

# Preliminary Geology of the North Meadow Creek Area, Tobacco Root Mountains, Southwest Montana— The North Meadow Creek Fault



Open-File Report 2025–1058

**Cover.** View southeast along the North Meadow Creek basin toward the Madison Range. Visible parts of the North Meadow Creek fault are designated by white lines (dashed where fault is buried). U.S. Geological Survey photograph taken July, 2025, by Gary Fuis.

# **Preliminary Geology of the North Meadow Creek Area, Tobacco Root Mountains, Southwest Montana—The North Meadow Creek Fault**

By Gary S. Fuis, Parker J. LeClair, and Chester A. Ruleman

Open-File Report 2025–1058

**U.S. Department of the Interior  
U.S. Geological Survey**

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## Conversion Factors

International System of Units to U.S. customary units

<b>Multiply</b>	<b>By</b>	<b>To obtain</b>
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)

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## Abstract

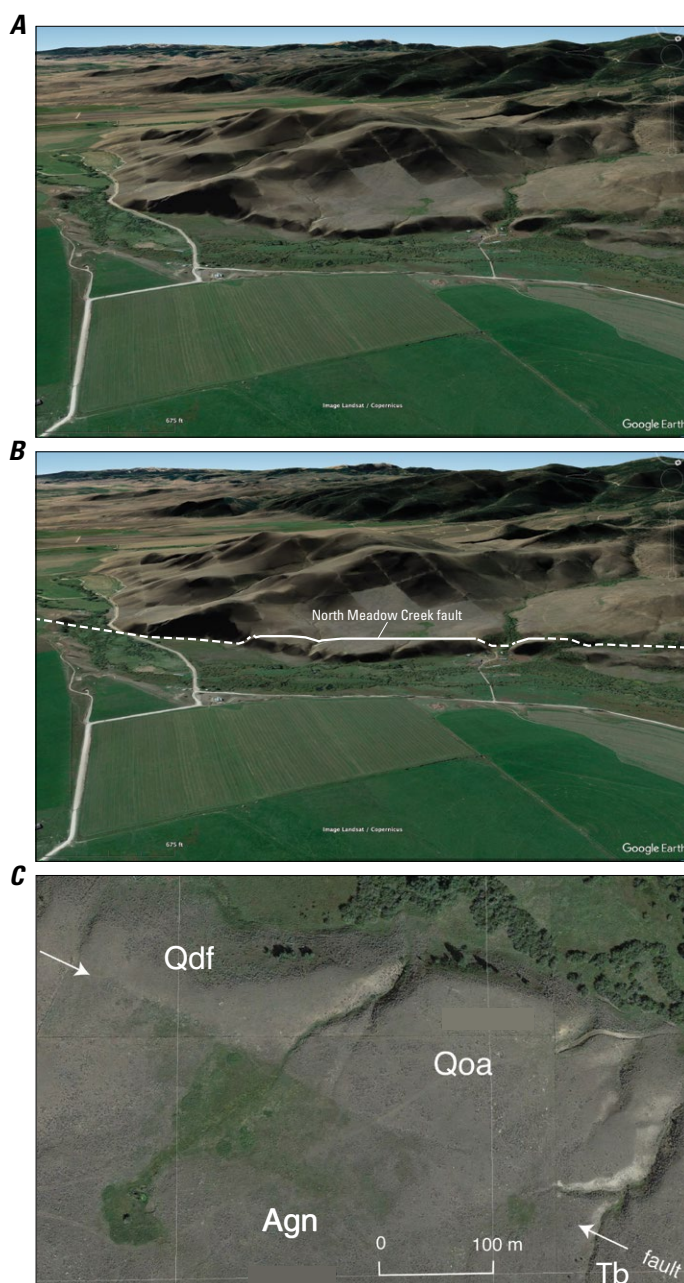
This report documents a previously unmapped fault, informally referred to herein as the North Meadow Creek fault, on the east flank of the Tobacco Mountains of southwestern Montana. This fault has an apparently long and complex history, including Quaternary offset of an older alluvial terrace, offset of a debris flow of presumed Pleistocene age, offset of rhyolite lava flows of presumed Tertiary age from their presumed source several kilometers east, on the opposite side of the fault, and offset and possible rotation of blocks of Archean gneiss on northeast side of the fault. The western part of the fault is covered by glacial moraines of two apparent ages, both Pleistocene.

## Introduction

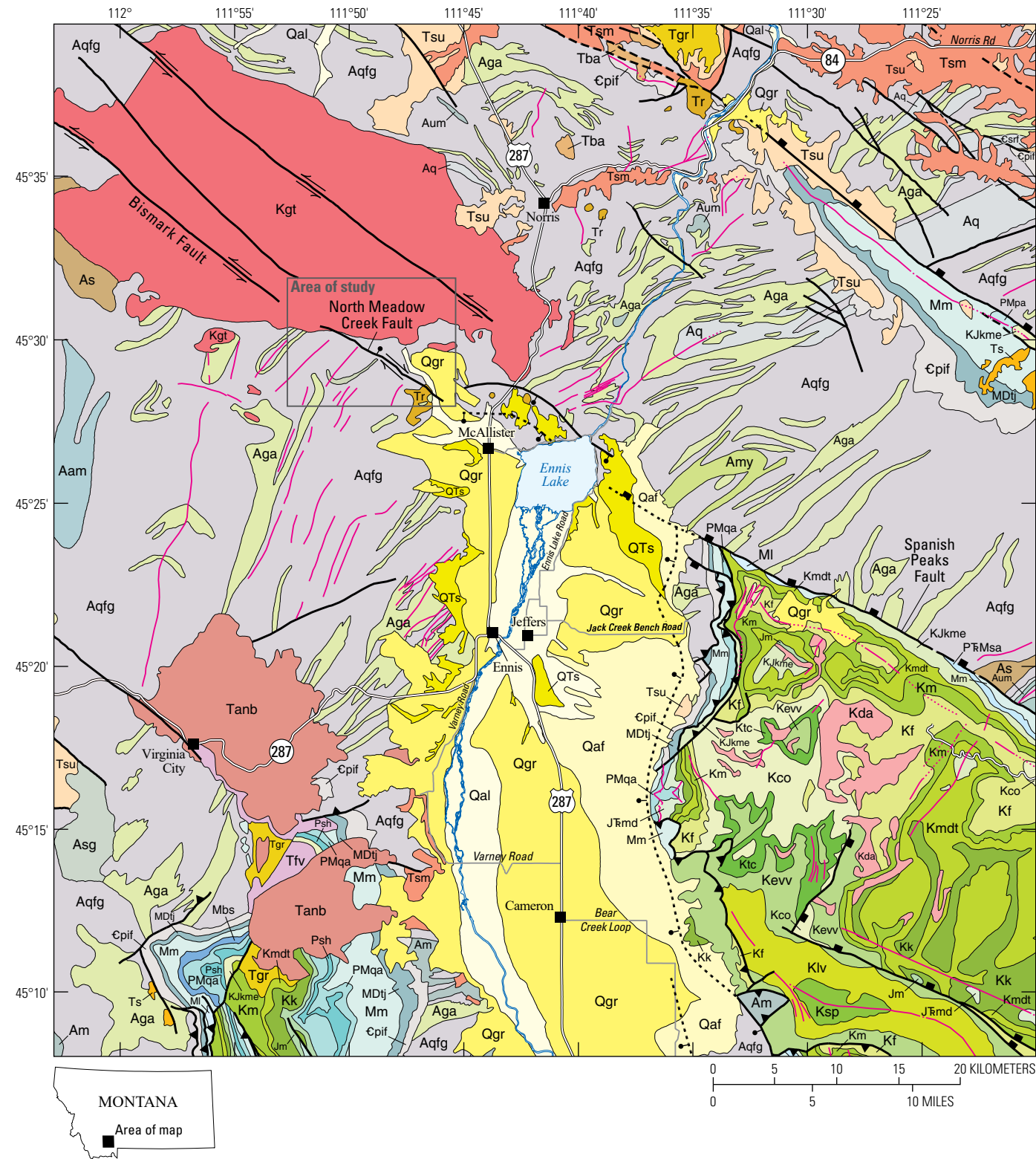
This report identifies a previously unmapped fault in the Tobacco Root Mountains of southwestern Montana. This unmapped fault, informally referred to herein as the North Meadow Creek fault, forms a low scarp on a likely Quaternary-aged alluvial terrace along North Meadow Creek, a drainage on the eastern flank of the Tobacco Root Mountains (fig. 1).

This scarp is located approximately 5 kilometers (km) northwest of McAllister, Montana (fig. 2). The North Meadow Creek fault strikes approximately 6 km northwestward from this scarp, where it is covered by glacial moraines in the Tobacco Root Mountains (fig. 3). The North Meadow Creek

**Figure 1.** Digitally rendered views from satellite imagery of North Meadow Creek fault near the southeast end of its mapped trace. (A) Looking south, uninterpreted, (B) Looking south, showing North Meadow Creek fault. Fault trace is solid where location certain, dashed where uncertain. (C) Looking from above, showing fault water barrier, unit labels are schematically overlaid for context. Landsliding along the fault is seen on the right in A and B. Fault measurement data from Fuis and others (2025). Aerial imagery from Google Earth, accessed September, 2014. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government. See <https://www.usgs.gov/about/organization/science-support/office-science-quality-and-integrity/guidance-disclaimer> for more information.



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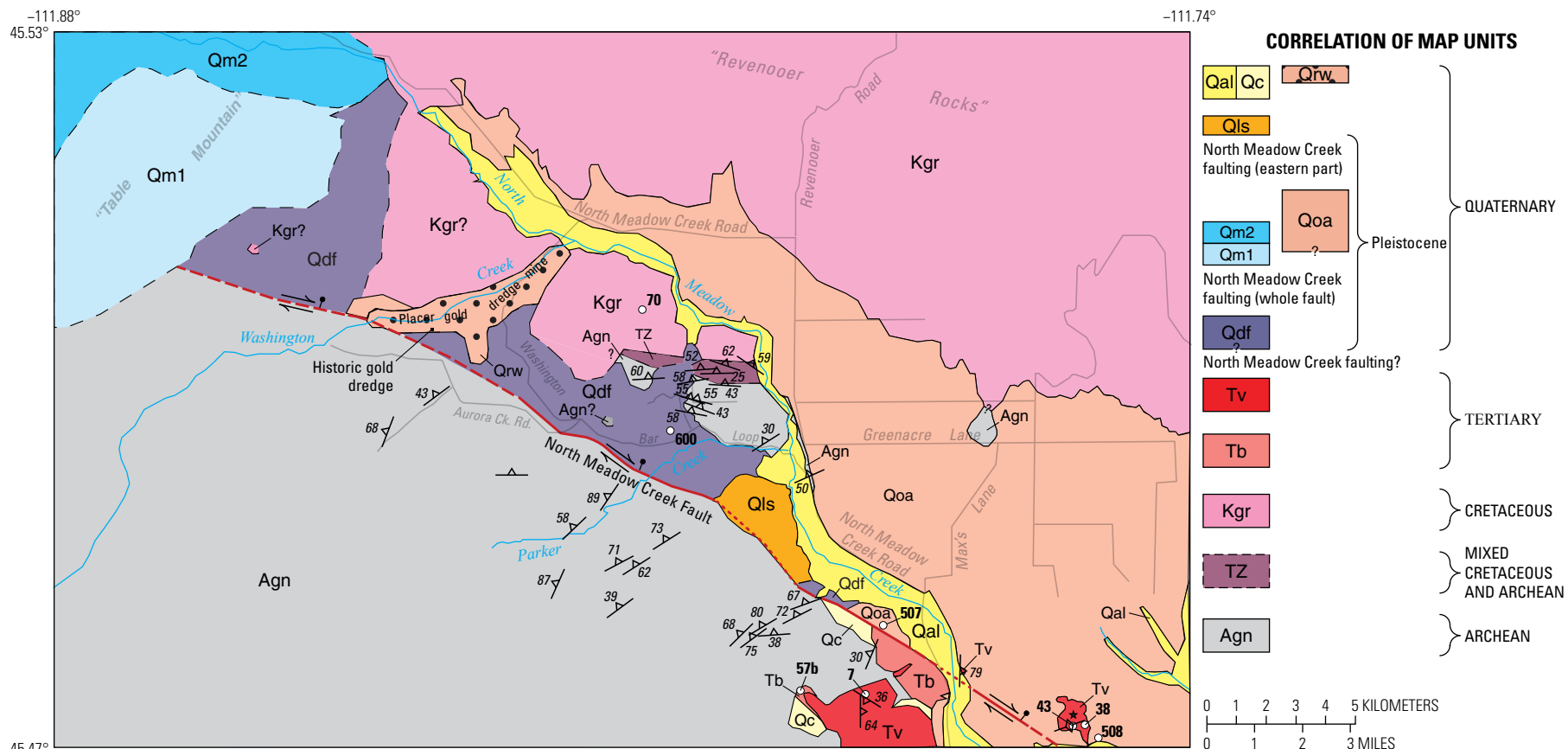
**SEDIMENTARY**

- Qal Alluvium (Holocene to Early Pleistocene)
- Qaf Alluvial fan deposit (Holocene to Early Pleistocene)
- Qgr Gravel (Holocene to Early Pleistocene)
- Tgr Gravel (Pliocene to Late Miocene)
- QTs Basin-fill deposit (Holocene to Tertiary)
- Ts Sediment or sedimentary rock (Tertiary)
- Tsu Upper Tertiary sediment or sedimentary rock (Tertiary)
- Tsm Middle Tertiary sediment or sedimentary rock (Tertiary)
- Kevv Virgelle Formation and Everts Formation (Late Cretaceous)—Beaverhead and Livingston group, fine- to coarse-grained sandstone to mudstone
- Ktc Telegraph Creek Formation (Late Cretaceous)—Sandstone, siltstone, shale
- Klv Livingston Formation (Late Cretaceous)—Volcaniclastic sedimentary rock
- Ksp Sphinx Formation (Late Cretaceous)—Sandstone and conglomerate with carbonate and quartzite clasts
- Km Mowry Formation (Late Cretaceous)—Marine shale, siltstone, or sandstone
- Kco Cody Formation (Late Cretaceous)—Marine shale and fine-grained sandstone
- Kf Frontier Formation (Late Cretaceous)—Brackish to nonmarine sandstone, siltstone, carbonaceous shale
- Kmdt Muddy Formation and Thermopolis Formation (Early Cretaceous)—Marine sandstone with carbonaceous shale and shale with siltstone beds
- KJkme Kootenai Formation through Ellis Group (Early Cretaceous to Middle Jurassic)—Mudstone, siltstone, calcareous concretions, limestone, sandstone, carbonaceous shale
- Kk Kootenai Formation (Early Cretaceous)—Mudstone, siltstone, calcareous concretions, limestone, and quartzose sandstone
- J̄rmd Morrison Formation through Dinwoody Formation (Late Jurassic to Early Triassic)—Mudstone, limestone, sandstone, carbonaceous shale. Fluvial, Lacustrine, and marine
- Jm Morrison Formation (Late Jurassic)—Mudstone and marlstone with limestone and sandstone beds. Upper part carbonaceous black shale and coal
- Jme Morrison Formation and Ellis Group (Late to Middle Jurassic)—Mudstone, limestone, sandstone, carbonaceous shale. Fluvial, Lacustrine, and marine
- ̄rwd Woodside Formation and Dinwoody Formation (Middle to Early Triassic)—Siltstone, dolomite, and shale. Tidal flat and marine
- PMpa Phosphoria Formation through Amsden Formation (Permian to Late Mississippian)—Dolomite, limestone, chert, siltstone, sandstone, carbonate, shale. Marine to coastal plain
- PMsa Shedhorn Formation through Amsden Formation (Permian to Late Mississippian)—Quartzose sandstone, limestone, carbonate, shale. Marine to coastal plain
- Psh Shedhorn Formation through Amsden Formation (Permian to Late Mississippian)—Quartzose sandstone, nearshore marine

**EXPLANATION**

- PMqa Quadrant Formation through Amsden Formation (Middle Pennsylvanian to Late Mississippian)—Sandstone, possibly quartzite, carbonate, shale. Marine to coastal plain
  - Mbs Heath, Otter, and Kibbey Formations (Late to Middle Mississippian)—Sandstone and quartzose sandstone, gypsum, limestone, siltstone, and shale. Marine, tidal, and coastal plain
  - Mm Mission Canyon Formation and Lodgepole Formation or Castle Reef Formation and Allan Mountain Formation (Middle to Early Mississippian)—Limestone, chert, mudstone. Shallow marine
  - MI Lodgepole Formation (Middle to Early Mississippian)—Limestone, chert, and calcareous mudstone beds, and black shale. Shallow marine
  - MDtj Three Forks Formation and Jefferson Formation (Early Mississippian to Late Devonian)—Fossiliferous and calcareous shale with limestone, dolomite, and quartzite
  - ̄srfr Snowy Range Formation (Late Cambrian)—Limestone, shale, conglomerate, and sandstone
  - Cpif Pilgrim Formation through Flathead Formation (Middle Cambrian)—Limestone, shallow marine
- IGNEOUS**
- Tfv Felsic volcanic rock (Tertiary)
  - Tanb Andesite and basalt (Tertiary)
  - Tba Basalt (Tertiary)
  - Tr Rhyolite (Tertiary)
  - Kda Dacite (Late Cretaceous)
  - Kgt Granite (Late Cretaceous)
- METAMORPHIC**
- Aum Ultramafic rock (pre-Cambrian: Archean)
  - Aam Amphibolite (pre-Cambrian: Archean)
  - Aga Gneiss and Amphibolite (pre-Cambrian: Archean)
  - Am Marble (pre-Cambrian: Archean)
  - Amb Metabasite (pre-Cambrian: Archean)
  - Amy Mylonite (pre-Cambrian: Archean)
  - Aq Quartzite (pre-Cambrian: Archean)
  - Aqfg Quartzofeldspathic gneiss (pre-Cambrian: Archean)
  - As Schist (pre-Cambrian: Archean)
  - Asg Schist and gneiss (pre-Cambrian: Archean)
- Contact**
- Fault—Solid where location is certain, long-dashed where location approximate, short-dashed where location inferred or queried, dotted where concealed
  - Generic fault—Slip-sense uncertain
  - Normal fault—Bar and ball on downthrown block
  - Reverse fault—Rectangle on upthrown block
  - Thrust fault—Sawteeth on upthrown block
  - Strike-slip fault—Arrows show relative motion
  - Fold—Solid where location certain, dotted where concealed. Type unknown

**Figure 2.** Geologic map of region surrounding North Meadow Creek study area (black rectangle). Annotated to include geographic and geologic information relevant to this report. Geologic units on the map of Vuke and others (2007) are relabeled in figure 3 of this report as follows: Aqfg, Aga are grouped together as Agn; Kgt is relabeled Kgr; QTbf and Qgr are grouped together as Qoa.



Base image from Google Earth photography September, 2014

**DESCRIPTION OF MAP UNITS**

- |   |   |   |
|---|---|---|
| <p><b>Qal, Qc</b> <b>Young alluvium; colluvium</b></p> <p><b>Qrw</b> <b>Reworked boulder alluvium</b>—Reworked chiefly by gold dredge</p> <p><b>Qls</b> <b>Landslide deposits</b></p> <p><b>Qoa</b> <b>Older alluvium</b>—Forms benches</p> <p><b>Qm2, Qm1</b> <b>Glacial moraines</b>—Clasts unsorted, subrounded; sizes up to 3 m, but commonly cobbles, pebbles; 1 older, 2 younger</p> <p><b>Qdf</b> <b>Debris flow</b>—Clasts unsorted, angular to subrounded; sizes up to 2 m but commonly cobbles, pebbles; buff to orange clayey matrix</p> | <p><b>Tv</b> <b>Rhyolite lava flow</b>—Varnished exterior; interior light pink to light gray; microphenocrysts of feldspar (few %), quartz (1%), mafic minerals (trace); obsidian float at base</p> <p><b>Tb</b> <b>Basal unit (rhyolite)</b>—Laminated light gray to gray sheared obsidian (shearing seen in thin section); unshaped obsidian at top, below lava flow (Tv); seen as float only</p> <p><b>Kgr</b> <b>Tobacco Root batholithic rocks</b> (Vuke and others, 2002)—Granitic rocks in “Revenoor Rocks” with abundant K-feldspar phenocrysts (up to 4 cm); near contact with unit Agn, includes both leucocratic and less silicic felsic rocks without large phenocrysts</p> | <p><b>TZ</b> <b>Transition zone between Kgr and Agn</b>—Outcrops of both units Kgr and Agn in close proximity</p> <p><b>Agn</b> <b>Layered gneiss</b>—Chiefly quartzo-feldspathic gneiss and amphibolite</p> <p>— <b>Contact</b>—Solid where location certain, dashed where location uncertain</p> <p>— <b>Fault</b>—Solid where location certain, dashed where location uncertain, dotted where buried, right-lateral and normal faulting (down towards bar and ball) indicated</p> <p><math>\frac{38}{\wedge}</math> Inclined</p> <p><math>\frac{\diamond}{\wedge}</math> Vertical</p> <p>★ <b>Volcanic center</b></p> <p><math>\frac{\circ}{38}</math> <b>Sample location and number</b></p> |
|---|---|---|

**Figure 3.** Preliminary geologic map of North Meadow Creek study area. See figure 2 for contextual location. Geologic units on the map of Vuke and others (2007), relabeled here as follows: Aqfg, Aga are grouped together as Agn; Kgt is relabeled Kgr; QTbf and Qgr are grouped together as Qoa. Foliation measurements from Fuis and others (2025). m, meters; cm, centimeters; %, percent.

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fault appears on neither the Geologic Map of Montana, Edition 1 (Vuke and others, 2007; fig. 2 of this report) nor the Quaternary Fault and Fold Database of the United States (U.S. Geological Survey and California Geological Survey, 2022). The North Meadow Creek fault offsets a number of rock units ranging in age from Quaternary to Archean. Offsets along the North Meadow Creek fault are uniformly down to the northeast and right-lateral.

### Geology of the North Meadow Creek Region

The Tobacco Root Mountains are in the Basin and Range Structural Province of Montana (Vuke and others, 2007). The oldest rocks exposed in the North Meadow Creek area are Archean metamorphic rocks (unit Agn, fig. 3), mostly composed of quartzofeldspathic gneiss and amphibolite (Kellogg and Williams, 2000; figs. 2, 3 of this report).

These Archean metamorphic rocks have northeast-striking foliation, variable steep dips, and outcrop predominantly southwest of the North Meadow Creek fault. Northeast of the North Meadow Creek fault, these Archean rocks have mostly east-west striking foliations and moderate north dips, but in the southeast part of this outcrop area, they have attitudes similar to those on the southwest side of the fault. Felsic lava flows (units Tv and Tb) and their inferred eruptive center appear on opposite sides of the North Meadow Creek fault (fig. 3). Obsidian float is commonly found in unit Tb (tables 1, 2, sample 57b), below the upper lava flow, unit Tv (tables 1, 2, sample 7), but no outcrops of obsidian have been found.

**Table 1.** Samples collected for geochemistry and potential future dating.

Sample ID	Geologic Unit	Lithology	Latitude	Longitude
7	Tv	Felsic lava flow	45°28'22"	111°47'3"
38	Tv	Felsic porphyry	45°28'15"	111°45'22"
43	Tv	Vent-phase felsic lava	45°28'13"	111°45'28"
57b	Tb	Obsidian	45°28'21"	111°47'15"
70	Kgr	Leucocratic granitic rock	45°30'26"	111°48'51"
600	Kgr	Porphyritic granitic boulder (2 m boulder embedded in Qdf)	45°29'48"	111°48'32"
507	Qoa	Cobble and pebble alluvium (top of Qoa terrace)	45°28'46"	111°46'56"
508	Qoa	Cobble and pebble alluvium (bottom of Qoa terrace)	45°28'7"	111°45'15"

**Table 2.** Major and trace element geochemistry.

[X-ray fluorescence geochemical analysis performed by Washington State University GeoAnalytical Lab. wt%, weight percent; ppm, parts per million]

Elemental Oxide	Sample ID				
	7	38	43	57b	70
	Normalized Major Elements (wt %)				
SiO <sub>2</sub>	70.92	64.23	73.36	68.32	77.31
TiO <sub>2</sub>	0.28	0.67	0.19	0.37	0.05
Al <sub>2</sub> O <sub>3</sub>	15.74	16.74	14.59	16.41	13.01
FeO	2.2	4.89	1.49	2.81	0.52
MnO	0.02	0.05	0.02	0.07	0.01
MgO	0.34	1.31	0.18	1.09	0.01
CaO	2.37	4.36	1.43	2.88	0.51
Na <sub>2</sub> O	4.28	4.5	3.8	4.64	3.51
K <sub>2</sub> O	3.65	2.97	4.14	3.25	5
P <sub>2</sub> O <sub>5</sub>	0.19	0.28	0.79	0.16	0.06
Total	100	100	100	100	100
	Unnormalized Trace Elements (ppm)				
Ni	11	16	6	16	4
Cr	10	32	8	36	7
Sc	2	8	1	4	0
V	26	89	8	22	5
Ba	2609	1979	2527	2290	30
Rb	83	61	88	77	273
Sr	502	735	384	611	38
Zr	169	222	154	304	56
Y	16	12	9	12	2
Nb	10.2	10.7	10.7	11.7	14
Ga	19	20	19	19	18
Cu	6	17	5	5	4
Zn	54	71	45	63	7
Pb	29	20	31	26	34
La	55	41	46	47	7
Ce	83	73	73	81	13
Th	9	7	10	9	25
Nd	32	27	23	27	3
U	1	0	0	2	6
Sum trace	3727	3442	3447	3662	545
In percent	0.37	0.34	0.34	0.37	0.05
Sum					
Major+Trace	97.89	98.26	97.1	99.85	99.1
Major+Trace oxides	97.94	98.32	97.14	99.9	99.11
w/LOI	99.96	99.88	100.05	100.11	99.75
If Fe <sup>3+</sup>	100.2	100.41	100.21	100.42	99.8

Native Americans excavated obsidian float in several locations. The eruptive center of units Tv and Tb is inferred from a vertical fabric and the presence of a likely intrusive porphyritic body on its eastern side (see [fig. 3](#); [tables 1, 2](#), samples 43 and 38, respectively).

The North Meadow Creek fault is the southwestern boundary of debris flow of presumed Pleistocene age (unit Qdf, [fig. 3](#)), consisting of angular to subrounded clasts as large as 2 meters (m) in diameter. Most clasts are cobbles and pebbles in a buff, orange, or brown fine-grained clayey matrix. The debris flow and the western part of the North Meadow Creek fault itself are overlain by glacial moraines in the Tobacco Root Mountains (“Table Mountain” in the northwest corner of [fig. 3](#)). The glacial moraines are separated into older and younger deposits (units Qm1 and Qm2, respectively, [fig. 3](#)). Boulders weather out of the younger moraine, forming an irregular surface. The older moraine has a smoother surface with fewer exposed boulders (up to 3 m in size). Similar glacial-moraine characteristics are seen in the Madison Range (to the east) at South Fork Indian Creek (south of [fig. 2](#)), where age designations have been assigned by [Ruleman and others \(2014\)](#) and [Ruleman and Brandt \(2025\)](#): Bull Lake for the older moraine and Pinedale for the younger moraine. Alluvium near the North Meadow Creek fault consists of older alluvium that forms benches along North Meadow Creek (unit Qoa, [fig. 3](#)) and younger alluvium in the creek bottoms (unit Qal, [fig. 3](#)).

To the south and west of North Meadow Creek lies Washington Creek, which contains an 8-km long section of reworked boulder alluvium (unit Qrw). Placer gold was mined from this alluvium using a floating dredge and earth-moving equipment. Additional placer gold was mined from isolated hydraulic-mine pits scattered throughout the map area. Dredging only occurred on the northeastern side of the North Meadow Creek fault ([fig. 3](#)).

## Geologic History

The geologic history herein describes the unit emplacement and faulting and landsliding in the North Meadow Creek area, in chronological order.

### Unit Emplacement

1. Sedimentary and igneous rocks were metamorphosed in the Archean, forming gneiss and amphibolite (unit Agn; Kellogg and Williams, 2000).
2. Granitic rocks of the Tobacco Root batholith were emplaced in the Cretaceous (unit Kgr; Vuke and others, 2002).
3. Felsic volcanic rocks were erupted in the Tertiary (units Tb, Tv; this study).
4. A debris flow, likely associated with glacial activity, was emplaced presumably in the Pleistocene (unit Qdf; this study).
5. Glacial moraines were emplaced (units Qm1, Qm2; this study).
6. Older alluvium (forming current benches) was deposited, probably largely coincident with emplacement of the glacial moraines (unit Qoa; this study).
7. Young alluvium was deposited in current creek bottoms (unit Qal; this study).
8. Boulder alluvium was reworked by dredging and earth-moving equipment in the creek bottom of Washington Creek (unit Qrw; this study).

### Faulting and Landsliding

1. The North Meadow Creek fault may have first ruptured following eruption of the felsic volcanic lava flows (units Tb, Tv).
2. The North Meadow Creek fault ruptured following emplacement of the debris flow (unit Qdf); this rupture may or may not have been accompanied by rotation of Archean blocks northeast of the fault.
3. The eastern part of the North Meadow Creek fault, at minimum, ruptured; two glacial moraines (units Qm1, Qm2) cover the western part of the fault.
4. Local landsliding occurred (unit Qls), covering part of the eastern part of the North Meadow Creek fault.

Samples were collected for potential future dating analysis of various geologic units including (see [tables 1, 2](#)):

1. Samples of the felsic lava flows (units Tb, Tv, for geochemistry and radiometric dating; samples 57b, 7, 43, 38),
2. Samples of boulders in the debris flow (unit Qdf, for exposure dating; sample 600; see [figure 3](#) for location), and
3. Samples of the older alluvium (unit Qoa, for optically stimulated luminescence and uranium-series dating; samples 507 [top of terrace deposit] and 508 [bottom of terrace deposit]; see [figure 3](#) for location).

## Discussion

The North Meadow Creek fault appears to have had a long and varied history, as in the “Geologic History” section. The North Meadow Creek fault offsets Archean rocks with different average attitudes on either side of the fault. This apparent change in attitudes may be related to either faulting or proximity of the northern outcrops to the Tobacco Root batholith (unit Kgr, see [tables 1, 2](#); sample 70). The North

Meadow Creek fault offsets felsic lava flows from their presumed eruptive source by more than 100 m and possibly as much as several kilometers-right-laterally. These felsic lavas are down-dropped to the northeast by more than 200 m and are of presumed Tertiary age. The North Meadow Creek fault bounds a debris flow of presumed Pleistocene age on its southwest side and is subsequently buried by glacial moraines to the west (on “Table Mountain,” fig. 3), making its Quaternary history complex. At its southeast end, it offsets older alluvial terraces (unit Qoa, fig. 3), of presumed Quaternary age (fig. 1). The older alluvium is faulted against Archean rocks (unit Agn, fig. 3) and volcanic rocks (unit Tb, fig. 3) just west of North Meadow Creek (figs. 1, 3), and the fault forms a dark line of vegetation and soil in irrigated ground on the bench just east of North Meadow Creek (fig. 3, solid fault line), accompanied by a subtle change in elevation, higher on the southwest side of the fault (Brett Owens, verbal commun.)

The North Meadow Creek fault itself may have been a source for the placer gold mined from the reworked boulder alluvium in Washington Creek, or the gold may have originated from the uplifted Archean gneiss on the southwest side of the fault.

The North Meadow Creek fault appears to align in strike with the Spanish Peaks fault, 20 km east in the Madison Range, and with the Bismark fault, a few kilometers west of the map area of figure 3 (see fig. 2). The Spanish Peaks fault offsets Archean rocks, upthrown on the northeast against Paleozoic and Mesozoic rocks on the southwest. This sense of offset is opposite to that of the North Meadow Creek fault, where rocks are down dropped on the northeast. The Bismark fault, as mapped, also appears to have an opposite sense of offset compared to the North Meadow Creek fault (fig. 2)—upthrown on the northeast. Field reconnaissance surveys to the west of the study area indicates that the North Meadow Creek fault does not connect with the mapped Bismark fault but instead extends to the west-northwest through the Twin Lakes area of the Tobacco Root Mountains, south of the mapped Bismark fault. In this area, interpreted southerly phases of the Tobacco Root batholith (see explanation of geologic map, fig. 3) are in proximity to Archean rocks on the southwest. No features indicating young faulting can be found in this area, however, which is largely covered by glacial till.

The interpreted normal offset on the North Meadow Creek fault is consistent with the modern north-northeast to northeast extension direction interpreted by numerous authors, including Eddington and others (1987), Smith and Arabasz (1991), and Schmeelk and others (2017).

## Conclusions

The North Meadow Creek fault is a newly mapped fault on the east flank of the Tobacco Root Mountains of southwest Montana that offsets rocks of ages from Quaternary to Archean. Offsets appear consistently right-lateral and down to the northeast. Faulting history appears complex.

## References Cited

- Eddington, P.K., Smith, R.B., and Renggli, C., 1987, Kinematics of Basin and Range intraplate extension, *in* Coward, M. P., Dewey, J. F., and Hancock, P. L., eds., Continental extensional tectonics: Geological Society of London Special Publication 28, p. 371–392.
- Fuis, G.S., LeClair, P., and Ruleman, C., 2025, Preliminary Geology of the North Meadow Creek Area, Tobacco Root Mountains, Southwest Montana—Measurements along the North Meadow Creek Fault: U.S. Geological Survey data release, <https://doi.org/10.5066/P146VWWS>.
- 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 IMAP 2690, scale 1:100,000, <https://doi.org/10.3133/i2690>.
- Ruleman, C.A., Larsen, M., and Stickney, M.C., 2014, Neotectonics and geomorphic evolution of the northwestern arm of the Yellowstone tectonic parabola—controls on intra-cratonic extensional regimes, southwest Montana: Geological Society of America, Field Guide 37, p. 65–87, [https://doi.org/10.1130/2014.0037\(03\)](https://doi.org/10.1130/2014.0037(03)).
- Ruleman, C.A., and Brandt, T.R., 2025, Surficial geology and Quaternary tectonics of the Madison Valley and fault zone, Madison, Gallatin, and Beaverhead Counties, southwest Montana: U.S. Geological Survey Scientific Investigations Map 3508, 1 sheet, scale 1:50,000, 45 p. pamphlet, <https://doi.org/10.3133/sim3508>.
- Schmeelk, D., Bendick, R., Stickney, M., and Bomberger, C., 2017, Kinematic evidence for the effect of changing plate boundary conditions on the tectonics of the northern U.S. Rockies: Tectonics, v. 36, p. 1090–1102, <https://doi.org/10.1002/2016TC004427>.
- Smith, R.B., and Arabasz, W.J., 1991, Seismicity of the intermountain seismic belt: Geological Society of America, The Geology of North America, Decade Map Volume 1, ch. 11, p. 185–228, <https://doi.org/10.1130/DNAG-CSMS-NEO.185>.
- U.S. Geological Survey and California Geological Survey, 2022, Quaternary fault and fold database for the United States, accessed December 2024 at <https://www.usgs.gov/programs/earthquake-hazards/faults>.
- Vuke, S.M., Lonn, J.D., Berg, R.B., and Kellogg, K.S., 2002, Preliminary geologic map of the Bozeman 30' x 60' quadrangle, southwestern Montana: Montana Bureau of Mines and Geology Open-File Report 469, scale 1:100,000.
- Vuke, S.M., Porter, K.W., Lonn, J.D., and Lopez, D.A., 2007, Geologic map of Montana—Edition 1: Montana Bureau of Mines and Geology Geologic Map 62, Butte, Mont.

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