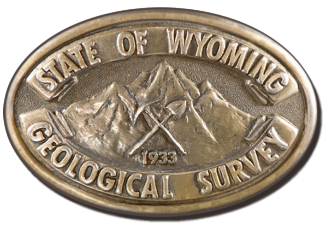

Interpreting the past, providing for the future

Preliminary Surficial Geologic and Landslide Maps of the Blind Bull Creek and Pickle Pass Quadrangles, Lincoln County, Wyoming

Seth J. Wittke, James P. Mauch, and Derek T . Lichtner

Open File Report 2020-5
May 2020

Wyoming State Geological Survey

Erin A. Campbell, Director and State Geologist

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Layout by Christina D. George

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Laramie, Wyoming: 2020

This Wyoming State Geological Survey (WSGS) Open File Report is preliminary and may require additional compilation and analysis. Additional data and review may be provided in subsequent years. For more information about the WSGS, or to download a copy of this Open File Report, visit www.wsgs.wyo.gov. The WSGS welcomes any comments and suggestions on this research. Please contact the WSGS at 307-766-2286, or email wsgs-info@wyo.gov.

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INTRODUCTION

The primary purpose of this project was to map the trace of the northern extent of the Greys River fault. The map area is defined by the boundaries of the Blind Bull Creek and Pickle Pass 7.5' quadrangles in northern Lincoln County, Wyoming. Previous work indicates the fault terminates at 43° north latitude (Rubey, 1973, Jones, 1995). However recent mapping has shown the fault to extend ~10 km (6 mi) farther north (Wittke and others, 2016).

A second objective was to revisit and field confirm existing landslide mapping in the area (Case and others, 1996) and map landslides that have occurred since the most recent mapping was completed. Two local events, the Blind Bull and Porcupine Creek landslides, occurred in the past five years, causing significant damage to U.S. Forest Service roads and economic losses to local communities. These, and other minor slides in the area, suggested new mapping was needed.

Additional geologic data were created through the course of the mapping campaign. Terraces of the Greys River were mapped based on height above the modern channel. Abandoned pediment surfaces originating from the Salt River Range to the west of the map area and from the Wyoming Range to the east of the Greys River were mapped as well. Detrital zircon analysis was conducted on a sample from the deposit in an attempt to provide a maximum depositional age. Finally, the surficial geology of the area, including glacial deposits associated with Pinedale- and Bull Lake-age glacial episodes, was mapped.

This project was completed in cooperation with the U.S. Geological Survey (USGS) 2019 STATEMAP grant award G19AC00142. This map continues a long-term Wyoming State Geological Survey (WSGS) project to investigate poorly understood, or unmapped, Quaternary-age faults in Wyoming and produce information that will lead to a better understanding of the hazards they pose.

PREVIOUS WORK

The Hayden surveys of 1872, 1877, and 1878 mapped the bedrock geology of the Wyoming-Utah-Idaho thrust belt at a scale of 1:250,000. Schultz (1914) mapped the Wyoming Range and Greys River Valley at 1:125,000. The most detailed bedrock mapping in the Blind Bull Creek quadrangle is Rubey's (1973) 1:62,500-scale geologic map of the Afton quadrangle and part of the Big Piney quadrangle. Schroeder's (1979) 1:24,000-scale map is the most detailed bedrock map available for the Pickle Pass quadrangle.

Landslide maps of the Driggs 1° x 2° (Case and others, 1991) and Preston 1° x 2° (Case and Coombs, 1991) quadrangles encompass Pickle Pass and Blind Bull Creek, and unpublished preliminary 7.5' landslide maps are on file at the WSGS (Case and Halberg, 1996). Jones (1995) mapped the entire known Greys River fault trace at 1:48,000 and mapped a cumulative 8 km (5 mi) of the fault at 1:15,840 in several sections of the Blind Bull Creek quadrangle. Most recently, the WSGS published 1:100,000-scale maps of the surficial geology and Quaternary faults of the Afton quadrangle (Larsen and others, 2015) and Jackson quadrangle (Wittke and others, 2016).

METHODS

The area was mapped in detail in 2019. Preliminary mapping was conducted by interpretation of 2015 and 2017 National Agriculture Imagery Program aerial imagery, 2001 National Aerial Photography Program stereo pairs, USGS topographic maps, National Elevation Dataset digital elevation models, a small Light Detection and Ranging dataset (Tennant, 2016) along the Greys River, and Unmanned Aerial Vehicle imagery acquired by the Wyoming Geographic Information Science Center. Compilation of previously published and unpublished maps and reports was also completed.

Field mapping of landforms and surficial deposits was conducted over the course of six weeks between June and September 2019. Special consideration was given to drainages crossed by the fault trace. Fault scarp profiles were surveyed in select locations and modeled in MatLab with a script provided by Christopher DuRoss (USGS), allowing for surface offsets to be calculated. A single bulk sample of a pediment surface was collected for detrital zircon analysis. The sample was sent to the Arizona LaserChron Center at the University of Arizona for age determination.

LOCATION AND GEOLOGIC SETTING

Structure and Bedrock Geology

The map area is in the Wyoming-Utah-Idaho thrust belt. Ordovician through Cretaceous bedrock is exposed in the study area. Paleozoic strata were deposited in shallow marine environments on the passive margin of the Wyoming craton, and consist primarily of well-cemented carbonates and sandstones (Bighorn, Darby, Madison, Amsden, Wells, and Phosphoria). An assortment of Triassic through lowermost Cretaceous siliciclastics and carbonates were deposited in a variety of terrestrial and nearshore environments (Dinwoody, Woodside, Thaynes, Ankareh, Nugget, Twin Creek, Preuss, Stump, and Gannet Group). The thick Upper Cretaceous section consists primarily of nonresistant shales and sandstones deposited in the marine, nearshore, and deltaic environments of the Western Interior Seaway (Bear River, Aspen, and Blind Bull).

From the Cretaceous through the Eocene, the Sevier orogeny produced a north–south-trending belt of west-dipping, east-directed thrust faults (Royse, 1993). Horizontal displacement of individual thrust sheets is up to 64 km (40 mi). In the Blind Bull Creek quadrangle, the Greys River valley lies between the Darby thrust to the east and the Absaroka thrust to the west. In both quadrangles the thrust faults emplace hanging walls of resistant Paleozoic limestone and quartzite over less competent Cretaceous shales. The strike of bedrock units is generally north-south, with dips from 20° to 50° west. The map area also contains several folds in Mesozoic rocks.

The Greys River valley is at the eastern margin of the Basin and Range Province, where east-west extension, superimposed on the thrust belt, began about 17 Ma (Eaton, 1982). The Greys River fault, a south-trending, down-to-the-west normal fault, is the easternmost active Basin and Range fault (Jones, 1995). It parallels the western side of the Wyoming Range and is approximately 64 km (40 mi) long. The map area includes the northernmost 22 km (13.5 mi) of the fault.

SURFICIAL GEOLOGY

Surficial Deposits

Surficial deposits range from bedrock outcrop to alluvium across the map areas. Bedrock outcrops are primarily exposed in steeper terrain and in areas of resistant lithology. Grayback ridge, in the Pickle Pass quadrangle, as well as Middle Ridge and Deadman Mountain, which span the boundary between the maps, are dominated by bedrock outcrop and associated residuum. However, outcrop can also be found under thin mantles of glacial outwash and alluvium along the Little Greys and Greys rivers and in other locations of the maps with competent geologic formations.

Colluvium and slopewash are found throughout the maps. The combination of high relief, steep terrain, and easily weathered bedrock promotes significant mobilization of material by gravity and water. Slopewash is generally more prevalent in areas dominated by Cretaceous units, whereas colluvium is more prevalent in more competent Jurassic and older units. In addition, slopewash is typically found on dip slopes, whereas colluvium is common at the base of bedrock cliffs and escarpments near the crests of the numerous ridges in the area. One exception to this pattern is Grayback Ridge, north of the Little Greys River. Here the dip slope contains a significant amount of colluvium derived from the Mississippian Madison and Pennsylvanian-Permian Wells formations. Residuum is found throughout the maps, typically on shallower slopes or areas with limited material mobilization.

A number of lacustrine deposits were also mapped in the area. These deposits are the result of small water filled basins, formed by landslides choking narrow drainages or behind glacial moraines or till piles. Due to their small size, a number of areas containing lacustrine deposits are not shown on the maps.

Alluvium and alluvial fan deposits are found in valley floors and along modern drainage floors. Many alluvial fans are incised by modern streams, suggesting these fans record an older, higher base level and were likely deposited during periods of glacial outwash.

Terraces

Five terrace levels were identified along the Greys River in the Blind Bull Creek quadrangle. Alluvium (shown as "a" on the maps) comprises the active channel and modern floodplain. The youngest terrace unit (t1) has treads between 1 and 2 m (3.3-6.6 ft) above grade. The oldest unit (t5) consists of a terrace greater than 25 m (82 ft) above grade. This study makes no attempt to date mainstem Greys River terrace levels.

An outwash terrace, likely of Pinedale age, is present along the Little Greys River in the Pickle Pass quadrangle (fig. 1). This terrace converges with the modern floodplain near Blind Trail Creek, and no other terraces are present along the Little Greys downstream to the quadrangle boundary. Some Greys River tributaries, such as Deadman and Blind Bull creeks, preserve a limited number of small terraces.

Figure 1. Photograph of an outwash terrace 10 m (32.8 ft) above the Little Greys River. The Little Greys River is visible through the trees in the lower left. View to the east-southeast, September 10, 2019.

Pediments and Associated Deposits of Unknown Age

Map unit r_1 (QTf of Rubey, 1973) consists primarily of poorly bedded, unconsolidated, subangular to rounded cobbles. The deposit mantles ridges that slope gently toward the mainstem Greys River (fig. 2), described by Rubey (1973) as remnants of an "old pediment surface." The sloping surfaces are laterally continuous across modern tributary drainages. The contact of r_1 with bedrock is unconformable and dips approximately 5° toward the modern Greys River, from both the Salt River Range (west) and the Wyoming Range (east). Elevation projections show the surfaces converge about 50 m (160 ft) above the modern channel. The relief from the lowest to highest elevation r_1 deposit is approximately 380 m (1,200 ft), suggesting a complex, protracted history of deposition, incision, and pediment formation in the Greys River valley.

Although most field observations of r_1 were of unconsolidated material, cemented conglomerate was observed along Meadow and Deadhorse creeks. It is uncertain whether the cemented outcrops are an anomaly or if elsewhere the unit was at one time cemented but has been since heavily weathered.

A detrital zircon bulk sample, taken along the South Fork of Meadow Creek, provided a minimum grain age of 379 Ma (Appendix 1) and did not provide a useful constraint for the r_1 depositional age. The sample ages are consistent with bedrock formations found in the Salt River Range to the west, which, through erosional processes, were undoubtedly incorporated into the r_1 deposit.

Schroeder (1979) mapped Quaternary pediments in the Pickle Pass quadrangle along Stewart Creek and the South Fork of the Little Greys River, which are mapped collectively as f_1d in this work. Most of these flat surfaces dip 4° east toward the modern drainages. The deposits atop the pediments generally consist of unconsolidated angular gravel sourced locally from the Cretaceous Aspen Formation. Two other pediment-like surfaces, however, rise con-

Figure 2. Photograph of r_1 surfaces gently sloping toward the Greys River. Orange arrows highlight the surfaces. Photo taken from Middle Ridge, view to the south, September 24, 2019.

spicuously above the others, dipping 9° east and projecting to about 50 m (160 ft) above the modern channel. These higher surfaces project to 30 m (98 ft) above the nearest Bull Lake moraines, suggesting that they predate the Bull Lake glaciation, and are mantled with a lithologically diverse assemblage of gravel and cobbles of unknown source.

It is unclear at this point if there is any relation between the r_1 surfaces mapped in the Blind Bull Creek quadrangle and the f_1d unit mapped in the Pickle Pass quadrangle.

Landslides

Bedrock lithology strongly influences landslide type within the map area. The steep slopes of resistant Paleozoic units such as the Wells Formation and the Madison Limestone are associated with a modest number of rockslides, block slides, and debris flows. Other Mesozoic and Paleozoic units produce a variety of mostly small debris flows and slumps. Cretaceous shales in the Blind Bull and Aspen formations are extremely susceptible to landslides, producing large slump-flow complexes and blockslides.

Large landslide complexes are numerous in the Cretaceous formations east of the Darby thrust (fig. 3). In the upper reaches of the Little Greys River, Willow Creek, and in the west-flowing tributaries of the Greys River, such as Deadman and Blind Bull creeks, the bedrock dips in the same direction as the stream gradient. Headward erosion and glaciation have resulted in broad, failure-prone dipslopes of Cretaceous Blind Bull Formation, which have produced a mix of large landslides in the upper reaches of these drainages.

Rock glaciers occur in the high cirques of several ridges, including Deadman Mountain, Grayback Ridge, and Mount McDougal (Blind Bull Creek quadrangle).

Glacial Deposits

This study differentiates glacial deposits of Bull Lake and Pinedale age based on landscape position, moraine morphology, and the mapping of Jones (1995). A large expanse of Bull Lake till borders a 5.4-km (3.4-mi) reach of the Little Greys River (fig. 4). The Deadman Creek and Blind Bull Creek drainages also contain significant amounts of Bull Lake till. Smaller volumes are found along Meadow Creek. The most extensive Pinedale deposits occupy the Blind Bull Creek drainage. Deadman Creek also contains major Pinedale deposits. Evidence of Pinedale glaciation along the Little Greys River is limited to outwash terraces and a few isolated moraines preserved in the upper canyon reach. Several other drainages in the map area contain moraine-like features of possible, unconfirmed glacial origin.

Figure 3. Numerous landslides visable along the west-dipping slopes of the Wyoming Range south of Deadman Mountain. View is to the northwest, August 14, 2019.

Figure 4. Photograph of extensive Bull Lake moraines, Little Greys River. The photographer is on a Bull Lake moraine. In the middle ground, the Little Greys River Road travels across a flat, broad expanse of inset glacial outwash, likely of Pinedale age. The relatively low-relief slopes beyond are also Bull Lake moraines (arrows). At the horizon, Deadman Mountain rises above the surrounding landscape. View to the southeast, June 19, 2019.

Pinedale deposits are found in the upper cirques east of the crest of the Wyoming Range on both maps. Pinedale deposits can also be found west of the range crest in small pockets as end and recessional moraines in the canyons. Bull Lake deposits are only preserved beyond the extent of the Pinedale glacial advances, generally in areas of subdued topography and tributary junctions west of the Greys River fault in both areas, where their basal bedrock contacts can be perched up to 20 m (65.6 ft) above the modern grade.

This work reinterprets prior mapping of glacial deposits in several locations. First, between Trail and Moffat creeks, the extent of glacial deposits is less than previously mapped because, (1) elevation above grade of Rubey's (1973) unit is in places unrealistic for Bull Lake glaciers, (2) potential lateral moraines adjacent to the drainages suggest a limit to glaciation, and (3) Rubey (1973) identified weathered Twin Creek limestone as glacially transported Madison Limestone. Second, between Deadman and Little Blind Bull creeks, much of what Rubey (1973) mapped as glacial deposits are interpreted here as of slumps of Nugget Sandstone and weathered Twin Creek Limestone. Lastly, a modest area of Twin Creek Limestone crops out north of Trail Creek where Rubey (1973) and Jones (1995) mapped glacial deposits.

Jones (1995) mapped Holocene "neoglacial" deposits in the cirques of Deadman and North Sheep creeks on the Blind Bull Creek quadrangle. This study reinterprets both of these deposits as landslides. Evidence for Holocene periglacial activity is limited to protalus ramparts and associated frost-shattered felsenmeer on the east side of Grayback Ridge.

GREYS RIVER FAULT

The Greys River fault is Pleistocene-Holocene in age (Jones, 1995) and is considered a Class A fault by the USGS (fault no. 728, McCalpin, 1994). The fault bounds the west side of the Wyoming Range, extending 64 km (40 mi) from the headwaters of the Greys River north to its intersection with the Little Greys River. The fault is normal, with its downthrown block to the west. Dip at the surface is approximately 50°–70° to the west (Rubey, 1973; Webel, 1987; Jones, 1995). The fault generally parallels bedrock strike, and at the surface it offsets primarily Permian and Triassic sedimentary rocks. At depth the fault truncates the Darby thrust and then, decreasing in dip, soles into the master Absaroka/Darby/Prospect decollement 8.2 km (5.1 mi) below the surface (Webel, 1987).

Fault scarps are common in tributary canyons of the Greys River, but are often severely weathered and heavily vegetated (fig. 5). Scarps are difficult to identify above and between drainages, where the slopes are steep and densely forested, and where the fault tends to follow bedding planes. However, aerial imagery interpretation of larger-scale lineations allows for mapping of the fault for most of its length.

Mapping of the Greys River fault was supplemented with field-surveyed scarp profiles and digital surface models acquired from an unmanned aerial vehicle to characterize rupture extent and surface offset.

Figure 5. Photograph of fault scarp in Pinedale deposits, Blind Bull Creek. The Greys River fault offsets Pinedale deposits by 3.93 m (12.89 ft). View to the southeast, June 18, 2019.

SUMMARY

This publication presents detailed maps of the surficial geology of the Blind Bull Creek and Pickle Pass 7.5' quadrangles, Lincoln County, Wyoming. A primary result is the refined and extended trace of the northern Greys River fault, which will serve as the foundation for a future study on the rupture extent and surface offset of this Holocene fault. This work also presents detailed field landslide mapping, which updates and supersedes previous photogeologic mapping from the 1990s. Other key results include mapping of previously undifferentiated Pinedale and Bull Lake glacial deposits and fluvial terraces along the Greys River, as well as mapping and detrital zircon analysis of an undated pediment surface. These results have important implications for regional seismic hazard modeling, protection of infrastructure in the Greys River valley from landslide hazards, and understanding the post-orogenic landscape evolution of the Wyoming-Utah-Idaho thrust belt.

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Appendices

APPENDIX 1

U-Pb Methods

Detrital zircon geochronology analyses were carried out at the Arizona LaserChron Center at the University of Arizona, and the following text is modified from Pecha (2019).

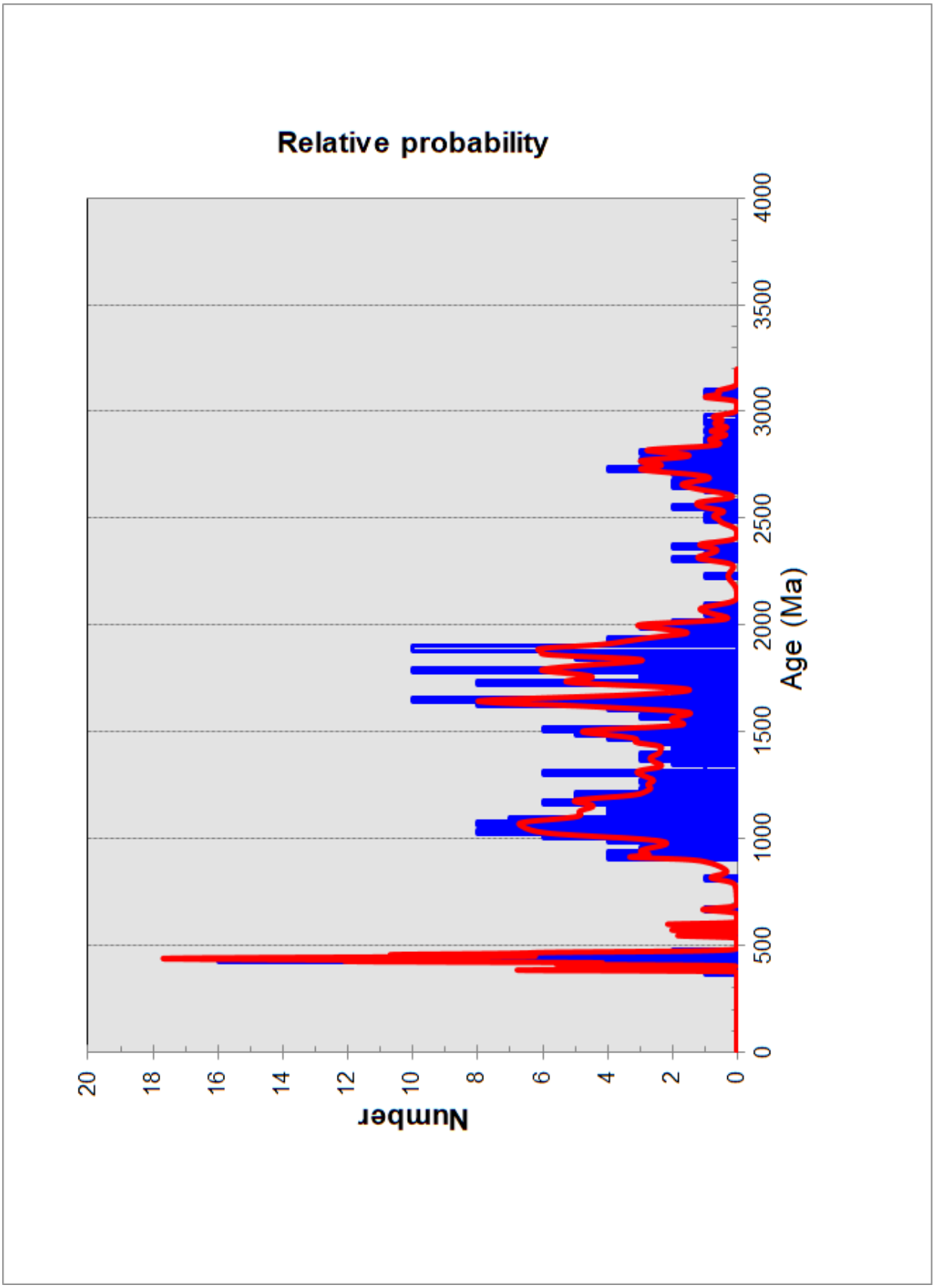
Zircon grains were extracted from bulk sample, including density separation using a Wilfley table and heavy liquids (methylene iodide). The resulting heavy mineral fraction then underwent separation using a Frantz LB-1 magnetic barrier separator to isolate the zircons. A representative split of the entire zircon yield of each sample was incorporated into a 1-inch epoxy mount along with multiple fragments of each of the three zircon standards (FC1, SL-mix, and R33). The mounts were sanded down approximately 20 microns, polished progressively using 9-, 5-, 3-, and 1-micron polishing pads, and backscatter electron (BSE) imaged using a Hitachi S-3400N scanning electron microscope (SEM) equipped with a Gatan Chroma CL2 detector. Prior to isotopic analysis, the mounts were cleaned in an ultrasound bath of one percent HNO_3 and one percent HCl in order to remove any residual common Pb from the surface of the mount.

U-Pb geochronology of individual zircon crystals was conducted by laser ablation multicollector inductively coupled mass spectrometry (LA-ICPMS) at the Arizona LaserChron Center (Gehrels and others, 2006, 2008). The isotopic analyses involved ablation of zircon using a Photon Machines Analyte G2 excimer laser coupled to a Thermo Element 2 single-collector-ICPMS.

Drill rate is approximately 1 micron per second, resulting in a final ablation pit depth of about 12 microns. The errors in determining the $^{206}Pb/^{238}U$ and $^{206}Pb/^{204}Pb$ result in a final measurement error of approximately 1–2 percent (at 2σ level) in the $^{206}Pb/^{238}U$ age for each analysis. The errors in determining $^{206}Pb/^{207}Pb$ and $^{206}Pb/^{204}Pb$ also result in approximately 1–2 percent (at 2σ level) uncertainty in age for grains that are older than 900 Ma, however, they are substantially larger for younger grains due to the low intensity of the ^{207}Pb signal.

The common Pb correction is accomplished by using the Hg-corrected ^{204}Pb and assuming an initial Pb composition from Stacey and Kramers (1975). Uncertainties of 1.5 for $^{206}Pb/^{204}Pb$ and 0.3 for $^{207}Pb/^{204}Pb$ are applied to these compositional values based on the variation in Pb isotopic composition in modern crystalline rocks. Interference of ^{204}Hg with ^{204}Pb is accounted for measurement of ^{202}Hg during laser ablation and subtraction of ^{204}Hg, according to the natural $^{202}Hg/^{204}Hg$ of 4.35.

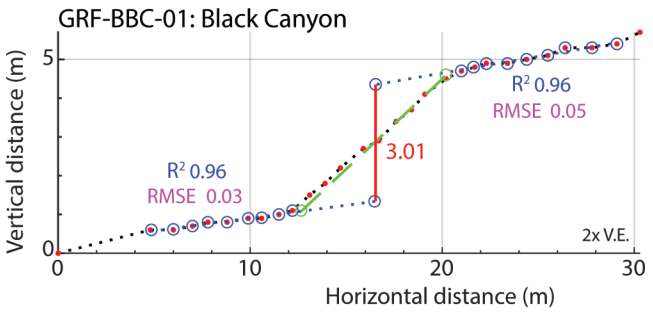
Distribution of grain ages associated with sample BBC-190912-DL-A taken along the South Fork of Meadow Creek in the Blind Bull Creek quadrangle.

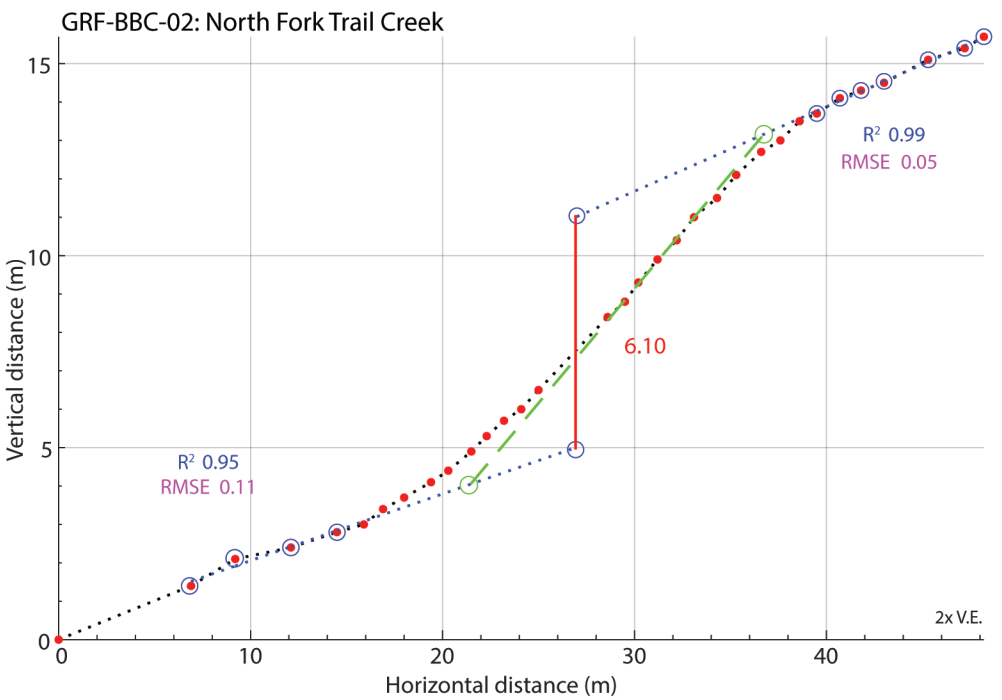


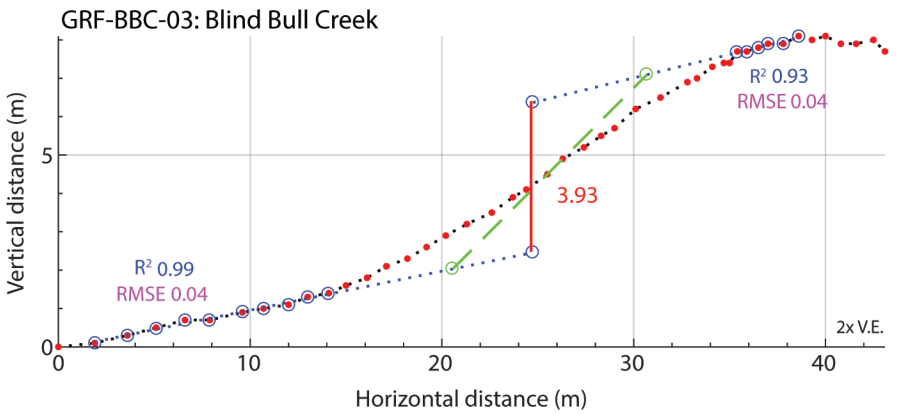
APPENDIX 2

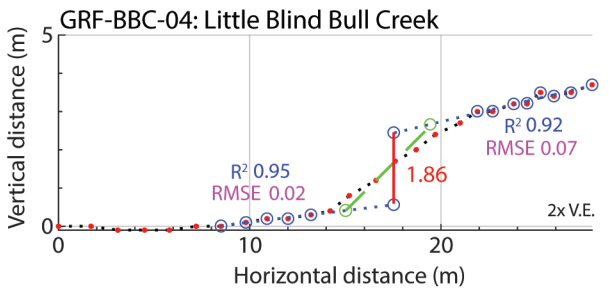
Fault Scarp Profiles

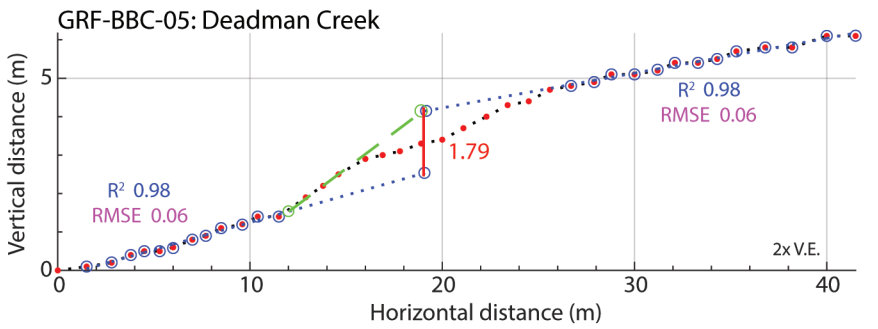
The profiles found in Appendix 2 were taken along the Greys River fault using a laser rangefinder. Results of the field surveys were entered into a MatLab script written by Christopher DuRoss (USGS) which provided offset values (shown on profile graphs). Profile names coincide with sample locations on the Pickle Pass and Blind Bull Creek quadrangles.

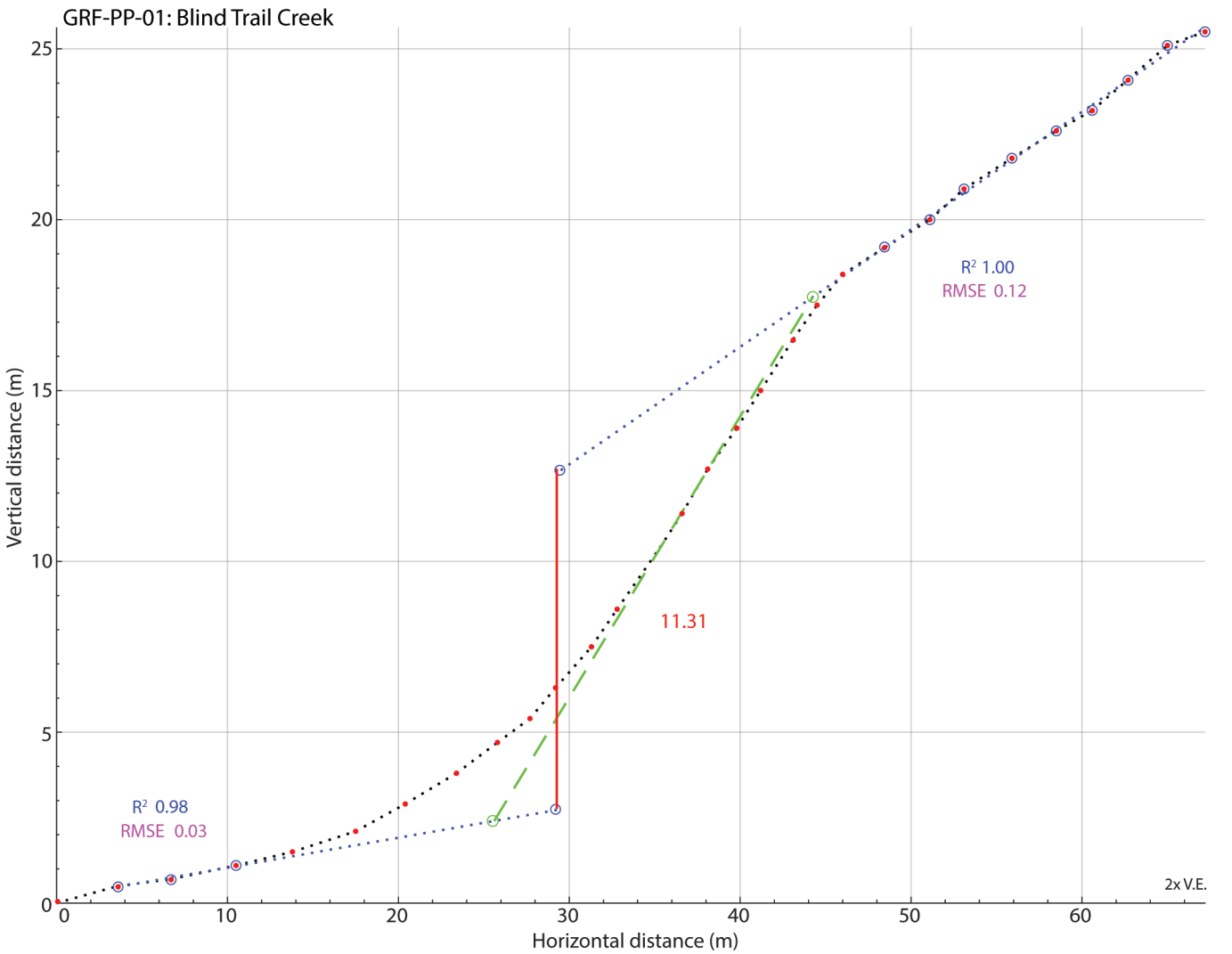


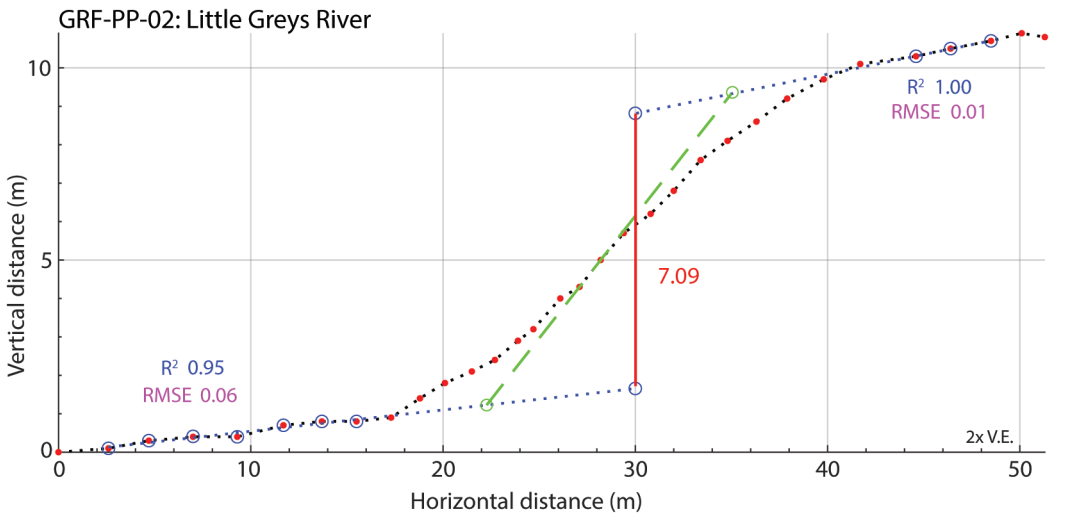


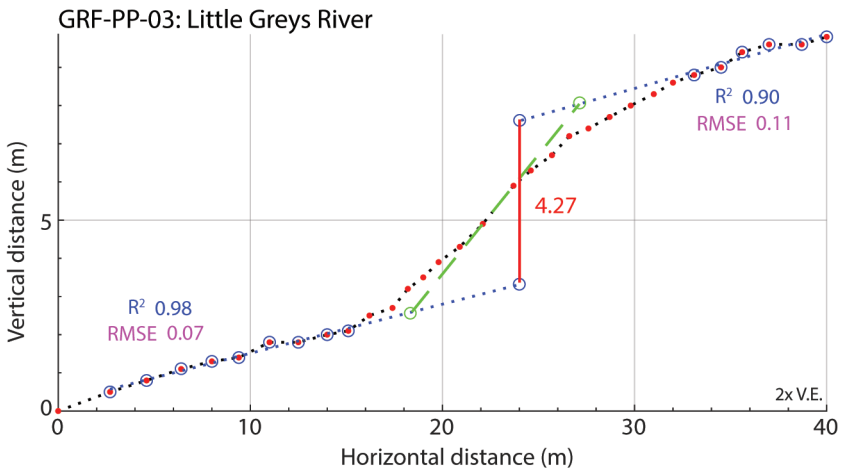


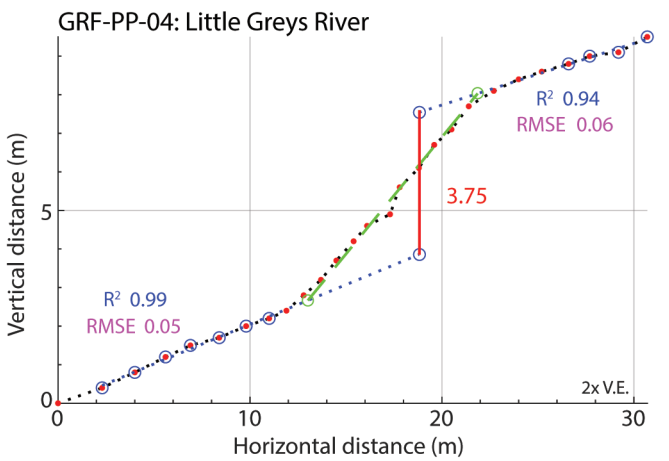

GRF-BBC-04: Little Blind Bull Creek
Vertical distance (m)
Horizontal distance (m)
R² 0.95
RMSE 0.02
1.86
R² 0.92
RMSE 0.07
2x V.E.

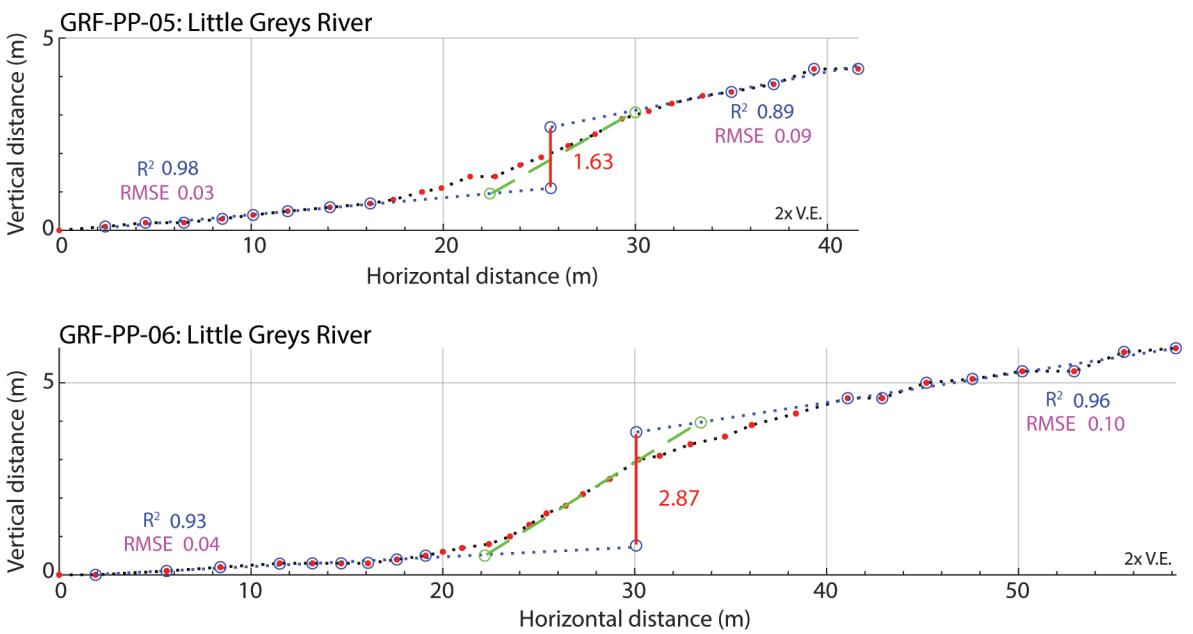

GRF-BBC-05: Deadman Creek
Vertical distance (m)
Horizontal distance (m)
R² 0.98
RMSE 0.06
1.79
R² 0.98
RMSE 0.06
2x V.E.


GRF-PP-01: Blind Trail Creek
Vertical distance (m)
Horizontal distance (m)
R² 0.98
RMSE 0.03
11.31
R² 1.00
RMSE 0.12
2x V.E.


GRF-PP-02: Little Greys River
Vertical distance (m)
Horizontal distance (m)
R² 1.00
RMSE 0.01
7.09
R² 0.95
RMSE 0.06
2x V.E.


GRF-PP-03: Little Greys River
Vertical distance (m)
Horizontal distance (m)
R² 0.90
RMSE 0.11
4.27
R² 0.98
RMSE 0.07
2x V.E.


GRF-PP-04: Little Greys River
Vertical distance (m)
Horizontal distance (m)
R² 0.94
RMSE 0.06
3.75
R² 0.99
RMSE 0.05
2x V.E.


GRF-PP-05: Little Greys River
Vertical distance (m)
Horizontal distance (m)
R² 0.98
RMSE 0.03
R² 0.89
RMSE 0.09
1.63
2x V.E.
GRF-PP-06: Little Greys River
Vertical distance (m)
Horizontal distance (m)
R² 0.93
RMSE 0.04
R² 0.96
RMSE 0.10
2.87
2x V.E.

WYOMING STATE GEOLOGICAL SURVEY
Erin A. Campbell, Director and State Geologist
Laramie, Wyoming

Interpreting the past, providing for the future

OPEN FILE REPORT 2020-5 (SHEET 1 of 4) Blind Bull Creek 1:24,000-scale Surficial Geologic Map

Base map from U.S. Geological Survey 1:24,000-scale topographic map of the Blind Bull Creek, Wyoming Quadrangle, 1980

Base hillshade derived from USDA/NRCS–National Cartography & Geospatial Center 10-meter Digital Elevation Model (DEM), 2019; azimuth 315º, sun angle 45º, vertical exaggeration 1.2

Projection: Universal Transverse Mercator (UTM), zone 12
North American Datum of 1927 (NAD 27)
1,000-meter grid ticks: UTM, zone 12
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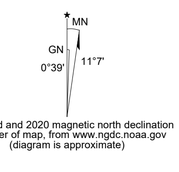


UTM grid and 2020 magnetic north declination at center of map, from www.ngdc.noaa.gov (diagram is approximate)

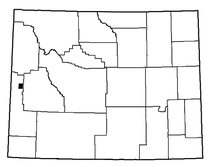
SCALE 1:24,000

1 0.5 0 1 Mile

1,000 0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 Feet

1 0.5 0 1 Kilometer

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929



WYOMING QUADRANGLE LOCATION

Digital cartography by Derek T. Lichtner
Map edited by Suzanne C. Luhr

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PRELIMINARY SURFICIAL GEOLOGIC MAP OF THE BLIND BULL CREEK QUADRANGLE, LINCOLN COUNTY, WYOMING

by

Seth J. Wittke, Derek T. Lichtner, and James P. Mauch

2020

EXPLANATION

DESCRIPTION AND CLASSIFICATION OF MAP UNITS

Alluvium—Sediment deposited during recent geologic time by channelized running water in the bed of a stream or on its floodplain. Does not include subaqueous deposits

- Alluvium and alluvial fan deposits with minor components of slopewash (**afs**)
- Alluvium and slopewash (**as**) with minor components of alluvial fan deposits (**asf**)
- Alluvium and terrace deposits (**at**) with minor components of slopewash (**ats**)

Terrace deposits—Relict alluvial deposits that are above the modern floodplain and form relatively flat, horizontal, or gently inclined surfaces which are bounded by a steeper ascending slope on one side, and a steeper descending slope on the opposite side

- Terrace deposits, undifferentiated (**t**), or terrace deposits associated with the mainstem Greys River, tread elevation measured above grade:
  - 1–2 m (3.3–6.6 ft) (**t_1**)
  - 2–3 m (6.6–9.8 ft) (**t_2**)
  - 3.5–6 m (11.5–20 ft) (**t_3**)
  - 8–15 m (26–49 ft) (**t_4**)
  - 25–30 m (82–98 ft) (**t_5**)

Alluvial fan deposits—Sediment deposited by running water in a fan-shaped landform where a stream emerges from a confined catchment onto a plain or broad valley floor

- Dissected alluvial fan deposits (**fd**)
- Alluvial fan deposits (**fa**) and alluvium with minor components of slopewash (**fas**)

Lacustrine deposits— Fine-grained sediment deposited in lakes, ponds, and slackwater environments

- Lacustrine deposits **(w)**

Disturbed ground—Areas that have been disturbed by human earth moving activities, such as large open pit mines, gravel pits, or quarries

- Disturbed ground **(M)**

Landslide deposits—Soil and rock material that has fallen, slid, or flowed downslope, usually en masse, under gravitational influence; refer to Sheet 2 for a map of landslide types

- Landslide **(l)**

Glacial deposits—Unsorted and unstratified sediment deposited by a glacier at its flanks, base, or toe in the form of moraines

- Glacial deposits of Pinedale age (**g_p**), glacial deposits of Bull Lake age (**g_{bl}**), or possible glacial deposits (**g?**)

Slopewash and colluvium—Slopewash is primarily fine-grained soil and rock material that has moved down a slope by gravity, assisted by running water. Colluvium is a loose, heterogeneous, and incoherent mass of soil material and/or rock fragments deposited by rainwash, raveling, or slow continuous downslope creep, usually at the foot of a cliff or on the surface of a slope, and deposited there chiefly by gravity

- Slopewash and alluvium with minor components of alluvial fan deposits (**saf**) or residuum (**sar**)
- Slopewash and residuum with minor components of bedrock outcrops (**srR**)
- Colluvium and bedrock outcrops (**cR**) with minor components of residuum (**cRr**) or slopewash (**cRs**)
- Colluvium and slopewash with minor components of bedrock outcrops (**csR**)

Residuum—A residual deposit remaining in place after the decomposition of bedrock. Residuum is an accumulation of rock debris formed by weathering and remaining essentially in place after all but the least soluble constituents have been removed, usually forming a comparatively thin surface layer concealing the unweathered or partially altered bedrock below

- Residuum and bedrock outcrops with minor components of slopewash (**rRs**)
- Residuum and colluvium with minor components of bedrock outcrops (**rcR**)
- Residuum and slopewash with minor components of bedrock outcrops (**rsR**)
- Residuum, rarely cemented, and/or unconsolidated deposits of uncertain origin that mantle remnants of a high erosion surface in the Greys River valley, mapped by Rubey (1973) as "fanglomerate or till" of Quaternary or Tertiary age (**r_t**)

Bedrock outcrops—Areas where the underlying bedrock is exposed and unaltered at the surface

- Bedrock outcrops and colluvium with minor components of slopewash (**Rcs**)
- Bedrock outcrops and residuum with minor components of colluvium (**Rrc**) or slopewash (**Rrs**)
- Bedrock outcrops and slopewash with minor components of colluvium (**Rsc**), colluvium and residuum (**Rscr**), or residuum (**Rsr**)

MAP SYMBOLS

Definitions: *Certain—Estimated location <25 m (82 ft)*
Approximate—Estimated location 25–100 m (82–330 ft)

Greys River fault—Continuous where certain, long dash where approximate; bar and ball on downthrown block of normal fault

The Greys River fault bounds the west side of the Wyoming Range, extending 63 km (39 mi) from the headwaters of the East Fork of the Greys River north to its intersection with the Little Greys River. The fault is normal, with its downthrown block to the west. The average strike is N 3° W, and dip at the surface is approximately 50°–70° to the west (Rubey, 1973; Webel, 1987; Jones, 1995). At a depth of 2 km (1.2 mi) the Greys River fault joins the Darby thrust (Webel, 1987).

The Greys River fault is Pleistocene–Holocene in age. It is considered a Class A fault (No. 728) by the U.S. Geological Survey, denoting confirmed Quaternary displacement. Radiocarbon ages of faulted alluvial deposits and scarp-derived colluvium from three trench sites indicate Holocene surface rupturing events at 5,080–5,310 yrs B.P. and 1,910–2,110 yrs B.P. The recurrence interval appears to be variable, but has been 2.0–5.2 ka in the middle-late Holocene. Average slip rate is 0.2–1.0 mm/yr (0.008–0.04 in/yr) (McCalpin, 1994; Jones, 1995).

Fault scarps are common in tributary drainages of the Greys River, where the fault offsets Pleistocene glacial deposits and occasionally Pleistocene–Holocene alluvium and debris flow deposits. Scarp heights range from 2–11 m (7–36 ft). Pronounced scarps are less common on the steep bedrock ridges between drainages. In aerial imagery the approximate location of the fault is traceable for most of it length. The Greys River fault is subparallel to bedrock strike and typically offsets Permian and Triassic sedimentary rocks. Regional cross sections by Rubey (1973) and Webel (1987) depict the fault in the subsurface.

GRF-BBC-01 **Fault scarp profile location**—Leader line indicates location of profile; figures and data in accompanying report

BBC-190912-DL-A **Detrital zircon sample location**

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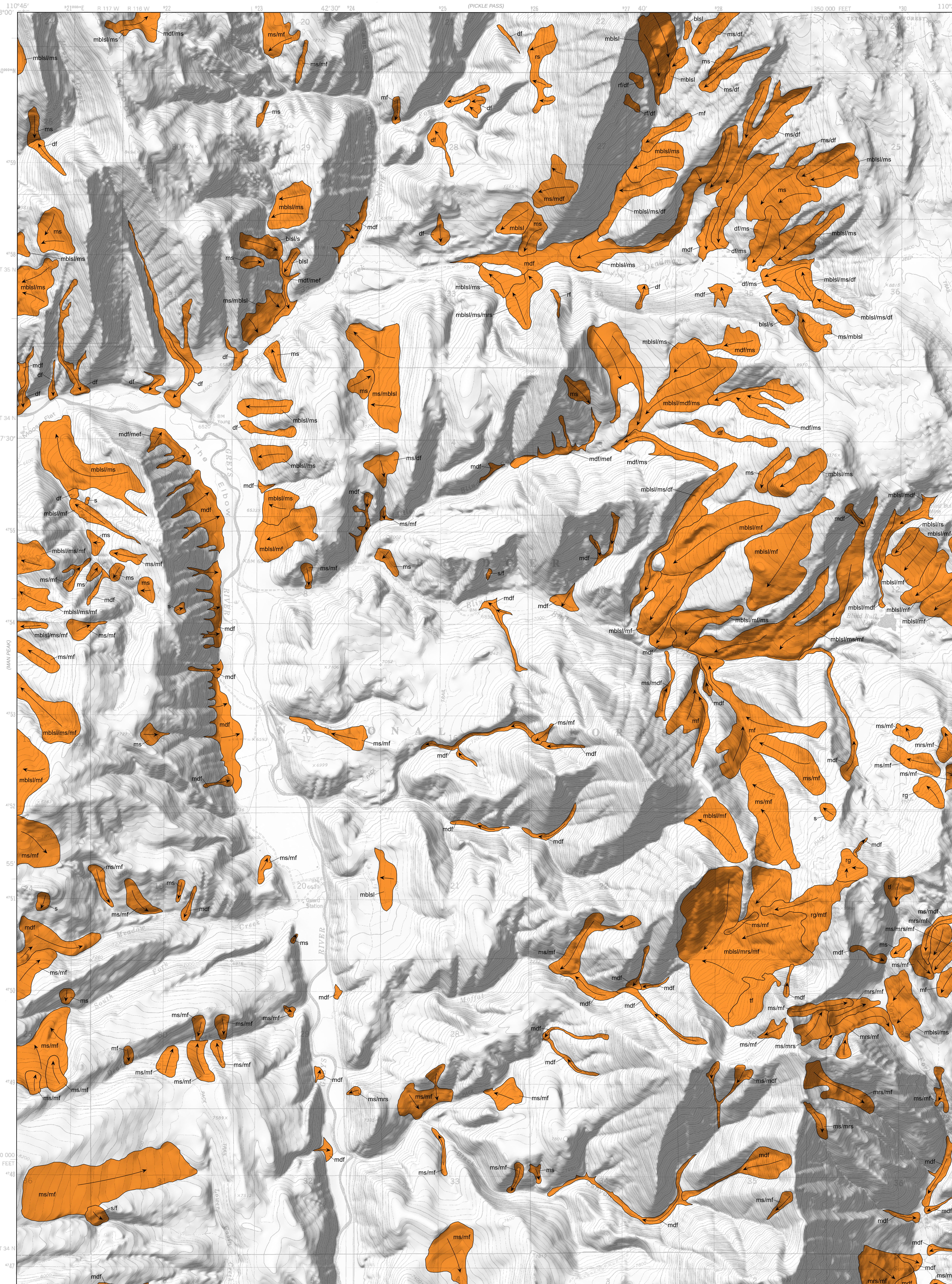
WYOMING STATE GEOLOGICAL SURVEY
Erin A. Campbell, Director and State Geologist
Laramie, Wyoming

Interpreting the past, providing for the future

OPEN FILE REPORT 2020-5
(SHEET 2 of 4)
Blind Bull Creek 1:24,000-scale
Landslide Map

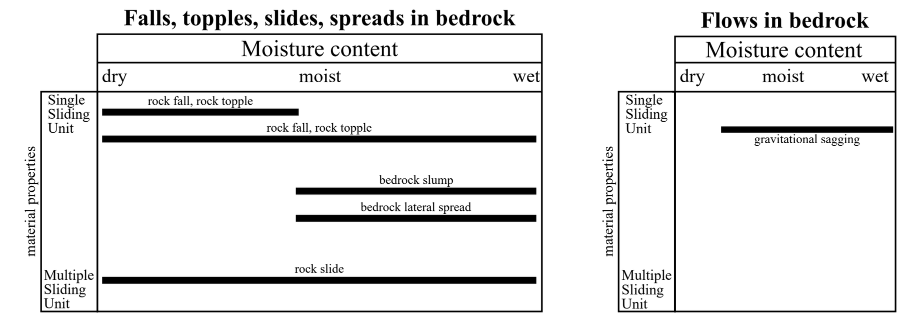


EXPLANATION

WYOMING LANDSLIDE CLASSIFICATION[1]

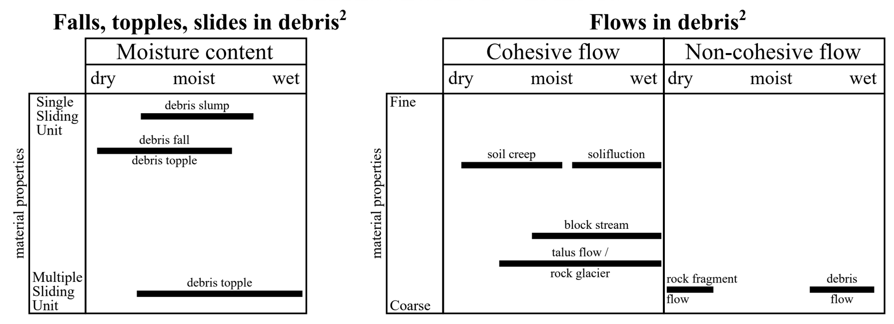
BEDROCK SLOPE MOVEMENTS

Falls, topples, slides, spreads in bedrock | **Flows in bedrock**



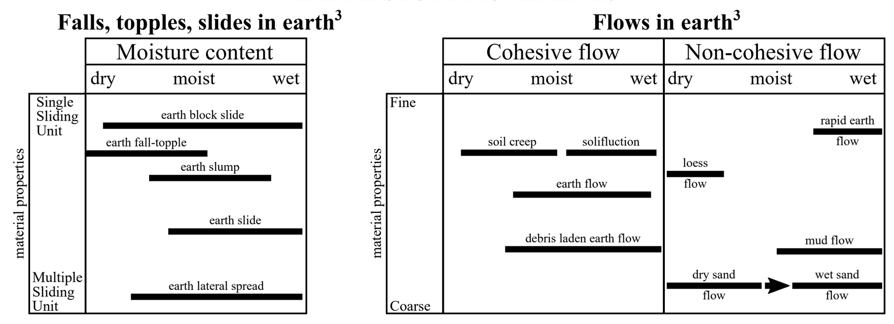
DEBRIS SLOPE MOVEMENTS

Falls, topples, slides in debris[2] | **Flows in debris[2]**



EARTH SLOPE MOVEMENTS

Falls, topples, slides in earth[3] | **Flows in earth[3]**



[1] Classification modified from Varnes (1978), Campbell (1985), and Case (1996).

[2] *Debris* is defined as an engineering soil in which 20 to 80 percent of the fragments are larger than 2 mm (0.08 in).

[3] *Earth* is defined as an engineering soil in which 80 percent of the fragments are smaller than 2 mm (0.08 in).

DESCRIPTION OF MAP UNITS

Landslide deposits—Soil and rock material that has fallen, slid, or flowed downslope, usually en masse, under gravitational influence (mapped units include complex slope movements[4])

blsl	block slide
df	debris flow
f	flow (earth or debris-laden earth)
m	multiple
mblsl	multiple block slide
mdf	multiple debris flow
mef	multiple earth flow
mf	multiple flow (earth or debris-laden earth)
mrs	multiple rock slide
ms	multiple slump (bedrock, debris, or earth)
rf	rock fall
rg	rock glacier
rs	rock slide
s	slump
tf	talus flow
/	complex, in combination with

[4] *Complex slope movements*. Most landslides are combinations of the basic mechanisms described above. The most common combination is a slump/flow, which begins with a slump that becomes fractured and disaggregated as it moves downslope. If the water content is high enough, the displaced material may continue downslope as an earth or debris flow, eventually involving more material and far outrunning the length of the initial slump. Other common types of complex slope movement include block slide/flow, rock slide/rock fall, and slump/block slide.

Landscape location and local bedrock lithology are the main factors that determine landslide type in the Blind Bull Creek quadrangle:

(1) Cretaceous shales in the Blind Bull and Aspen formations are susceptible to landslides, producing large slump-flow complexes and block slides. Landslide complexes are especially numerous in the upper reaches of Blind Bull Creek and Deadman Creek, east of the Darby thrust, where headward erosion and glaciation have resulted in broad dipslopes of failure-prone shale.

(2) The steep slopes of resistant Paleozoic units such the Wells Formation and the Madison Limestone are associated with a modest number of rockslides, debris flows, and block slides.

(3) Other Mesozoic and Paleozoic units produce a variety of mostly small debris flows and block slides.

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MN
GN
0°39'
11°7'

UTM grid and 2020 magnetic north declination at center of map, from www.ngdc.noaa.gov (diagram is approximate)

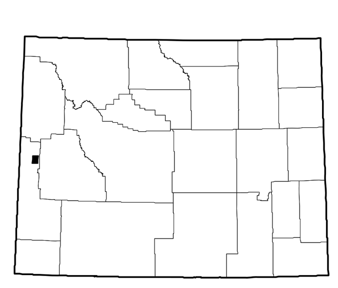
SCALE 1:24,000

1 0.5 0 1 Mile

1,000 0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 Feet

1 0.5 0 1 Kilometer

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929



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Digital cartography by Derek T. Lichtner
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PRELIMINARY LANDSLIDE MAP OF THE BLIND BULL CREEK QUADRANGLE, LINCOLN COUNTY, WYOMING

by

Seth J. Wittke, Derek T. Lichtner, and James P. Mauch

2020

WYOMING STATE GEOLOGICAL SURVEY
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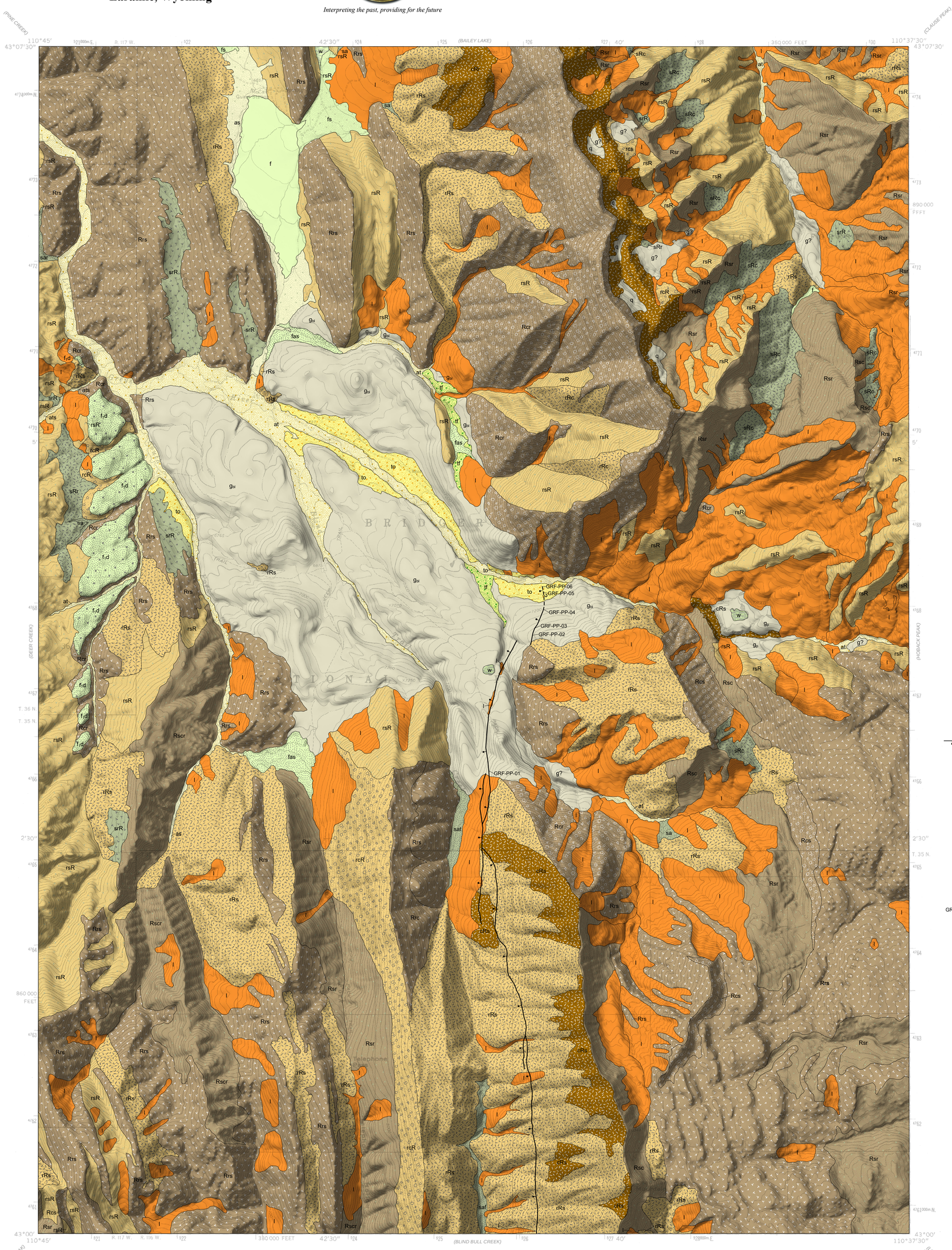
OPEN FILE REPORT 2020-5
(Sheet 3 of 4)
Pickle Pass 1:24,000-scale Surficial Geologic Map



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Terrace deposits—Relict alluvial deposits that are above the modern floodplain and form relatively flat, horizontal, or gently inclined surfaces which are bounded by a steeper ascending slope on one side, and a steeper descending slope on the opposite side

- Terrace deposits and alluvial fan deposits (**tf**)
- Terrace deposits composed of glacial outwash; deposits 5–10 m (16–33 ft) thick. Terrace tread is 14 m (46 ft) above grade at eastern extent and converges with the modern floodplain near the mouth of Blind Trail Creek (**to**)

Alluvial fan deposits—Sediment deposited by running water in a fan-shaped landform where a stream emerges from a confined catchment onto a plain or broad valley floor

- Alluvial fan deposits (**f**)
- Alluvial fan deposits and alluvium with minor components of slopewash (**fas**)
- Alluvial fan and slopewash deposits (**fs**)
- Gently sloping, dissected erosion surface mantled with a veneer of alluvium, mapped by Schroeder (1979) as Quaternary pediments; two distinct surfaces that grade to 15–30 m (50–100 ft) and 50–65 m (165–215 ft) above the modern floodplain (**f,d**)

Lacustrine deposits—Fine-grained sediment deposited in lakes, ponds, and slackwater environments

- Lacustrine deposits (**w**)

Landslide deposits—Soil and rock material that has fallen, slid, or flowed downslope, usually en masse, under gravitational influence; refer to Sheet 2 for a map of landslide types

- Landslide deposits (**l**)

Glacial and periglacial deposits—Unsorted and unstratified sediment deposited by a glacier at its flanks, base, or toe in the form of moraines; or periglacial deposits derived from seasonal freeze-thaw and other geomorphic processes typical of alpine environments with permanent snowfields

- Glacial deposits of Pinedale age (**g_p**), glacial deposits of Bull Lake age (**g_{bl}**), possible glacial deposits (**g?**), or periglacial deposits that consist of protalus ramparts and associated frost-weathered talus slopes (**q**)

Slopewash and colluvium—Slopewash is primarily fine-grained soil and rock material that has moved down a slope by gravity, assisted by running water. Colluvium is a loose, heterogeneous, and incoherent mass of soil material and/or rock fragments deposited by rainwash, raveling, or slow continuous downslope creep, usually at the foot of a cliff or on the surface of a slope, and deposited there chiefly by gravity

- Slopewash and alluvium (**sa**) with minor components of alluvial fan deposits (**saf**), residuum (**sar**), or terrace deposits (**sat**)
- Slopewash and bedrock outcrops with minor components of colluvium (**sRc**) or residuum (**sRr**)
- Slopewash and residuum with minor components of bedrock outcrops (**srR**)
- Colluvium and bedrock outcrops with minor components of residuum (**cRr**) or slopewash (**cRs**)

Residuum—A residual deposit remaining in place after the decomposition of bedrock. Residuum is an accumulation of rock debris formed by weathering and remaining essentially in place after all but the least soluble constituents have been removed, usually forming a comparatively thin surface layer concealing the unweathered or partially altered bedrock below

- Residuum and bedrock outcrops with minor components of colluvium (**rRc**) or slopewash (**rRs**)
- Residuum and colluvium with minor components of bedrock outcrops (**rcR**) or slopewash (**rcs**)
- Residuum and slopewash with minor components of bedrock outcrops (**rsR**)

Bedrock outcrops—Areas where the underlying bedrock is exposed and unaltered at the surface

- Bedrock outcrops and colluvium with minor components of slopewash (**Rcs**) or residuum (**Rcr**)
- Bedrock outcrops and residuum with minor components of colluvium (**Rrc**) or slopewash (**Rrs**)
- Bedrock outcrops and slopewash with minor components of colluvium (**Rsc**), colluvium and residuum (**Rscr**), or residuum (**Rsr**)

MAP SYMBOLS

Definitions: *Certain—Estimated location <25 m (82 ft)*
Inferred—Estimated location >100 m (328 ft)

Greys River fault—Continuous where certain, short dash where inferred, queried where existence uncertain; bar and ball on downthrown block of normal fault

The Greys River fault bounds the west side of the Wyoming Range, extending 63 km (39 mi) from the headwaters of the East Fork of the Greys River north to its intersection with the Little Greys River. The fault is normal, with its downthrown block to the west. The average strike is N 3° W, and dip at the surface is approximately 50°–70° to the west (Rubey, 1973; Webel, 1987; Jones, 1995). At a depth of 2 km (1.2 mi) the Greys River fault joins the Darby thrust (Webel, 1987).

The Greys River fault is Pleistocene–Holocene in age. It is considered a Class A fault (No. 728) by the U.S. Geological Survey, denoting confirmed Quaternary displacement. Radiocarbon ages of faulted alluvial deposits and scarp-derived colluvium from three trench sites indicate Holocene surface rupturing events at 5,080–5,310 yrs B.P. and 1,910–2,110 yrs B.P. The recurrence interval appears to be variable, but has been 2.0–5.2 ka in the middle-late Holocene. Average slip rate is 0.2–1.0 mm/yr (0.008–0.04 in/yr) (McCalpin, 1994; Jones, 1995).

Fault scarps are common in tributary drainages of the Greys River, where the fault offsets Pleistocene glacial deposits and occasionally Pleistocene–Holocene alluvium and debris flow deposits. Scarp heights range from 2–11 m (7–36 ft). Pronounced scarps are less common on the steep bedrock ridges between drainages. In aerial imagery the approximate location of the fault is traceable for most of its length. The Greys River fault is subparallel to bedrock strike and typically offsets Permian and Triassic sedimentary rocks. Regional cross sections by Rubey (1973) and Webel (1987) depict the fault in the subsurface.

GRF-PP-01 **Fault scarp profile location**—Leader line indicates location of measured profile; figures and data in accompanying report

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Base map from U.S. Geological Survey 1:24,000-scale topographic map of the Pickle Pass, Wyoming Quadrangle, 1965, photo inspected, 1979

Base hillshade derived from USDA/NRCS–National Cartography & Geospatial Center 10-meter Digital Elevation Model (DEM), 2019; azimuth 315°, sun angle 45°, vertical exaggeration 1.2

Projection: Universal Transverse Mercator (UTM), zone 12
North American Datum of 1927 (NAD 27)
1,000-meter grid ticks: UTM, zone 12
10,000-foot grid ticks: Wyoming State Plane Coordinate System, west zone

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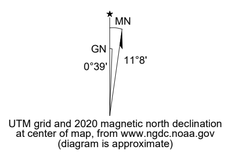


UTM grid and 2020 magnetic north declination at center of map, from www.ngdc.noaa.gov (diagram is approximate)

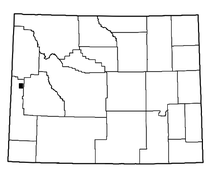
SCALE 1:24,000

1 0.5 0 1 Mile

1,000 0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 Feet

1 0.5 0 1 Kilometer

CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL



WYOMING QUADRANGLE LOCATION

Digital cartography by Derek T. Lichtner and James P. Mauch

Map edited by Suzanne C. Luhr

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PRELIMINARY SURFICIAL GEOLOGIC MAP OF THE PICKLE PASS QUADRANGLE LINCOLN COUNTY, WYOMING

by

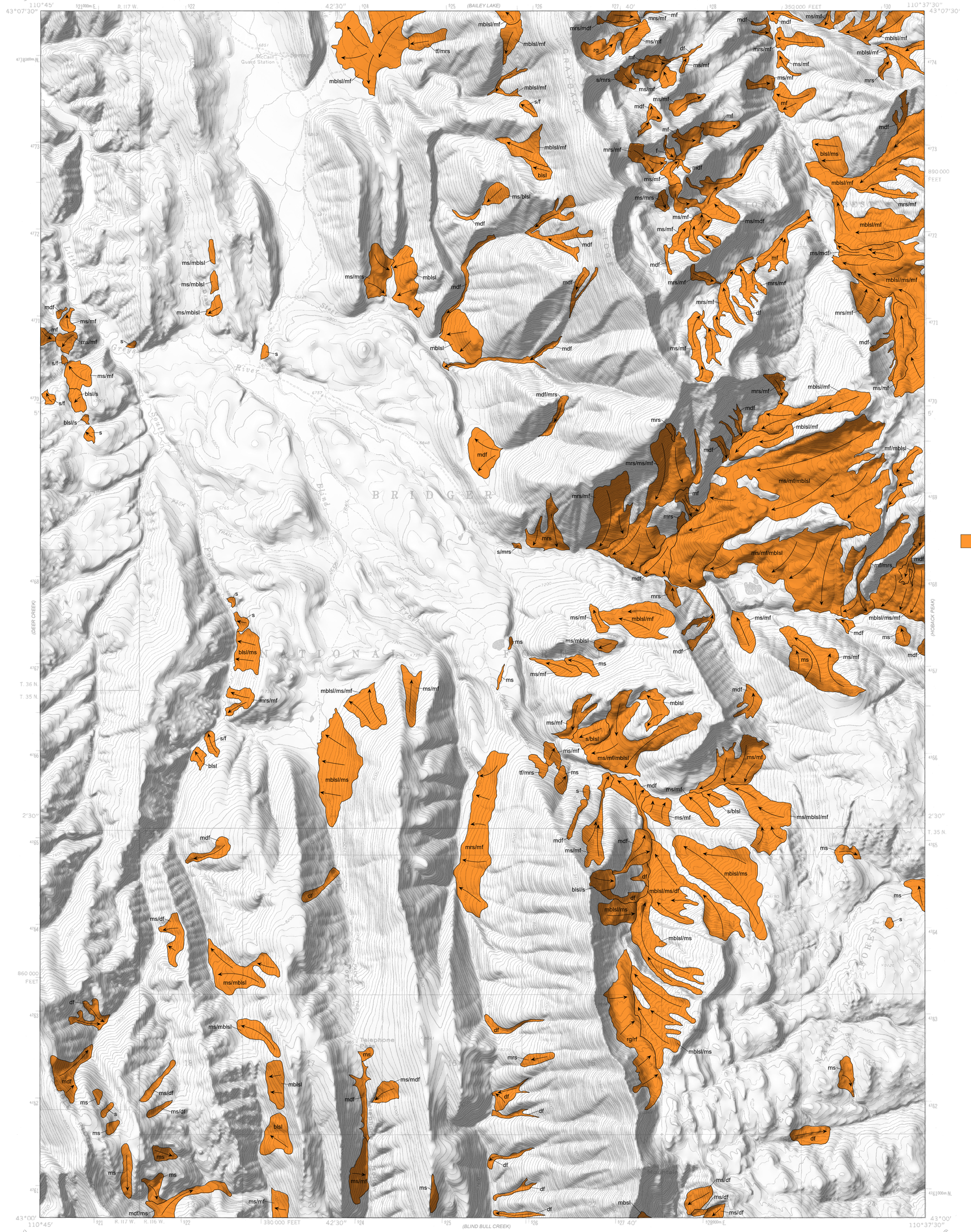
Seth J. Wittke, James P. Mauch, and Derek T. Lichtner

2020

WYOMING STATE GEOLOGICAL SURVEY
Erin A. Campbell, Director and State Geologist
Laramie, Wyoming

Interpreting the past, providing for the future

OPEN FILE REPORT 2020-5
(Sheet 4 of 4)
Pickle Pass 1:24,000-scale Landslide Map



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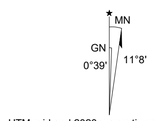
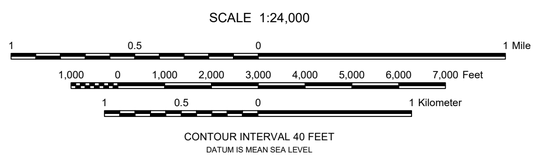
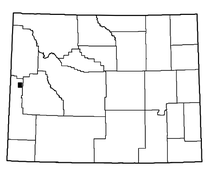


UTM grid and 2020 magnetic north declination at center of map, from www.ngdc.noaa.gov (diagram is approximate)



CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL



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2020

EXPLANATION

WYOMING LANDSLIDE CLASSIFICATION[1]

BEDROCK SLOPE MOVEMENTS

Falls, topples, slides, spreads in bedrock

material properties	Moisture content: dry	moist	wet
Single Sliding Unit	rock fall, rock topple		
		rock fall, rock topple	
		bedrock slump	
		bedrock lateral spread	
Multiple Sliding Unit		rock slide	

Flows in bedrock

material properties	Moisture content: dry	moist	wet
Single Sliding Unit		gravitational sagging	
Multiple Sliding Unit			

DEBRIS SLOPE MOVEMENTS

Falls, topples, slides in debris[2]

material properties	Moisture content: dry	moist	wet
Single Sliding Unit	debris slump		
	debris fall		
	debris topple		
Multiple Sliding Unit		debris topple	

Flows in debris[2]

material properties		Cohesive flow: dry	moist	wet	Non-cohesive flow: dry	moist	wet
Fine			soil creep	solifluction			
				block stream			
				talus flow / rock glacier			
Coarse					rock fragment flow		debris flow

EARTH SLOPE MOVEMENTS

Falls, topples, slides in earth[3]

material properties	Moisture content: dry	moist	wet
Single Sliding Unit	earth block slide		
	earth fall-topple		
		earth slump	
		earth slide	
Multiple Sliding Unit		earth lateral spread	

Flows in earth[3]

material properties		Cohesive flow: dry	moist	wet	Non-cohesive flow: dry	moist	wet
Fine			soil creep	solifluction			rapid earth flow
				earth flow	loess flow		
				debris laden earth flow			mud flow
Coarse					dry sand flow		wet sand flow

[1] Classification modified from Varnes (1978), Campbell (1985), and Case (1996).

[2] *Debris* is defined as an engineering soil in which 20 to 80 percent of the fragments are larger than 2 mm (0.08 in).

[3] *Earth* is defined as an engineering soil in which 80 percent of the fragments are smaller than 2 mm (0.08 in).

DESCRIPTION OF MAP UNITS

Landslide deposits—Soil and rock material that has fallen, slid, or flowed downslope, usually en masse, under gravitational influence (mapped units include complex slope movements[4])

blsl	block slide
df	debris flow
f	flow (earth or debris-laden earth)
m	multiple
mblsl	multiple block slide
mdf	multiple debris flow
mf	multiple flow (earth or debris-laden earth)
mrs	multiple rock slide
ms	multiple slump (bedrock, debris, or earth)
rf	rock fall
rg	rock glacier
rs	rock slide
s	slump
tf	talus flow
/	complex, in combination with

[4] *Complex slope movements*. Most landslides are combinations of the basic mechanisms described above. The most common combination is a slump/flow, which begins with a slump that becomes fractured and disaggregated as it moves downslope. If the water content is high enough, the displaced material may continue downslope as an earth or debris flow, eventually involving more material and far outrunning the length of the initial slump. Other common types of complex slope movement include block slide/flow, rock slide/rock fall, and slump/block slide.

Landscape position and local bedrock lithology are the main factors that determine landslide type in the Pickle Pass quadrangle:

(1) Cretaceous shales in the Blind Bull and Aspen formations are susceptible to landslides, producing large slump-flow complexes and block slides. Landslide complexes are especially numerous in the upper reaches of the Little Greys River and Willow Creek, east of the Darby thrust, where headward erosion and glaciation have resulted in broad dipslopes of failure-prone shale.

(2) The steep slopes of resistant Paleozoic units such the Wells Formation and the Madison Limestone are associated with a modest number of rockslides, debris flows, and block slides.

(3) Other Mesozoic and Paleozoic units produce a variety of mostly small debris flows and slumps.

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