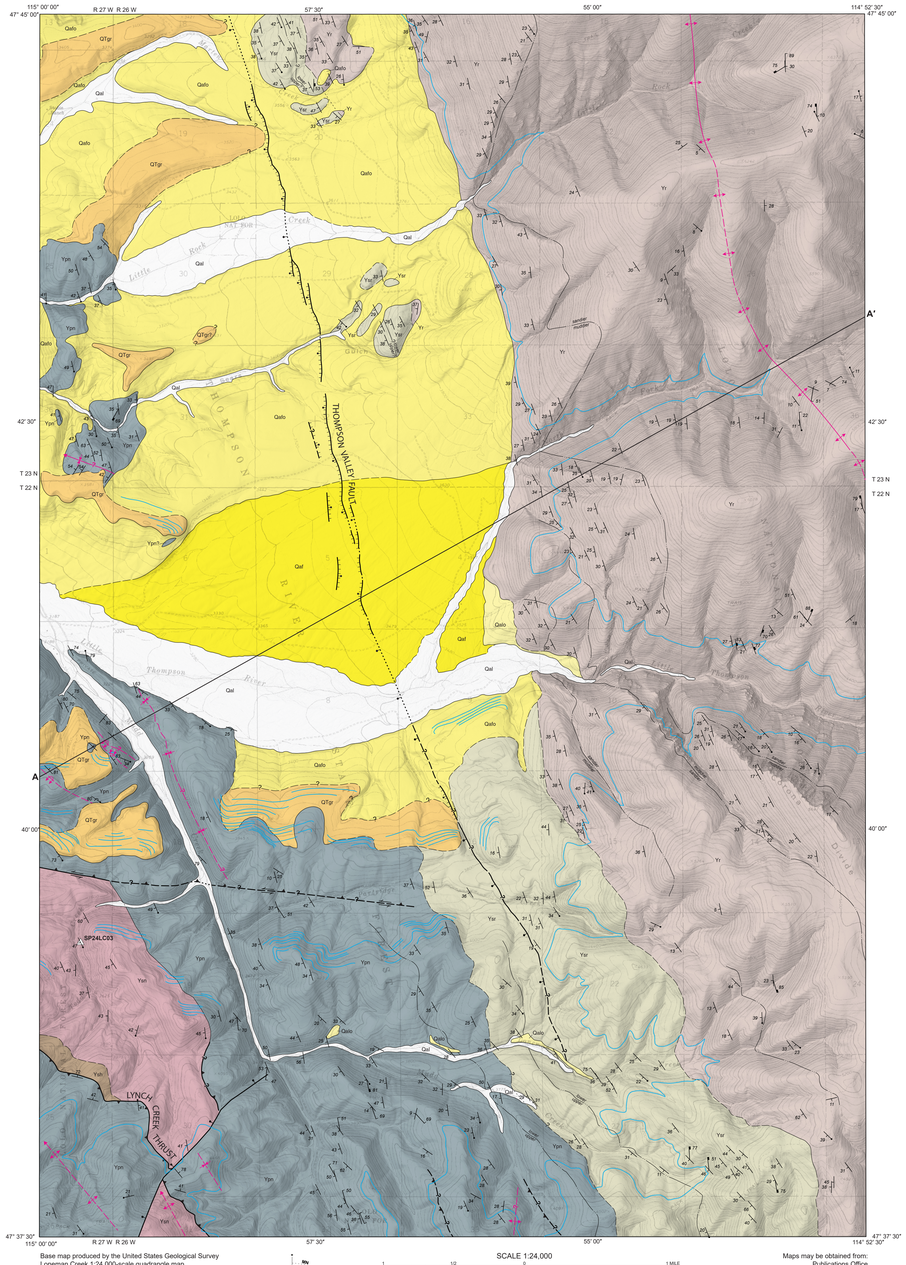


Base map produced by the United States Geological Survey
Loneman Creek 1:24,000-scale quadrangle map
Control by: USGS and USC&GS
Compiled from aerial photographs taken 1963
Field checked: 1964
Projection: Polyconic
Grid:1000 meter Universal Transverse Mercator Zone 11
Vertical Datum: Mean sea level
Horizontal Datum: 1927 North American Datum

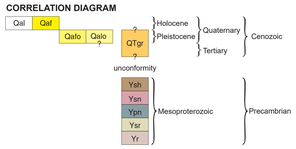
Shaded relief created from the USGS 3D Elevation Program (3DEP) 1-meter digital elevation model.

UTM GRID AND 2021 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24,000
CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Maps may be obtained from:
Publications Office
Montana Bureau of Mines and Geology
1300 West Park Street
Butte, Montana 59701-8997
Phone: (406) 496-4174
https://mbmg.mtech.edu

CORRELATION DIAGRAM



MAP SYMBOLS

Contacts and Faults

? = Identity or existence questionable

	Accurate	Approximate	Concealed
Contact			
Internal contact			
Normal fault—Ball and bar on hanging wall			
Normal fault scarp—Ball and bar on hanging wall			
Thrust fault—Sawteeth on hanging wall			
Oblique thrust fault—Sawteeth on hanging wall; Arrows show relative motion			

Structure Lines

? = Identity or existence questionable
Large arrowhead shows direction of plunge

	Accurate	Approximate	Concealed
Anticline			
Overturned anticline—Beds on one limb are overturned; arrows show dip direction of limbs			
Syncline			
Overturned syncline—Beds on one limb are overturned; arrows show dip direction of limbs			

Geologic Lines

Former shoreline of Glacial Lake Missoula—Highstand shown at 4,250 ft (1,295 m) elev.

Geochron Points

△ Sample: U-Pb geochronology (table 2)

Orientation Points

- Inclined bedding—Showing strike and dip
- Inclined bedding, where top direction of beds is known from local features—Showing strike and dip
- Vertical bedding—showing strike
- Overturned bedding, where top direction of beds is known from local features—Showing strike and dip
- Small, minor inclined joint—Showing strike and dip
- Small, minor inclined joint, for multiple observations at one locality—Showing strike and dip
- Inclined cleavage—Showing strike and dip
- Inclined cleavage, for multiple observations at one locality—Showing strike and dip

Figure 1. Overview map of the Loneman Creek 7.5′ quadrangle (green box) and surrounding area. Major faults shown. Maximum extent of glacial ice and highstand of Glacial Lake Missoula modified from Smith and others (2021).

INTRODUCTION

The Loneman Creek 7.5′ quadrangle is situated in the headwaters of the Little Thompson River within the Salish Mountains, about 15 mi (25 km) north of Plains, Montana (fig. 1). The quadrangle is underlain by unglaciated, mostly forested, mid-elevation mountains north of Loneman Divide, about 10 mi (20 km) south of the Cordilleran ice sheet margin of the last glacial maximum (e.g., Alden, 1953). The gentle mountains in the southern half of the quadrangle are dissected by Mudd Creek and its tributaries, which include Loneman Creek. In the north half of the quadrangle, the southern end of the Thompson River Valley is bounded by a sharp, linear range front. Bedrock highs throughout the valley suggest that the basin is fairly shallow, with less than 2,000 ft (600 m) of valley fill. Deep canyons of Little Rock Creek and forks of the Little Thompson River breach the mountain front. Elevations in the quadrangle reach up to about 6,400 ft (1,950 m) on the flanks of Cook Mountain and Little Thompson Peak, in the northeast part of the quadrangle. The low point of about 3,100 ft (945 m) elevation occurs along Little Rock Creek, on the western edge of the map.

PREVIOUS MAPPING AND METHODS

Previous geologic mapping in the Loneman Creek 7.5′ quadrangle is limited. The southern part of the quadrangle is included in Sears (1991, unpublished, 1:100,000 scale). Ostenaa and others (1990, 1:24,000 scale) mapped the surficial geology of the Thompson River Valley and identified a Quaternary fault scarp of the Thompson Valley fault, which cuts alluvial fans in the valley. Harrison and others (1986; 1:250,000 scale) is the only geologic map that covers the entire study area.

Digital elevation models (DEMs) derived from 1-m (1/3-ft) resolution light detection and ranging (Lidar) data of Sanders County were used to identify and map surficial deposits, geomorphic features, and scarps of Quaternary normal fault splays. DEMs were also used to create topographic profiles and estimate unit thicknesses. The Lidar data, DEMs, and hillshades used in this study are available through the Montana Lidar Inventory (https://msl.mt.gov/geoinfo/nrcs_partnership/imagery_and_elevation).

The rock sample collected for U-Pb geochronology was processed at the MBMG mineral separation laboratory. Zircon was isolated by standard density and magnetic separation techniques. Zircon separates were analyzed by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) by Daniel Brennan and Amanda Willingham, MBMG, at the University of California, Santa Barbara. Low zircon yield for this sample precludes interpretation of maximum depositional age and provenance. All data are reported in Brennan and others (2026).

GEOLOGIC SUMMARY

Deposition of the Belt Supergroup

The bedrock exposed in the Loneman Creek 7.5′ quadrangle comprises a thick (>19,000 ft, 5.8 km), moderately tilted section of slightly metamorphosed siliciclastic and carbonate rocks of the Belt Supergroup. The exposed section reveals portions of the Ravalli, Piegan, and Missoula Groups, which were deposited in an enormous playa lake basin (e.g., Winston, 2007, 2016). The observed sediment types in the map area (table 1) suggest that deposition of the Revett to the Shepard Formation occurred near the center of the Belt Basin, after about 1,470 to 1,440 Ma (Constenius and others, in review; Sears and others, 1998). The Revett Formation was deposited mostly by subareal sheetfloods that entered the playa during an extensive dry period (e.g., Winston, 2016). The playa was flooded, with subaqueous conditions persisting during deposition of the upper St. Regis Formation and Piegan Group (e.g., Hrabar, 1971; Grotzinger, 1981; Winston, 2007). During contraction of the Belt Sea, evaporation exceeded fresh-water inflows and carbonate (mostly dolomite) cement overprinted the thin siliciclastic sediments of the lower Piegan Group (Winston, 2007). During relative highstands or expansions of the Belt Sea, storm events with sizable waves drove sandy bedforms across the basin (Winston, 2007). The Belt Basin returned to episodic playa and shallow-water conditions during deposition of the Snowslip Formation (Lemoine, 1979). The Shepard Formation highlights a brief return of the Belt Sea, with mixed carbonate and siliciclastic deposition in the basin.

Structural Geology

Bedrock exposures of the Belt Supergroup in the quadrangle mostly define a large WSW-dipping panel that coincides with the western limb of the Purcell Anticlinorium (Harrison and Cressman, 1993). The Purcell Anticlinorium (fig. 1) is a fault-bend fold that exerts a footwall ramp that exhumed the Lewis thrust plate as it was translated up and out of the Belt Basin during the Cretaceous to early Eocene Cordilleran Orogeny (e.g., Sears, 1988, 2001). Local bedding orientations reflect folding parallel to the anticlinorium; joints accommodated local tension near the fold hinge (figs. 2a, 2b). Pressure solution cleavage occurs locally in argillites and limestones, and is commonly inclined relative to bedding (figs. 2c, 2d). When cleavage in the Ravalli Group is restored (fig. 2d), it is WSW-dipping in the west limb and ESE-dipping in the east limb of the anticline, suggesting that each limb accommodated general shear towards the anticline crest. When cleavage in weaker carbonates of the Piegan Group is restored, pressure-solution cleavage is perpendicular to bedding, perhaps reflecting early layer–parallel shortening. Orientations of bedding, joints, cleavage, and fold hinges yield a consistent shortening direction, suggesting that they formed during progressive ENE-directed shortening, with flexural slip occurring on both limbs of the Purcell Anticlinorium.

While most of the bedding orientations reflect fault-bend folding in the regional-scale Purcell Anticlinorium, smaller and tighter, overturned to isoclinal folds occur in rocks of the Piegan Group (fig. 2a). An inferred left-lateral backthrust separates tight folds to the north, with a wavelength of about 1/2 mi (3/4 km), from a continuous dip panel to the south. These tight folds occur in the hanging wall and are cut obliquely by the backthrust, suggesting early fault–propagation folding. The inferred left-lateral, thrust kinematics are consistent with the top-to-the-ENE sense of slip that is inferred for the structurally higher Lynch Creek Thrust (Parker and Lonn, 2026).

A normal fault cuts thrust faults in the southwestern corner of the quadrangle, reflecting regional post-orogenic extension. The normal fault bends towards the NE as it approaches the southern tip of the nearby Thompson Valley Fault. This geometry may indicate a relay ramp, where the active fault tip of the NE-striking normal fault may be propagating towards the Thompson Valley Fault, attempting to connect the two segments.While scarps constrain Quaternary offset of the Thompson Valley Fault (Ostenaa and others, 1990), the southern continuation of the fault trace is more difficult to delineate in the bedrock. The apparent thickness of the St. Regis Formation decreases towards the south, suggesting that slip on the Thompson Valley fault decreases southward, and the fault tip may occur somewhere near the southern boundary of the quadrangle. No evidence of normal faulting was found along the range front within the map area. These observations attest to recent activity on the youthful Thompson Valley Fault (Ostenaa and others, 1990).

Quaternary Geology

The southern end of the Thompson River Valley is partly exhumed, exposing numerous Quaternary and possibly Tertiary sedimentary deposits that record recent tectonic activity. Undated gravel deposits (QTgr), possibly Tertiary in age, suggest that the valley was carved by an older north-flowing river system. The older gravel deposits are confined to the hanging wall of the Thompson Valley Fault, suggesting that deposition may have coincided with the onset of faulting. Bedrock and older surficial deposits were eroded in much of the valley. In the Pleistocene, Glacial Lake Missoula flooded the valley, as is evident by numerous shorelines between about 3,500 and 4,000 ft (1,065 and 1,220 m) elevation. In the Quaternary, after the final draining of Glacial Lake Missoula, a large silty alluvial fan, sourced by the North Fork of the Little Thompson River, formed near the southern margin of the valley. Sometime after deposition of the Quaternary fan, multiple surface-rupturing earthquakes occurred along this segment of the Thompson Valley Fault, creating a series of fault scarps that are up to 26 ft (8 m) high in the quadrangle (Ostenaa and others, 1990). Since the last surface-rupturing earthquake, incision of older alluvial fans and deposition of alluvial sediments have occurred within the quadrangle.

Erosion and normal faulting created the local segment of the Thompson River Valley, prior to or during the Pleistocene. Erosion has generally dominated over deposition since the onset of local normal faulting. The modern topography, including the prominent range front, is therefore largely a reflection of erosional, not tectonic, processes.

DESCRIPTION OF MAP UNITS

Qal **Alluvium (Holocene)**—Unconsolidated, moderately sorted stream-rounded gravel and sand deposited by modern streams. Channel deposits include rounded clasts, up to cobble- or small boulder-sized. Unit is inset into older alluvium and colluvium in the Thompson River Valley. Thickness up to about 75 ft (23 m) near the Little Thompson River.

Qalf **Alluvial fan deposit (Holocene)**—Unconsolidated, poorly sorted deposits of subrounded to angular pebble to cobble gravel with uncommon boulders in a silty matrix. Silty alluvial fans, sourced from the North Fork of the Little Thompson River, form low-angle surfaces. Fine-grained fan deposits consist of silt with some pebbles and sand, suggesting reworking from Pleistocene lacustrine deposits. Inset into older alluvial fan deposits (Qalo). Thickness may be as much as 50 ft (15 m).

Qalo **Alluvial fan deposit, older than Qaf (Pleistocene)**—Unconsolidated, poorly sorted to moderately sorted deposits of angular to subrounded pebbles to cobbles and finer sediment in a tan to pink silty matrix. Clasts are lithologically homogeneous, suggesting a local source area of Belt rocks. Forms extensive, low-angle lag surfaces north of Loneman Creek, which may be older, fine-grained alluvial fans. May contain local colluvium, including uncommon angular boulders, near hillslopes. Rests on bedrock, becoming more extensive and presumably thicker towards the center of the Thompson River Valley. Inset into older gravel deposits (QTgr). Ostenaa and others (1990) mapped several generations of fan deposits, which they interpreted to be early to late Wisconsin (ca. 75–12 Ka) in age. Thickness is poorly constrained, but up to about 400 ft (120 m) thick.

Qalo **Alluvium, older than Qal (Pleistocene?)**—Unconsolidated, moderately sorted deposits of stream-rounded pebble to cobble gravel. Local boulders occur near the mouth of the Little Thompson River canyon. Most clasts are derived from quartzite of the Revett Formation (Yr) in the local highlands near the Corona Divide. Forms small terraces that rest on bedrock with lags of rounded cobbles along Loneman Creek and the Little Thompson River. Apparent thickness is up to 100 ft (30 m).

QTgr **Gravel deposit (Tertiary? to Pleistocene?)**—Unconsolidated lag of subrounded pebbles to cobbles. Clasts are mostly quartzite, sourced by a variety of units. Forms an armored lag on flat hill tops in the Thompson River Valley, about 100 ft (30 m) or more above modern drainages. Basal contact with bedrock ranges in elevation from about 3,800 to 3,450 ft (1,160 to 1,050 m) and slopes gently northward (~3°), towards the Little Thompson River Valley. Red quartzites and argillites, similar to lithologies in the Missoula Group, suggest a southwestern source. Well-developed Glacial Lake Missoula shorelines suggest a Pleistocene or older age. Thickness of about 60 ft (18 m).

BELT SUPERGROUP

The Belt Supergroup is a very thick (50,000 ft, 15 km; Lonn and others, 2020) succession of low-grade metasedimentary rocks with well-preserved primary sedimentary structures. Formations have gradational contacts and are defined by their sedimentary rock protoliths. Because depositional features are preserved, the descriptions in this map refer to the inferred primary grain sizes (sand, silt, clay) of the sedimentary rock protolith rather than the general metamorphic rock types (quartzite, siltite, argillite). Graded layers less than about 1 in (3 cm) thick are termed couplets; about 1–4 in (3–10 cm) thick are termed couplets. Layers greater than 4 in (10 cm) thick are termed beds; greater than about 1 foot (30 cm) are termed thick beds.

Common associations of primary grain sizes, layer thicknesses, bed geometry (bedforms), and sedimentary structures define sediment types (e.g., Winston and Link, 1993; Winston and Smith, 2016). Similarly, when diagenetic features obscure primary features, lithotypes are used. Unit descriptions refer to the associations of key litho- and sediment types that best define formations. See table 1 for detailed descriptions of the litho- and sediment types of the Piegan Group. See Parker (2025) for annotated photos of sediment types of the Ravalli Group, exposed in the neighboring Murr Creek 7.5′ quadrangle.

Ysh **Shepard Formation of the Missoula Group (Mesoproterozoic)**—Dark green siltite and light green argillite microcouplets and couplets that are dolomitic. Weathers to thin plates with a characteristic orange-brown rind. Contains common ripples and load casts, and rare desiccation cracks. Locally contains thin, "starved" ripples of white fine-grained quartzite up to a few centimeters thick. Unit is poorly exposed. The section in the map area is not complete, but unit is estimated to be 1,000 ft (300 m) thick based on exposures in the west-adjacent Calico Creek 7.5′ quadrangle.

Ysn **Snowslip Formation of the Missoula Group (Mesoproterozoic)**—Interbedded dark green siltite to light green argillite couplets, purple fine-grained quartzite to silite couples, and distinctive rosy red siltite to argillite couplets. Beds of fine-grained feldspathic quartzite up to a few decimeters thick also occur. Desiccation cracks and mud rip-up clasts are abundant (mudcracked couple sediment type, table 1), and distinguish the Snowslip Formation from the overlying Shepard Formation and underlying Piegan Group. Bedding surfaces commonly contain bumps that resemble trace fossils, but were probably formed by microbial mats (Horodyski, 1982). The lower 500 ft (150 m) of the formation is characterized by dolomitic and non-dolomitic dark green siltite to light green microlaminae similar to those found in the Shepard Formation. Apparent thickness of about 3,300 ft (1,005 m).

Ypn **Piegan Group (Mesoproterozoic)**—Banded, wavy continuous to discontinuous dark gray to white, tan-weathering fine-grained quartzite with sharp, dark argillite caps, interlayered with dark gray, tan to orange-brown-weathering dolomitic intervals with pervasive molartooth structure (pinch-and-swell couple sediment type and tabular molartooth lithotype; table 1, fig. 2). Thicker sand beds, around 4–6 in thick (10–20 cm), commonly have internal flat to hummocky laminations (hummocky cross-stratified sediment type; table 1). Layering ranges from couplet to bed scale, with common scoured bases, sand-filled subaqueous shrinkage cracks ("crinkle cracks" of Winston and Smith, 2016), soft-sediment deformation, ripple cross lamination, and hummocky cross-stratification throughout. Dolomite and calcite cement commonly overprints and obscures primary sedimentary structures, often forming massive outcrops about 3 ft (1 m) thick, with pervasive molartooth structure (tabular molartooth lithotype; table 1). Hummocky cross-stratified sand and tabular molartooth (table 1) are generally more common in the poorly exposed lower part. Internal contact is placed below the lowest interval of pinch-and-swell couples, which are widespread throughout the upper part of the unit. Lower contact with the St. Regis Formation is gradational, placed just below the stratigraphically lowest float of the tabular molartooth lithotype. Upper contact is not exposed in the map area. Unit is apparently correlative with the cyclic and sandy members of the Wallace Formation of Grotzinger (1981) and the Helena and Wallace Formations of Winston (2007), which cannot be differentiated in the map area. Lower part appears to be mostly correlative with the lower Helena member of the Helena Formation of Winston (2007). Apparent thickness of about 6,500 ft (1,980 m) in the footwall of the Lynch Creek Thrust.

Ysr **St. Regis Formation of the Ravalli Group (Mesoproterozoic)**—Gray to green, tan-weathering, very fine-grained quartzite or siltite to argillite couples and couplets, and purple, mudcracked, even, very fine-grained quartzite or siltite to argillite couples and couplets (lenticular, even, and mudcracked couplet sediment types, table 1). Lenticular and even couples (table 1) range from about ¼–4 in (½–10 cm) thick. Lenticular couples range from indistinct, wavy, and continuous layers with subtle grading to distinct ripped layers of white, well-sorted fine-grained quartz sand with rare dolomitic cement. Rippled sand layers are recessive and tan-brown weathering, ranging from discontinuous layers of isolated crests to continuous beds of climbing symmetric ripple sets. Mudcracked couples (table 1) range from about ¼–1½ in (½–4 cm) thick, with common polygonal desiccation cracks and mud chips with up turned cusps. Isolated, aligned to intersecting spindle-shaped, sand-filled subaqueous shrinkage cracks ("crinkle cracks" of Winston and Smith, 2016) are common throughout. Lower part consists mostly of interbedded purple and green to gray mudcracked, even, and lenticular couples and couplets (type 1 cycle of Winston and Lyons, 1997). Upper part consists mostly of green to gray, tan-weathering lenticular couples and even continuous couples and couplets, sometimes with partly dolomitic cement and recessive weathering voids (type 2 cycle of Winston and Lyons, 1997). Internal contact placed below the stratigraphically lowest occurrence of molartooth structure. Upper contact is gradational, placed just below the lowest beds of either the molartooth lithotype (table 1) or red-weathering, dolomitic, fine- to medium-grained quartzite (hummocky cross-stratified sediment type, table 1). Unit is apparently correlative with the upper St. Regis of Hrabar (1971). The lower part is partly correlative to the St. Regis Formation of Mauk (1983), Grotzinger (1981), and Winston (2007, 2016); upper part is correlative to the green member of the Wallace Formation of Grotzinger (1981), and the Empire Formation of Winston (2007). Apparent thickness of about 3,400 ft (1,035 m).

Yr **Revett Formation of the Ravalli Group (Mesoproterozoic)**—Gray to blue-gray to white, tan-weathering, thick-bedded, very fine-grained quartzites with abundant asymmetric climbing ripples and uncommon crossbedding (flat-laminated sand sediment type; table 1), with interbedded thin to thick tabular siltites and very fine-grained quartzites with thin mud drapes (mudchipped sand, massive and graded silt sediment types; table 1) and purplish to greenish argillite composed of very fine sand or silt-to-clay couples with abundant desiccation cracks (mudcracked couples sediment type). Quartzite is generally defined by well cemented, very fine-grained and well-sorted quartz sand, commonly with flat laminations near the base and climbing ripple sets (asymmetric, straight crested, and lunate) near the top of beds. Diagenetic banding, thin mud drapes, and load structures are common. Rare crossbedding. Quartzite and siltite beds are tabular, ranging from about 4 in (10 cm) to 6 ft (2 m) thick. Internal contacts denote relatively muddier or sandier intervals, labeled on map. Upper contact is gradational, placed below the lowest lenticular couple interval, typically within green argillite (table 1, fig. 2). Lower contact not exposed. Thickness is about 5,500 ft (1,675 m).

Figure 2. Lower hemisphere stereographic projections and rose diagram showing measured fabrics related to ENE-directed horizontal shortening within the map area. Shading denotes Kamb contouring with 2σ-uncertainty envelopes of plotted poles to planes. For point data, calculated best-fit poles and great circles are shown in pink and labeled with plunge magnitude followed by trend azimuth. For plane data, mean planes are shown in black with labels showing dip direction (azimuth) followed by dip magnitude.(A) Poles to bedding planes, with calculated fold hinge labeled. Hollow dots indicate overturned bedding. Best-fit great circle approximates the profile plane of the inferred cylindrical folds, parallel to the shortening direction (~070°). (B) Rose diagram showing the strike of measured joint planes. Plotted using 30° bins. Arrow shows mean strike direction, with 2σ-uncertainty envelope shown in light gray. (C) Poles to pressure solution cleavage planes, with mean cleavage plane shown. (D) Restored poles to pressure solution cleavage planes plotted after rotating associated bedding to horizontal. Mean cleavage plane shown and labeled for each data population. Colors correspond to map unit.

No vertical exaggeration

Strike-slip fault motion—minus, away from observer; plus, towards observer

Geologic units on cross-section only:

Yb Burke Formation of the Ravalli Group

Table 1. Descriptions and interpreted depositional environment of litho- and sediment types referred to in the text. See Parker (2025), Winston (2007, 2016), and Winston and Link (1993) for more detailed descriptions of these general sediment types.

Sediment Type	Description	Interpretation
Hummocky cross-stratified	Tabular bedded coarse silt to medium sand with internal flat laminae and low-angle hummocky cross laminae. Low-relief, convex-up hummocks with rare low-angle truncations, overlying flat laminae with sharp bases. Defines laterally continuous, tabular beds, typically ranging from about 4–16 in (10–40 cm) thick. Commonly interbedded with pinch-and-swell couples.	Sand bed load was transported and deposited by storm waves along the lake bottom. Suspended load has been winnowed away by constant wave action and currents.
Pinch-and-swell couples	Wavy, discontinuous layers and lenses of fine sand, sharply overlain by clay. Layers are couplet, couple, and bed scale, with sharp contacts and abrupt grading. Bases commonly have rippled scour and sand-filled crinkle cracks (Winston and Smith, 2016) cutting down into the underlying mud. Sand is typically gray with a slight blue or purple hue. Mud is typically dark black, and is commonly dolomitic. Hummocks are common in the thicker sand lenses.	Sand bed load was transported and deposited on a sourced and/or loaded muddy perennial lake bottom by storm waves. Mud settled out of suspension after or during the waning storm, in a perennial lake.
Tabular molartooth	Beds and thick beds, about 20–80 in (½–2 m) thick, of internally massive, tan- to orange-weathering dolostone and/or gray limestone with pervasive molartooth structure. Includes banded dolostone to limestone couples and nodules of light gray limestone in tan to orange dolostone, with sparse molartooth structure. Primary sedimentary structures are obscured, often beyond recognition. Recessive, often found as blocky float.	Diagenetic overprint, where dolomitic or calcitic cement precipitated in saturated, shallowly buried mud beneath a contracting perennial lake. Molartooth structure likely formed very early, just beneath the surface, as biogenic gas escaped wet mud during compaction (Furnes and others, 1998). Calcite cement later replaced the fill of the molartooth structure.
Even couples	Even to wavy, continuous, graded, very fine sand/silt to clay couples and couplets with sharp, planar contacts. Wavy couples and couplets have parallel lower and upper contacts. Commonly purple or green and tan weathering.	Mud settled out from turbid water, below wave base or in still, protected water, after or during storms, in a perennial lake. Wavy layers were deformed during compaction of the wet sediment.
Lenticular couples	Fine sand/silt lenses, with sharp planar bases and ripple cross-laminae, capped by clay. Couple to couplet scale, with common crinkle cracks. Commonly green, tan weathering. Sandy, symmetrical ripple crests are often recessive weathering.	Sand bed load was transported, and deposited on a muddy perennial lake bottom (or flooded playa) by gentle storm or fair weather waves. Mud settled out from turbid water after storms or times of increased wave action.
Microcouplets	Even, continuous silt to clay microcouplets and couplets, less than about ¼ in (½ cm) thick. Sometimes layers are continuous but contorted. Desiccation cracks uncommon. Usually black, light purple, or green, sometimes tan-weathering. Recessive.	Mud settled out from slightly turbid water. Deposited either below wave base or in still, protected water. May have been deposited along a perennial lake bottom or where a distal sheetflood met a ponded playa.
Mudcracked couples	Even to wavy, continuous very fine sand/silt to clay couples and couplets with common desiccation cracks, asymmetric ripples, and mud chips. Commonly purple or green.	Coarse bed load was transported and deposited during a sheetflood. Mud settled out from turbid water during the waning flood or just after. Mud subsequently dried out and cracked. Deposited in a playa.
Massive and graded silt	Tabular, very fine sand/silt beds and couplets, about 2–8 in (5–20 cm) thick, with sharp bases, massive to flat-laminated interiors, uncommon graded muddy silt tops, and rare, very thin, mm-scale (<1/8 in) mud/clay drapes with desiccation or crinkle cracks and common load structures. Often drab gray color, with slight purple, blue, or green hue in muddy intervals.	Coarse bed load was transported and deposited during a sheetflood. Trace amounts of mud settled out from turbid water as the flood waned. Most mud bypassed deposition. Mud subsequently dried out and cracked. Deposited low on a gently sloping alluvial apron.
Mudchipped sand	Crudely bedded to massive, fine/very-fine sand beds, about 8–80 in (20 cm–1½ m) thick, with sharp bases and rare internal laminae, defined by slight grading with interstitial mud. Uncommon cross-laminae, asymmetric ripples, and mud chips. Rare, very thin mud drapes with desiccation cracks. Often has slight purple, blue, or green hue, indicating interstitial mud.	Coarse bed load was transported and deposited during a decelerating and shallowing sheetflood. Trace amounts of mud were deposited with the bedload, from the very turbid flood waters. Mud settled out from turbid water during the waning flood or just after. Mud subsequently dried out and cracked. Deposited on a gently sloping alluvial apron.
Flat-laminated sand	Tabular bedded fine/very fine sand beds with sharp bases, massive to flat-laminated lower parts, uncommon climbing-ripple upper parts, and rare mud drapes with desiccation cracks. Often white, tan, or drab gray color, with slight purple or blue hue in muddy intervals.	Coarse bed load was transported and deposited during a decelerating and shallowing sheetflood. Flat laminae deposited during faster flow; climbing ripples during slower flow. Most mud bypassed deposition. Deposited higher on a gently sloping alluvial apron.

Table 2. U-Pb zircon geochronology.

Sample	Sediment Type	Unit	Latitude (°N)	Longitude (°W)	# of Spot Analyses	Maximum Depositional Age (Ma)	2σ	MSWD
SP24LC03	Mudcracked couples	Ysn	47.6561	-114.9950	15/17	NA	—	—

Note. Low yield precludes interpretation of maximum depositional age and provenance. See Brennan and others (2026) for available data. Zircon separates were prepared at MBMG and analyzed by LA-ICP-MS at the University of California, Santa Barbara. Latitudes and longitudes are in the 1984 World Geodetic Survey (WGS84) datum.
*Numerator denotes the number of spot analyses with a concordance of >0.90; denominator denotes the total number of analyses in the sample.

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