie grassy slopes as high as 210 m (689 ft) above present drainage south of Cherry Creek (Figure 2) in northeastern part of map; generally only upper surfaces of larger clasts are exposed. Represents either debris flows or large fan deposits; abundant Archean metaquartzite clasts suggest major source area to south, where outcrops of Archean metaquartzite are common. Topography changed substantially since deposition. Age interpretation based on stratigraphic position overlying unit Tmva. Maximum exposed thickness about 60 m (197 ft).
- Tmva** **Madison Valley Formation (upper Miocene)**—White, light gray, light-brownish-gray, and yellowish-white, moderately indurated to well-indurated, locally vuggy limestone, calcareous sandstone, tuffaceous siltstone and sandstone, pebbly sandstone, and pebble conglomerate. Moderately rounded to poorly rounded clasts are as large as 30 cm (1 ft), but most are less than 5 cm (2 in); about 50 percent of clasts are white Archean quartzite, 40 percent are Archean gneiss, and remainder are vein quartz, aplite, fine-grained quartzite (probably from Middle Proterozoic Belt Supergroup) and vesicular basalt (similar to basalt that crops out about 1.5 km [1 mi] north of the northeastern part of the map). Plant fossils (twig debris) found in some ash beds; bone fragments found in some pebbly beds. Interlayered ash deposits are common, especially in association with limestone. Maximum $^{40}\text{Ar}/^{39}\text{Ar}$ age on sanidine from just east of Ennis Lake (NW1/4 Sec. 6, T. 5 S., R. 1 E), is 16.2+/- 0.19 Ma (Kellogg and Williams, 2000). Also dated as Miocene (Barstovian and partly Clarendonian) based on vertebrate fossils in the Madison Plateau area (Dorr, 1956). Maximum thickness about 150 m (492 ft).
- Tspc** **Conglomerate of Spring Creek (Miocene?)**—Well-indurated, clast- and matrix-supported, conglomerate with very light gray, calcareous matrix. Clasts well rounded, dominantly Belt Supergroup quartzite with some volcanic clasts, including rare pumice fragments, and sparse Archean gneiss clasts. Clasts as much as 30 cm (1 ft) in diameter. Contains subordinate gray calcareous, tuffaceous sandstone. Overlies Limestone of O'Dell Creek. Interpretation of Miocene(?) age based on conformable relationship with O'Dell Creek map unit. Exposed thickness about 100 ft (30 m).

Todc **Limestone of O'Dell Creek (Miocene?)**—Very light gray, massive, aphanitic, interbedded, tuffaceous limestone as much as 20 m (66 ft) thick that overlies about 6 m (20 ft) of tuffaceous sandstone and limestone, both in limited exposure. Locally contains abundant highly fractured and disaggregated white chert nodules 2 to 3 cm (approximately 1 in) in diameter. May correlate with the Madison Valley Formation. Exposed thickness about 120 ft (37 m).

Tmc **Milligan Creek Formation (Eocene)**—White, moderately indurated to well-indurated micritic, lacustrine limestone; horizontally bedded; beds typically 0.1–1 m (.3–3 ft) thick. Contains a few interbeds of white, limy, fine-grained quartz sandstone; locally tuffaceous. Exposed in northeastern part of map south of Cherry Creek (Figure 2). Exposed thickness about 100 m (328 ft).

Red Bluff Formation—Tentatively named the “Red Bluff formation” by Andretta and Alsup (1960); formally named by Kellogg (1994) and divided into two informal members, an upper conglomerate, sandstone, and siltstone member, and a lower diamictite member (Kellogg, 1994).

Trbu **Upper member (Oligocene and Eocene)**—Mainly white and light-yellowish-brown siltstone, sandstone, conglomerate with subordinate, but conspicuous brick-red and maroon mudstone and siltstone; locally tuffaceous. Beds typically 0.5–2 m (2–7 ft) thick. Most clasts are Archean gneiss and vein or pegmatitic quartz, but some are quartz monzonite derived from Late Cretaceous Tobacco Root batholith. Outcrops in and immediately adjacent to sec.13, T.3 S., R.1W. are highly silicified, probably because of hot-spring activity. Elsewhere, rock is weakly to moderately well indurated. At a site 1 km (0.6 mi) east of Norris, dips are as much as 40 degrees. Good exposure of unit at type locality along unnamed creek in W ½, sec. 13, T. 3 N., R. 1 W. Maximum exposed thickness about 100 m (328 ft).

Trbl **Lower member (Eocene)**—Subrounded to well-rounded, clast-rich, mostly clast-supported, moderately well indurated bouldery diamictite composed almost entirely of clasts of coarse-grained granodiorite or quartz monzonite derived from the Tobacco Root batholith; contains sparse boulders of aplite (probably derived from dikes in Tobacco Root batholith), quartz, and Archean gneiss; contains lenses of yellow-brown to very light brown, coarse-grained arkosic sandstone and pebbly conglomerate. Boulders are typically 0.5–2 m (2–7 ft) in diameter; locally much larger. Moderately well indurated sandy gross matrix derived from disintegration of boulders. Boulders greater than about 1 m (3 ft) in diameter commonly in contact with one another, possibly because of post-emplacement settling. Rounded boulders greater than 2 m (7 ft) in diameter well exposed behind U.S. Post Office in Norris; boulders as much as 7 m (23 ft) in diameter exposed on hill 0.5 km south of Norris, at type locality. Outcrops of granodiorite as wide as 15 m (46 ft) in NE ¼, sec. 27, T.3 S., R.1W. interpreted as exposed parts of enormous blocks within unit. Probably deposited by catastrophic debris flows that moved northeast from the Tobacco Root Mountains through gap in NW ¼, sec. 27, T.3S., R.1W. and then east down valley of ancestral Hot Springs Creek. The shoestring geometry of the deposit can be traced in benches as high as 100 m (328 ft) above stream level, to a point at least 2 km (6562 ft) downstream from confluence of Hot Spring Creek and Madison River, about 2 km (6562 ft) east of the northeastern corner of the map.

- Tba** Basalt (Oligocene?)
- Tanb** Andesite and basalt (Oligocene and Eocene)
- Tr** Rhyolite (Oligocene or Eocene)
- Tfet** Felsic tuff

Tertiary or Cretaceous igneous rock

- TKjb** Jasperoid breccia (early Tertiary or Late Cretaceous)
- TKrda** Rhyolite and/or dacite (early Tertiary or Late Cretaceous)

Cretaceous igneous rocks

- Kdap** Dacite porphyry (Late Cretaceous)
- Kit** Intrusive rock of Tobacco Root Batholith, undivided (Upper Cretaceous)
- Ks** Cretaceous sedimentary rocks, undivided—Includes Sphinx Conglomerate, Livingston Formation, Everts(?) Formation, Virgelle Sandstone, Telegraph Creek Formation, Cody Shale, Frontier Formation, Mowry Shale, Muddy Sandstone, Thermopolis Shale, and Kootenai Formation.
- Js** Jurassic sedimentary rocks, undivided—Includes Morrison, Swift, Rierdon, and Sawtooth Formations.
- JFs** Jurassic and Triassic sedimentary rocks, undivided—Includes Morrison, Swift, Rierdon, Sawtooth, Woodside, and Dinwoody Formations.
- PIPMs** Permian, Pennsylvanian, and Mississippian sedimentary rocks, undivided—Includes Shedhorn, Quadrant, and Amsden Formations.
- IPMs** Pennsylvanian and Mississippian sedimentary rocks, undivided—Includes Quadrant and Amsden Formations
- Ms** Mississippian sedimentary rocks, undivided—Includes Mission Canyon and Lodgepole Formations.
- MDs** Mississippian and Devonian sedimentary rocks, undivided—Includes Three Forks and Jefferson Formations.
- OCs** Ordovician and Cambrian sedimentary rocks, undivided—Includes Bighorn, Snowy Range, Pilgrim, Park, Meagher, Wolsey, and Flathead Formations.
- Cs** Cambrian sedimentary rocks, undivided—Includes Snowy Range, Pilgrim, Park, Meagher, Wolsey, and Flathead Formations.
- Amt** Archean metamorphic rocks, undivided

MAP SYMBOLS



Contact between geologic units



Terrace scarp—Barbs on downcut side.



Strike and dip of bedding—Number indicates angle of dip in degrees. Shown only for Cenozoic units.



Fault, normal—Long-dashed where approximately located, dotted where concealed. Ball and bar on downthrown side where relative movement known.



Fault, thrust—Teeth on upper plate; dotted where concealed.

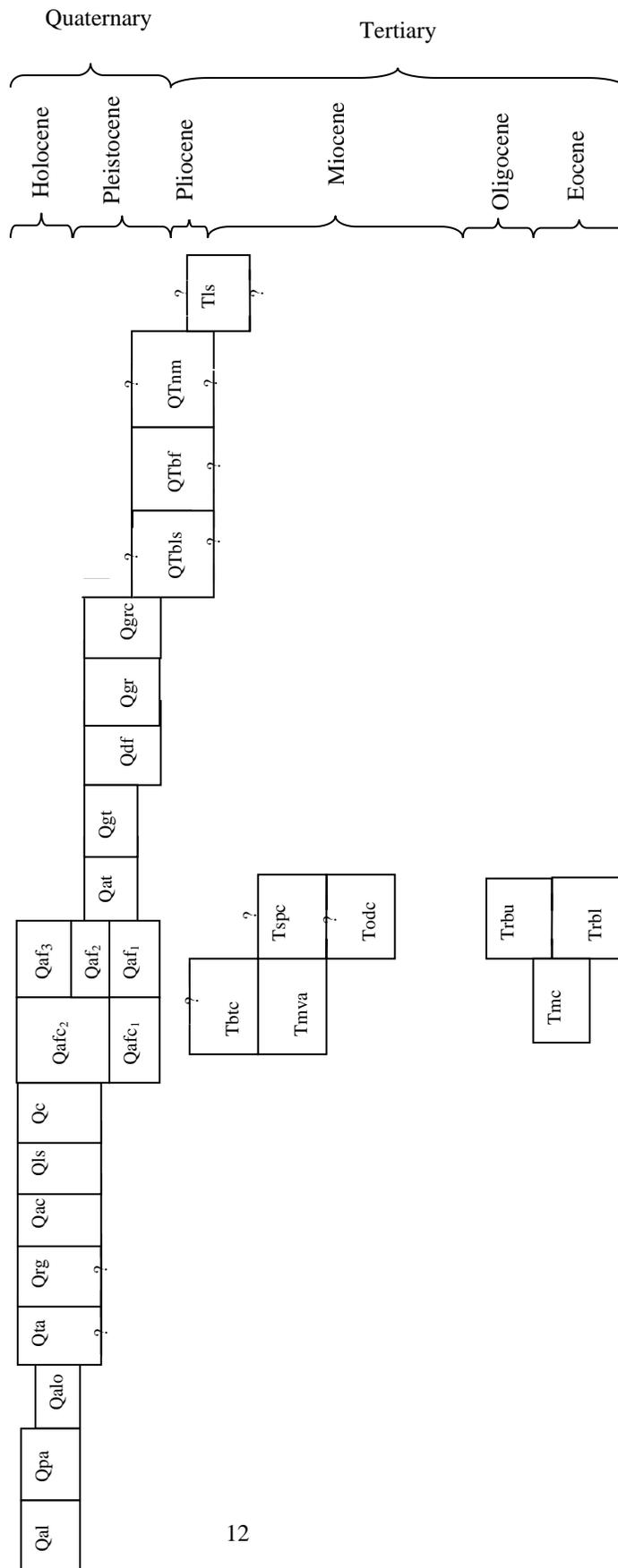


Fault, high-angle reverse—Symbols on upper plate; Long-dashed where approximately located, dotted where concealed.

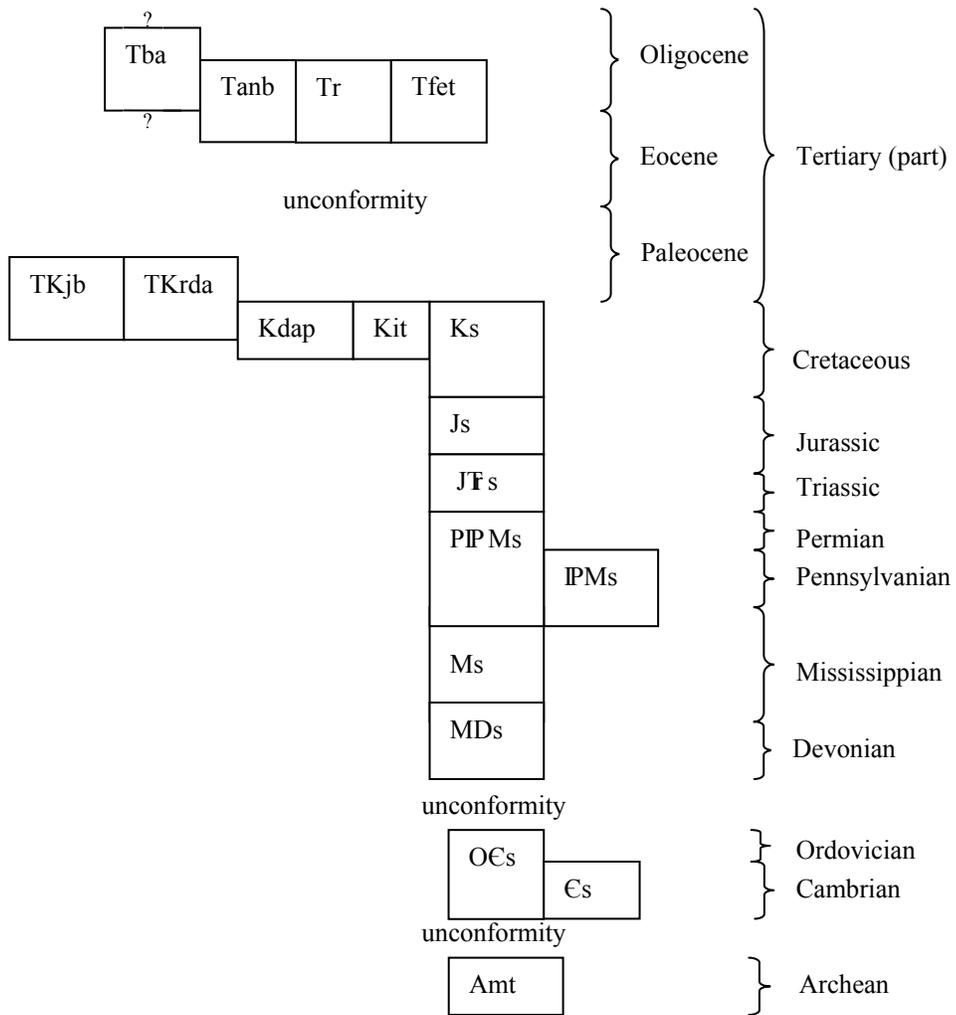


Mine waste

CENTRAL MADISON VALLEY
CORRELATION DIAGRAM FOR
SEDIMENTARY CENOZOIC UNITS



CENTRAL MADISON VALLEY
CORRELATION DIAGRAM FOR IGNEOUS, METAMORPHIC,
AND PRE-CENOZOIC SEDIMENTARY ROCKS



INDEX OF GEOLOGIC MAP SOURCES AND 7.5-MINUTE QUADRANGLES

Maltbys Mound 2, 12	Norris 8	Bear Trap Creek 9
Leonard Creek	Ennis Lake 1, 7	Cherry Lake 1, 6
Eight-mile Creek	Ennis 10	Fan Mountain 5
Varney 4	Cameron 3	Lake Cameron 11

1. Bearzi, 1987, scale 1:68,750.
2. Elliott, W.S., 1998, scale 1:24,000.
3. Hadley, J.B., 1969a, scale 1:62,500.
4. Hadley, J.B., 1969b, scale 1:62,500.
5. Kellogg, K.S., 1992, scale 1: 24,000.
6. Kellogg, K.S., 1993a, scale 1: 24,000.
7. Kellogg, K.S., 1993b, scale 1:24,000.
8. Kellogg, K.S., 1994, scale 1: 24,000.
9. Kellogg, K.S., 1995, scale 1: 24,000.
10. Leonard, R.B., and Wood, W.A., 1988, Fig. 3, scale 1:17,000.
11. Tysdal, R.G., 1990, scale 1:62,500.
12. Vitaliano, C.J. and Cordua, W.S., 1979, scale 1:62,500.

Entire map area:

Kellogg, K.S., and Williams, V.S., 2000, scale 1:100,000.

Kellogg, K.S., and Williams, V.S., 2005, scale 1:100,000.

CENTRAL MADISON VALLEY

REFERENCES CITED

- Andretta, D.B., and Alsup, S.A., 1960, Geology and Cenozoic history of the Norris-Elk Creek area, southwest Montana, *in* Campau, D.E., Anisgard, H.W., and Egbert, R.L., eds., West Yellowstone–Earthquake area, Billings Geological Society 11th Annual Field Conference Guidebook, p. 185–190.
- Bearzi, J.P., 1987, Soil development, morphometry, and scarp morphology of fluvial terraces at Jack Creek, southwestern Montana: Bozeman, Montana State University M.S. thesis, 131 p.
- Dorr, J.A., Jr., 1956, Anceney local mammal fauna, latest Miocene, Madison Valley formation, Montana: *Journal of Paleontology*, v. 30, no. 1, p. 62–74.
- Doser, D.I., 1985, Source parameters and faulting processes of the 1959 Hebgen Lake, Montana, earthquake sequence: *Journal of Geophysical Research*, v. 90, p. 4537–4555.
- Elliott, W.S., 1998, Geologic maps of the Harrison and Maltbys Mound 7.5 minute quadrangles, Madison County, Montana: Montana Bureau of Mines and Geology Open File Report 375, 2 sheet(s), 1:24,000.
- Hadley, J.B., 1969a, Geologic map of the Cameron quadrangle, Madison County, Montana: U.S. Geological Survey Geologic Quadrangle Map GQ–813, scale 1:62,500.
- Hadley, J.B., 1969b, Geologic map of the Varney quadrangle, Madison County, Montana: U.S. Geological Survey Geologic Quadrangle Map GQ-814, scale 1:62,500.
- Hadley, J.B., 1980, Geology of the Varney and Cameron quadrangles: U.S. Geological Survey Bulletin 1459, 108 p.
- de la Montagne, John, 1960, Geomorphic problems in the Madison Valley, Madison County, Montana: an introduction and synthesis, *in* Campau, D.E., Anisgard, H.W., and Egbert, R.L., eds., West Yellowstone–Earthquake area, Billings Geological Society 11th Annual Field Conference Guidebook, p. 165–169.
- Kellogg, K.S., 1992, Geologic map of the Fan Mountain quadrangle, Madison County, Montana: U.S. Geological Survey Geologic Quadrangle Map GQ–1706, scale 1: 24,000.
- Kellogg, K.S., 1993a, Geologic map of the Cherry Lake quadrangle, Madison County, Montana: U.S. Geological Survey Geologic Quadrangle Map GQ–1725, scale 1: 24,000.
- Kellogg, K.S., 1993b, Geologic map of the Ennis Lake quadrangle, Madison County, Montana: U.S. Geological Survey Geologic Quadrangle Map GQ–1729, scale 1:24,000.

- Kellogg, K.S., 1994, Geologic map of the Norris quadrangle, Madison County, Montana: U.S. Geological Survey Geologic Quadrangle Map GQ-1738, scale 1:24,000.
- Kellogg, K.S., 1995, Geologic map of the Bear Trap Creek quadrangle, Madison County, Montana: U.S. Geological Survey Geologic Quadrangle Map GQ-1757, scale 1:24,000.
- Kellogg, K. S., and Williams, V.S., 2000, Geologic map of the Ennis 30' x 60' quadrangle, Madison and Gallatin Counties, Montana, and Park County, Wyoming: U.S. Geological Survey Geologic Investigations Map I-2690, scale 1:100,000.
- Kellogg, K. S., and Williams, V.S., 2005, Geologic map of the Ennis 30' x 60' quadrangle, Madison and Gallatin Counties, Montana, and Park County, Wyoming, Montana Bureau of Mines and Geology Open File Report 529, 27 p., scale 1:100,000.
- Kellogg, K.S., Schmidt, C.J., and Young, S.W., 1995, Basement and cover-rock deformation during Laramide contraction in the northern Madison Range (Montana) and its influence on Cenozoic basin formation: *American Association of Petroleum Geologists Bulletin*, v 79, p. 1117–1137.
- Kuenzi, W.D., and Fields, R.W., 1971, Tertiary stratigraphy, structure, and geologic history, Jefferson basin, Montana: *Geological Society of America Bulletin*, v. 82, p. 3374-3394.
- Leonard, R.B., and Wood, W.A., 1988, Evaluation of a hydrothermal anomaly near Ennis, Montana: U.S. Geological Survey Professional Paper 1044-K, 53 p.
- Marvin, R.F., Wier, K.L., Mehnert, H.H., and Merritt, V.M., 1974, K-Ar ages of selected Tertiary rocks in southwestern Montana: *Isochron/West*, no. 10, p. 17-20.
- Paul, H.P., and Lyons, L.A. 1960, Quaternary surfaces along the Madison valley floor from Ennis Lake to English George Creek, Montana, *in* Campau, D.E., Anisgard, H.W., and Egbert, R.L., eds., *West Yellowstone–Earthquake area: Billings Geological Society 11th Annual Field Conference Guidebook*, p. 170–171.
- Pardee, J.T., 1950, Cenozoic block faulting in western Montana: *Geological Society of America Bulletin*, v. 62, p. 359-406.
- Peale, A.C., 1896, Three Forks, Montana sheet: U.S. Geological Survey Geological Atlas, Folio 24, 5 p., 4 maps.
- Rasmussen, D.L., and Fields, R.W., 1983, Structural and depositional history, Jefferson and Madison basins, southwestern Montana [abs.]: *American Association of Petroleum Geologists Bulletin*, v. 67, p. 1352.
- Rasmussen, D.L., and Fields, R.W., 1985, Cenozoic structure and depositional history, Jefferson and Madison intermontane basins, southwestern Montana [abs.], *in* Beaver, P.C., ed.,

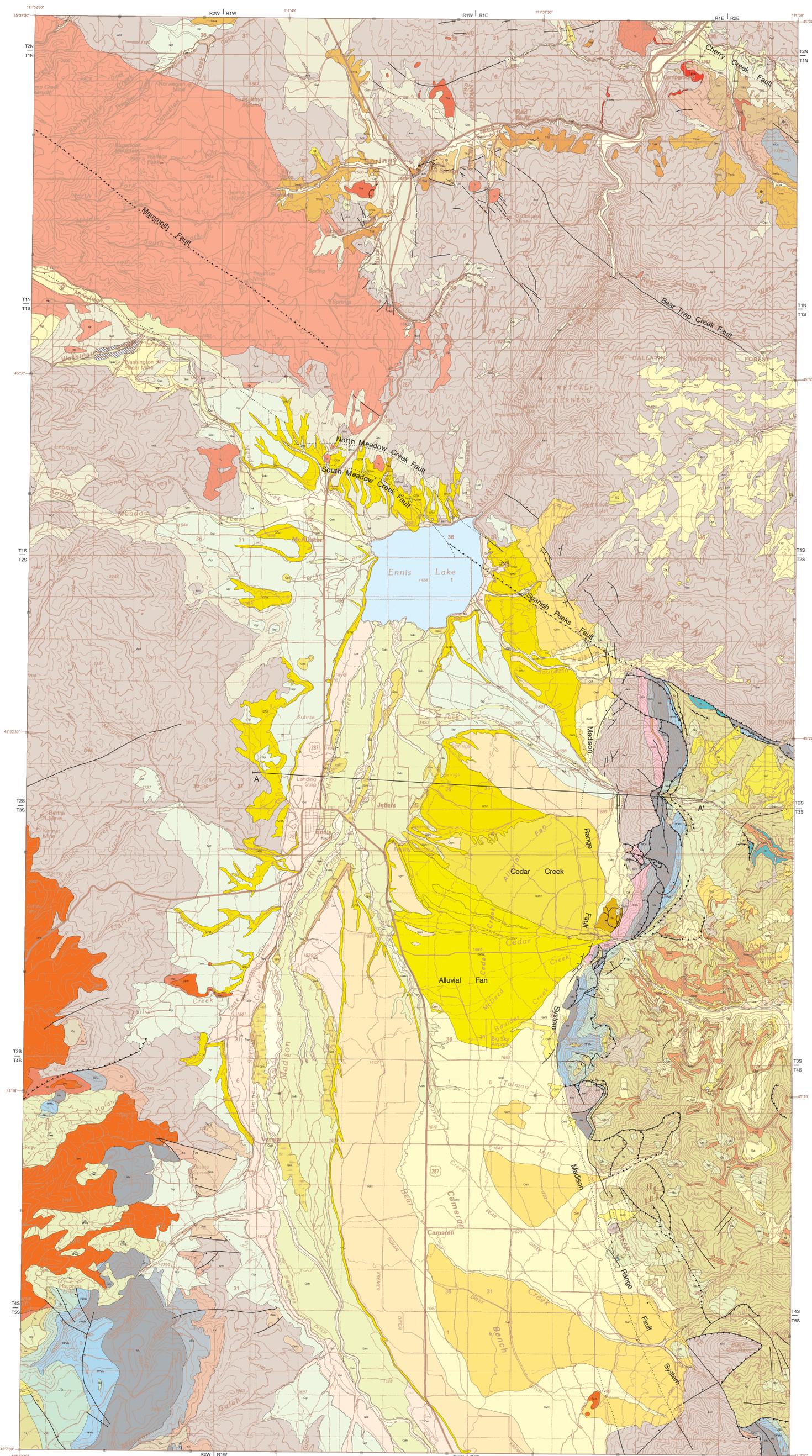
Geology and Mineral Resources of the Tobacco Root Mountains and adjacent region: Tobacco Root Geological Society, 10th Annual Field Conference, p. 14.

- Robinson, G.D., 1963, Geology of the Three Forks Quadrangle, Montana: U.S. Geological Survey Professional Paper 370, 143 p.
- Ritter, J.B., and 16 others, 1990, The Late Quaternary geology of Cedar Creek alluvial fan, Madison River Valley, southwestern Montana, *in* Hall, R.D., ed., Quaternary geology of the western Madison Range, Madison Valley, Tobacco Root and Jefferson Valley: Rocky Mountain Friends of the Pleistocene Field trip guidebook: Indianapolis, Indiana University, p. 120-138.
- Ruleman, C.A., 2002, Quaternary tectonic activity within the northern arm of the Yellowstone Tectonic Parabola and associated seismic hazards, southwest Montana, Bozeman, Montana State University, M.S. thesis, 153 p.
- Schmidt, C.J., 1975, An analysis of folding and faulting in the northern Tobacco Root Mountains, southwest Montana: Bloomington, Indiana University, Ph.D. dissertation, 480 p.
- Schmidt, C.J., and Garihan, J.M., 1985, Laramide tectonic development of the Rocky Mountain foreland of southwestern Montana, *in* J. Lowell and R. Gries, eds., Foreland basins and uplifts: Rocky Mountain Association of Geology Symposium, p. 271-294.
- Schneider, N.P., and Ritter, D.F., 1987, Late Pleistocene response of the Madison River to regional base level change for the Madison Valley, southwest Montana [abs.]: Geological Society of America Abstracts with Programs, v. 19, no. 5, p. 332.
- Stickney, M.C., Haller, K.M., and Machette, M.N., 2000, Quaternary faults and seismicity in western Montana: Montana Bureau of Mines and Geology Special Publication no. 114, scale 1:750,000.
- Streckeisen, Albert, 1976, To each plutonic rock its proper name: Earth Science Reviews, v. 12, p. 1-33.
- Tysdal, R.G., 1990, Geologic map of the Sphinx Mountain quadrangle and adjacent parts of the Cameron, Cliff Lake, and Hebgen Dam quadrangles, Montana: U.S. Geological Survey Miscellaneous Investigations Series Map I-1815, scale 1:62,500.
- Tysdal, R.G., Marvin, R.F., and DeWitt, E.H., 1986, Late Cretaceous stratigraphy, deformation, and intrusion in the Madison Range of southwestern Montana: Geological Society of America, v. 97, no.7, p. 859-86.
- Vitaliano, C.J., and Cordua, W.S., 1979, Geologic map of southern Tobacco Root Mountains, Madison County, Montana: Geological Society of America Map and Chart Series MC-31, scale 1:62,500.

Vuke, S.M., 2006, Geologic map of Cenozoic deposits of the Lower Jefferson Valley, southwestern Montana: Montana Bureau of Mines and Geology Open File Report 537, scale 1:50,000.

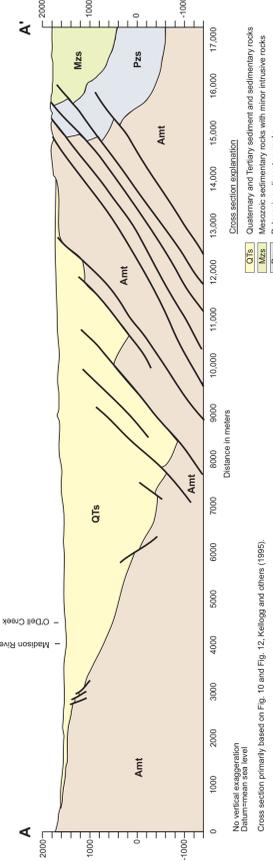
Witkind, I.J., 1960, The Hebgen Lake, Montana, earthquake of August 17, 1959, *in* Campau, D.E., Anisgard, H.W., and Egbert, R.L., eds., West Yellowstone–Earthquake area, Billings Geological Society 11th Annual Field Conference Guidebook, p. 31-44.

Young, S.L., 1985, Structural history of the Jordan Creek area, northern Madison Range, Madison County, Montana: Austin, University of Texas, M.S. thesis, 113 p.



- MAP UNITS**
- Qal Alluvium of modern channels and flood plains
 - Qch Paludal deposit
 - Qclm Older alluvium and floodplain deposits
 - Qca Talus deposit
 - Qcg Rock glacier deposit
 - Qac Alluvium and colluvium, undivided
 - Qlt Landslide deposit
 - Qat Alluvium of alluvial terrace
 - Qc Colluvium
 - Qc1 Cedar Creek alluvial fan deposit
 - Qc2 Cedar Creek alluvial fan deposit
 - Qd Damscion
 - Qaf Alluvial fan deposit
 - Qaf1 Alluvial fan deposit, youngest
 - Qaf2 Alluvial fan deposit, second youngest
 - Qaf3 Alluvial fan deposit, third youngest
 - Qgr Gravel
 - Qgl Glacial till
 - Qdf Debris flow deposit
 - Qgn Gravel of Canyon Bench
 - Qbls Blaine Springs amonose
 - Qtm Ennis basin II deposit
 - Qtm1 North Meadow sandstone
 - Qtm2 North Meadow sandstone
 - Tba Basalt
 - Tbc Bear Creek informal map unit
 - Tbu Red Bluff Formation, upper member
 - Tbl Red Bluff Formation, lower member
 - Tft Felsic tuff
 - Tl Landslide deposit
 - Tmc Milligan Creek Formation
 - Tmv Madison Valley formation, informal
 - Tt Rhyolite or rhyolitic sediment
 - Tsp Spring Creek informal map unit
 - Tod O'Dell Creek informal map unit
 - Teb Andesite and basalt flows
 - Tjp Jasperoid breccia
 - Tkd Rhyolite and/or dacite
 - Tk Intrusive rock of Tobacco Root Batholith, undivided
 - Tdp Dacite porphyry
 - Tc Cretaceous rocks, undivided
 - Tj Jurassic rocks, undivided
 - Tjt Jurassic and Triassic rocks, undivided
 - Tpm Permian, Pennsylvanian, and Mississippian rocks, undivided
 - Tm Mississippian and Devonian rocks, undivided
 - Td Devonian and Cambrian rocks, undivided
 - Tc Cambrian rocks, undivided
 - Tm Metamorphic rocks, undivided
 - Tm1 Mine dumps and tailings
 - W Water

For a more detailed description of the map units and symbols, please refer to the pamphlet accompanying this map.



USGS 7.5' quadrangles

Mulhys Mound	Norris	Bear Trap Creek
Leonard Creek	Ennis Lake	Cherry Lake
Eighmie Creek	Ennis	Fan Mountain
Varnoy	Cameron	Lake Cameron

Maps may be obtained from: Publications Office
Montana Bureau of Mines and Geology
1500 West Park Street
Butte, Montana 59717-6997
Phone: (406) 496-4167
Fax: (406) 496-4451
http://www.mbmng.mtech.edu

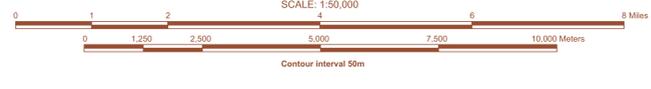
MBMG Open File 543

Geologic Map of Central Madison Valley (Ennis Area), Southwestern Montana

Karl S. Kellogg, Chester A. Ruleman, and Susan M. Vuke

2007

Base enlarged from U.S. Geological Survey:
Bozeman 30'x60' topographic quadrangle
Map date: 1989
Projection: UTM zone 12; 1927 NAD
and
Ennis 30'x60' topographic quadrangle
Map date: 1992
Projection: UTM zone 12; 1927 NAD



Partial support has been provided by the STATEMAP component of the National Cooperative Geologic Mapping Program of the U.S. Geological Survey under Contract Number 05HQ14G0093.
GIS production: Ken Sandau and Paul Thalg, MBMG Map layout: Susan Smith, MBMG

