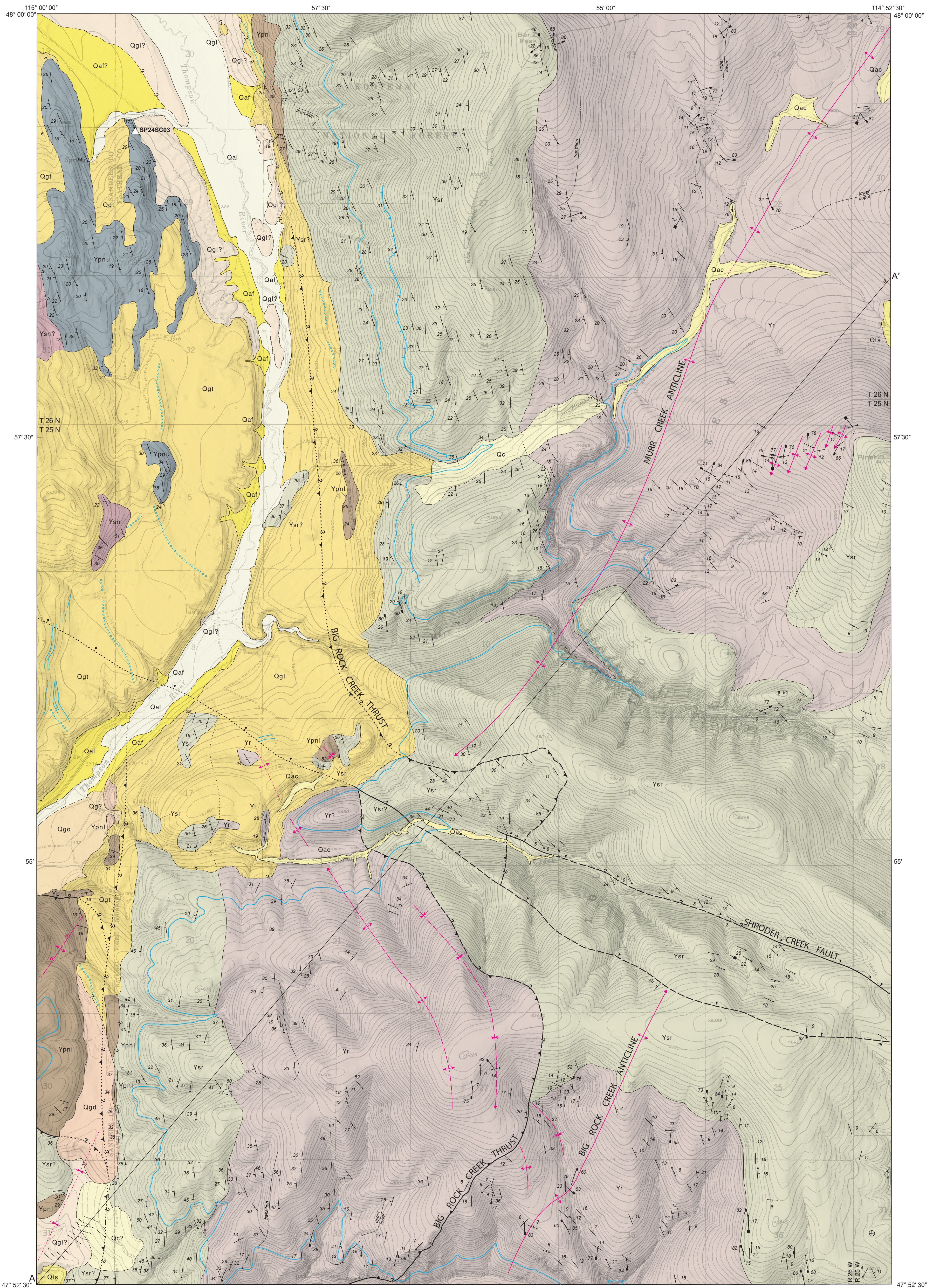

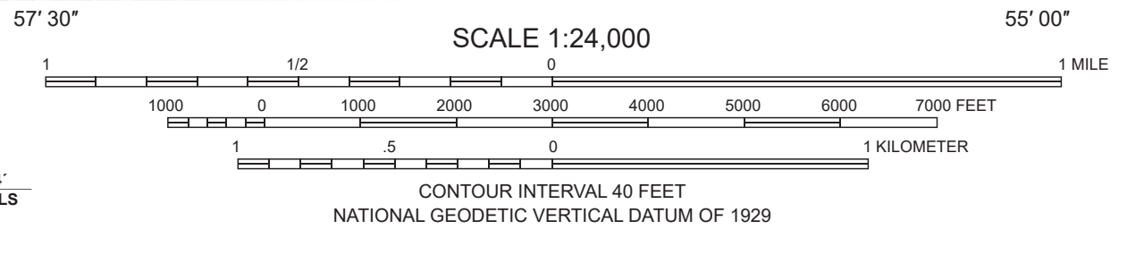
SCALE 1:24,000
1 1/2 0 1 MILE
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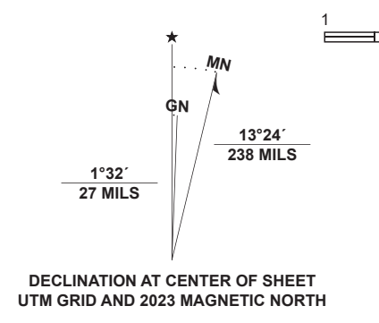
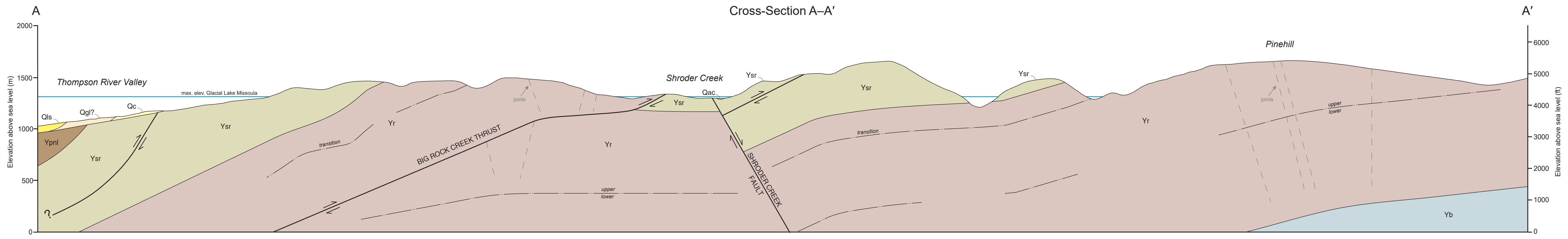
1 .5 0 1 KILOMETER
CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929


MN
GN
1°32′
27 MILS
13°24′
238 MILS
DECLINATION AT CENTER OF SHEET
UTM GRID AND 2023 MAGNETIC NORTH

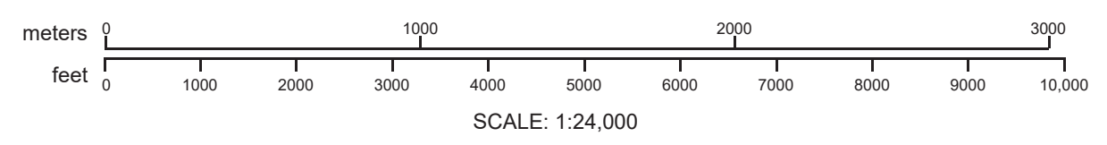
Base map produced by the United States Geological Survey
Shroder Creek 1:24,000-scale quadrangle map
Control by: USGS and USC&GS
Compiled from aerial photographs taken in 1963.
Field checked 1964.
Projection: polyconic
Grid:1000 meter Universal Transverse Mercator Zone 11
Vertical Datum: National Geodetic Vertical Datum of 1929
Horizontal Datum: 1927 North American Datum
Shaded relief created from lidar hillshade of digital elevation model (DEM). Lidar data for Flathead and Sanders Counties made available by the Montana State Library.

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

Cross-Section A–A′



No vertical exaggeration



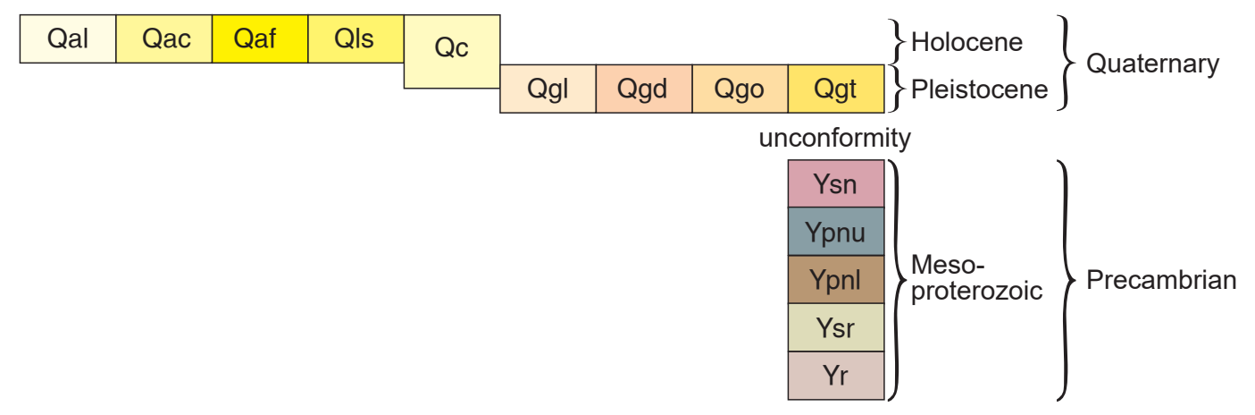
▨ Yb Burke Formation (cross-section only)

upper/lower Internal contact between informal upper and lower parts of Revett Formation (see unit description)

Schematic joint sets

Research supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award G24AC00336-00.
GIS production: Stuart D. Parker, Patricia E. Gallagher, and Yiwen Li, MBMG. Map layout: Susan Smith, MBMG. Editing: Susan Barth, MBMG.

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	——•—— ——•——?	— •— — •?—	····•···· ····•···?
Thrust fault—Sawteeth on hanging wall	——▼——	— ▼— — ▼?—	····▼····

Structure lines

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

	Accurate	Approximate	Concealed
Anticline	——↕——	— ↕ —	····↕····
Syncline	——✕——	— ✕ —	····✕····

Limit of glacial advance—Hachures on side of advancing ice

Crest line of moraine

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

Flood megaripple crest

⊕ Horizontal bedding

Inclined bedding—Showing strike and dip

Inclined bedding, where top direction of beds is known from local features—Showing strike and dip

Inclined cleavage—Showing strike and dip

Small, minor inclined joint—Showing strike and dip

Small, minor vertical joint—Showing strike

Small, minor inclined joint, for multiple observations at one locality—Showing strike and dip

Small, minor vertical joint, for multiple observations at one locality—Showing strike

△ Sample: U-Pb geochronology (table 2, fig.5)

INTRODUCTION

The Shroder Creek 7.5′ quadrangle is in the Salish Mountains, about 30 mi southwest of Kalispell (fig. 1). Within the quadrangle, a prominent rangefront bounds the east side of the Thompson River valley. The dip slope of the rangefront and deep canyons of Shroder and Murr Creeks expose much of the Ravalli Group of the Belt Supergroup. Pinehill is the highest point in the quadrangle, at 6,410 ft (1,954 m). Glacial and fluvial deposits fill the valley and cover much of the low hills to the west. Shorelines, lake deposits, delta deposits, and flood megaripples suggest that Glacial Lake Missoula inundated much of the Thompson River valley and the surrounding canyons, where elevations are as low as 3,250 ft (990 m).

PREVIOUS MAPPING AND METHODS

The quaternary geology of the quadrangle was mapped by Alden (1953, 1:500,000 scale), who placed the southernmost extent of the Cordilleran ice sheet near Bend (fig. 1). Early bedrock geologic maps of the quadrangle were completed as part of a geologic study and mineral assessment of Lincoln and Flathead Counties (Johns and others, 1963; Johns, 1970, 1:126,720 scale). Harrison and others (1986, 1:250,000 scale) later subdivided mapped rocks of the Belt Supergroup into formations, using a combination of stratigraphic names from the western and eastern edges of the basin.

Digital elevation models (DEMs) derived from recently availably 1-m resolution light detection and ranging (lidar) data of Sanders and Flathead Counties were used to help identify and map surficial deposits, faults, and glaciolacustrine landforms. 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). Available well logs from the Ground Water Information Center (https://mbmggwic.mtech.edu/) were used to constrain the thicknesses of surficial deposits and interpret their relative age relations.

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).

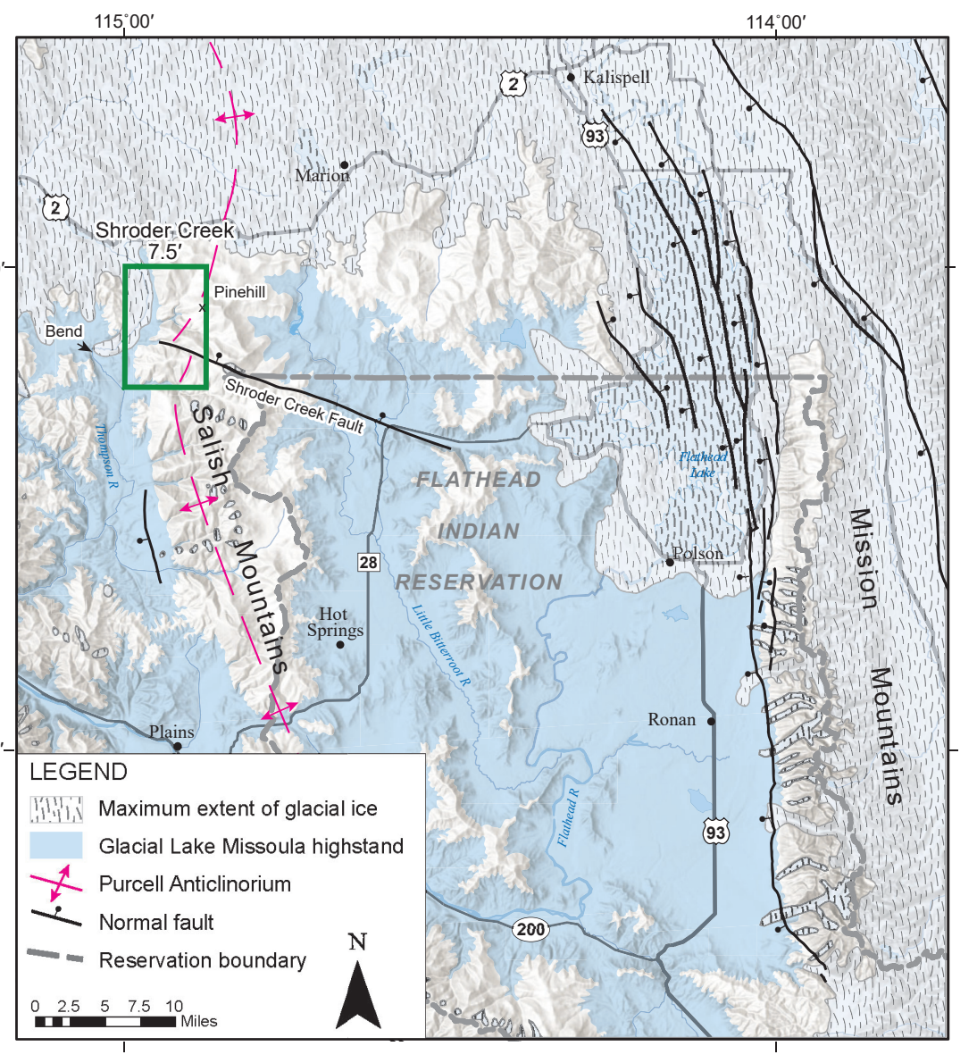


Figure 1. Overview map of Schroder Creek 7.5′ quadrangle (green box) and surrounding area. Active faults and questionable faults mentioned in the text are shown. Maximum extent of glacial ice and highstand of Glacial Lake Missoula modified from Smith and others (2021).

GEOLOGIC SUMMARY

Around 12,000 ft (3.6 km) of slightly metamorphosed siliciclastic and carbonate rocks belonging to the Belt Supergroup are exposed in the quadrangle. The exposed section reveals portions of the Ravalli, Piegan, and Missoula Groups. Available radiometric age constraints suggest this section was deposited between about 1,470 and 1,430 Ma (Brennan and others, 2026; Hirtz and others, 2024). The Revett Formation is characterized by event beds of the flat-laminated sand, massive and graded silt, and mudcracked couple sediment types (table 1). These rocks were deposited by sheetfloods, which flowed down a gentle, sandy alluvial slope into a flat, muddy playa (Winston, 2016). The St. Regis Formation contains interbedded mudcracked, lenticular, and even couples (table 1). A general upsection trend in sediment types suggests flooding of the basin, and a gradual transition from an intermittently dry playa to a shallow perennial lake (Winston and Lyons, 1997). The Piegan Group is dominated by even and pinch-and-swell couples (table 1), deposited along the lake bottom during storm events (Winston, 2007). Carbonate cement and molartooth structure obscure primary sedimentary structures, resulting in the tabular molartooth lithotype that characterizes the Piegan Group (fig. 2). Enigmatic molartooth structure (Bauerman, 1885) may have formed as biogenic gas escaped during dewatering of shallowly buried lake muds (Furniss and others, 1998). Overall, the Ravalli to the Piegan Group represents progressive flooding of the basin. The overlying Missoula Group represents a return to a sheetflood-dominated playa, as the lake dried up (Winston and Link, 1993).

The Lewis thrust (e.g., Sears and Hendrix, 2004; Fuentes and others, 2012) exhumed the Belt rocks during the Cretaceous to early Eocene Cordilleran Orogeny. The Purcell Anticlinorium (fig. 1), in the hanging wall of the Lewis thrust, overlies the footwall ramp that exhumed the Lewis thrust plate as it was translated up and out of the Belt Basin (e.g., Sears, 1988, 2001). In the quadrangle, the hinge of the regional-scale Purcell Anticlinorium coincides with the Murr Peak and Big Rock Creek anticlines. Sub-vertical, north–south-trending joints (fig. 3) accommodated local tension in the upper part of the hinge, during folding of the anticlinorium. A small thrust fault, herein named the Big Rock Creek thrust, shortened the west-dipping limb of the anticlinorium by at least about 12,000 ft (~3.6 km). Structurally incompetent carbonates near the base of the Piegan Group may have formed a local detachment horizon.

Folds and thrusts are cut by the Shroder Creek fault. Pervasive fractures, cataclasite, reddish iron staining, and basement lineaments that trend approximately 125° provide additional evidence of faulting. Johns and others (1963) originally mapped the Shroder Creek fault as a right-lateral strike-slip fault. Harrison and others (1986) extended the trace of the Shroder Creek fault and renamed it the Big Draw fault. Based on this mapping, about 1,500 ft (455 m) of normal throw on the Shroder Creek fault is required to restore the Murr Creek/Big Creek anticline, and the Big Rock Creek Thrust. Parallel normal faults have been mapped to the east (Scarberry, 2023; Parker, 2025), near the late Eocene–Oligocene Hog Heaven volcanic field. Johns and others (1963) also proposed a range-bounding normal fault, the Thompson Lakes fault, on the east side of the valley. No direct evidence of the Thompson Lakes fault was found along the rangefront, and the prominent rangefront is likely defined by the dip slope of the more resistant upper Ravalli Group against the recessive lower Piegan Group (fig. 2) that occurs throughout the valley. The hypothesized Thompson Lakes fault cannot be entirely ruled out due to uncertainties regarding the true thickness of the Piegan Group.

Glacial, fluvial, and lacustrine deposits have filled the Thompson River valley since the Pleistocene. Glacial till deposits drape the topography, occurring up to 4,400 ft (1,340 m) elevation. The terminal moraine mapped near the southwestern corner of the map marks the maximum southern extent of the Cordilleran ice sheet in this area. Here, at the ice terminus, a small delta prograded into Glacial Lake Missoula. In the Thompson River valley, the extent of the ice sheet continued about ½ mi (1 km) west of the map border, about 1½ mi (2.5 km) upstream of Bend (fig. 1). Mapped shorelines, lateral and terminal moraines, possible flood megaripples, widespread interbedded glacial outwash, till, and rhythmically bedded lake sediments suggest that the Thompson River valley experienced episodic flooding of Glacial Lake Missoula, as the terminus of the Cordilleran ice sheet advanced and retreated from about 14 to 20 ka years ago (Denlinger and others, 2021; Smith and others, 2018). Since the Pleistocene, about 120 ft (35 m) of incision has occurred along the Thompson River, coeval with widespread bedrock incision and drainage reorganization in the surrounding drainages.

DESCRIPTION OF MAP UNITS

Qal **Alluvium (Holocene)**—Unconsolidated, moderately sorted deposits of stream gravel and clay. Channel deposits include rounded clasts, up to cobble- or small boulder-sized. Unit is inset in older Pleistocene glaciofluvial deposits and bedrock along the Thompson River. Maximum thickness of 75 ft (22 m) in well logs near the northern map border.

Qac **Alluvium and colluvium (Holocene)**—Unconsolidated, poorly to moderately sorted deposits of angular to subrounded cobbles and pebbles in a tan to pink matrix of reworked non-calcareous loess. Deposited in flat drainage bottoms by sheetwash and hillslope processes from adjacent hillsides. Includes unconsolidated paludal deposits of silt, organic material, and minor clay deposited in marshes and fine-grained alluvial deposits of moderately sorted sand to clay deposited in streams. Thickness may be as much as 50 ft (15 m).

Qaf **Alluvial fan deposit (Holocene)**—Unconsolidated, poorly sorted deposits of subrounded boulders, cobbles, and pebbles, with a dominantly silt matrix. Form small alluvial fans and colluvial aprons of reworked glacial, fluvial, and lacustrine sediments. Fine-grained fans, sourced from reworked lacustrine deposits, consist of silt with some pebbles and sand. Thickness may be as much as 65 ft (20 m).

Qls **Landslide deposit (Holocene?)**—Unconsolidated, poorly sorted mass-wasting deposits, including outsized boulders and cobbles in a massive silty matrix. Maximum thickness is about 130 ft (40 m).

Qc **Colluvium (Holocene to Pleistocene?)**—Unconsolidated, poorly sorted deposits of angular pebbles, cobbles, and boulders supported by a white to tan matrix of reworked non-calcareous loess. Deposited in the nearly flat drainage bottom of the North Fork of Murr Creek by sheetwash and hillslope processes from adjacent hillsides. In the southwestern part of the map, the deposit contains megaripples from Glacial Lake Missoula floods, suggesting a Pleistocene age. Thickness may be as much as 50 ft (15 m).

Qgl **Glacial lake deposit (Pleistocene)**—Loosely consolidated, white to tan well-sorted clay to fine sand deposits. Deposits range from massive and clay rich, to rhythmically bedded with millimeter- to centimeter-scale grading from brown, very fine sand to tan clay. Interlayered with and likely concealed by glacial till and other glaciofluvial sediments. Sometimes contains scattered pebbles and outsized boulders. Commonly contains minor soft sediment deformation, including load structures and centimeter-scale normal faults. Rhythmically bedded sediments were likely deposited within Glacial Lake Missoula, while massive sediments may have been deposited within isolated kettle ponds. Thickness may be as much as 270 ft (82 m), based on a well log near the northern map border.

Qgd **Glacial deltaic deposit (Pleistocene)**—Unconsolidated to loosely consolidated, poorly sorted, subangular to round pebble to cobble gravel and sand. Limited diversity of clast lithologies suggests a semi-local source. Widespread silt suggests interbedded lake deposits. Near the mouth of Shroder Creek, the unit contains a thick deposit of well-sorted, very fine sand with faint inclined laminations that may be foresets. Coarser deposits near the southwestern corner of the map define a landform that resembles a gilbert-type delta, with a flat surface at about 3,940 ft (1,200 m) elevation and a steep face at the toe. Rests on glacial lake deposits and local bedrock. Maximum thickness is about 165 ft (50 m).

Qgo **Glacial outwash deposit (Pleistocene)**—Unconsolidated to loosely consolidated, moderately to well-sorted pebble to cobble gravel. Gravel is clast supported with crude bedding, sometimes with a sparse silt matrix. Clasts are subround to rounded, pebble to cobble and smaller. Forms fluvial terraces at about 3,340–3,380 ft (1,020–1,030 m) elevation near the bend in the Thompson River. Inset in glacial till. Thickness may be as much as 300 ft (90 m).

Qgt **Glacial till (Pleistocene)**—Unconsolidated to loosely consolidated, poorly sorted, diamict with boulder-sized and smaller clasts supported in a massive silty matrix. Clasts are typically subrounded to subangular, mostly pebble to cobble sized. Erratics are common. Contains interlayered rhythmically bedded lake sediments and alluvial deposits with crudely bedded pebble to cobble gravel and a sparse, silty-sand matrix. Apparent thickness of at least 325 ft (100 m), based on contact and surface elevations, but may be as thick as 525 ft (160 m), constrained by a well log near the northern map border.

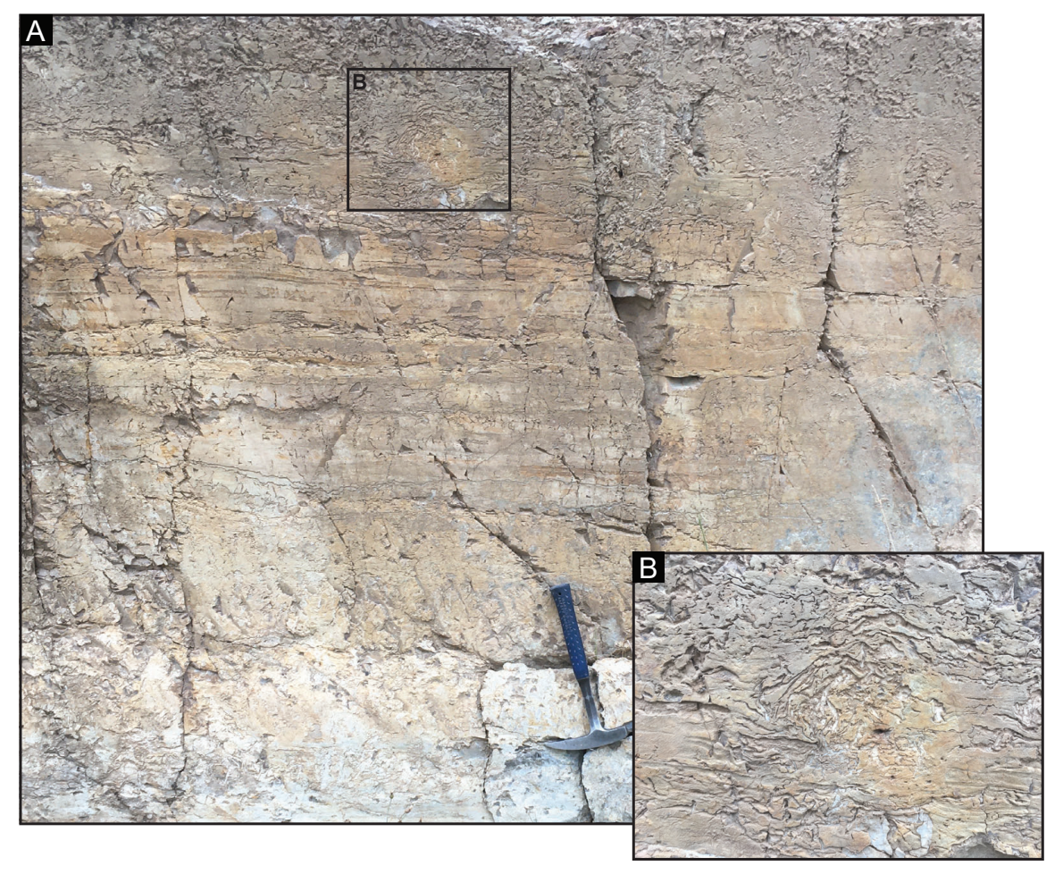
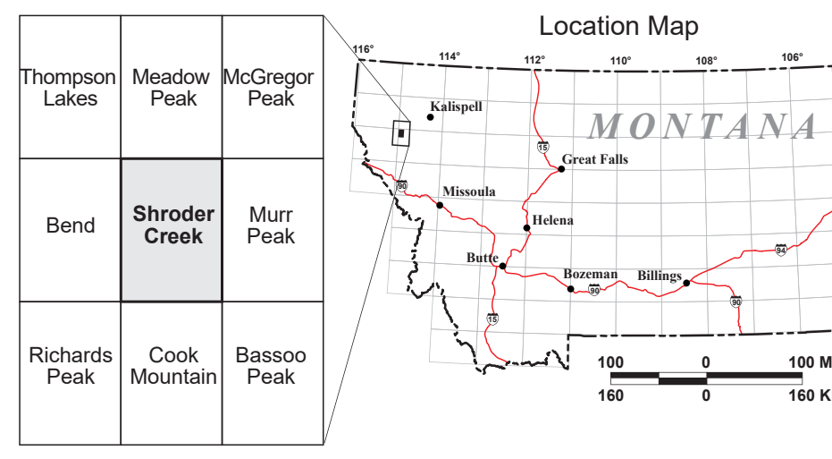


Figure 2. Outcrop photos of the lower Piegan Group (Helena Formation equivalent), showing the tabular molartooth lithotype. (A) Typical blocky, tan-weathering outcrop of the tabular molartooth lithotype. Note the green color of the unweathered portions. Continuous, even to wavy couples of the even couple sediment type can be seen in the middle part of the outcrop. Upper part of the bed shows where pervasive molartooth structure has obscured the primary sedimentary structures. (B) Inset shows detail of molartooth structure, which is filled with recessive, white sparry calcite.



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 are bound by gradational contacts and 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 couples. Layers greater than 4 in (10 cm) thick are termed beds; greater than about 1 ft (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.

Ysn **Snowslip Formation of the Missoula Group (Mesoproterozoic)**—Green and purple argillite consisting of even and cracked silt to clay couples (table 1). Desiccation cracks and ripples are common. Uncommon dolomitic intervals with molartooth structure occur near the basal contact. Poorly exposed. Gradational lower contact placed below the stratigraphically lowest mudcracked couple (table 1). Upper contact is not exposed. At least 1,250 ft (380 m) thick.

Ypnu **Piegan Group, upper (Mesoproterozoic)**—Banded, gray to white, fine-grained quartzite with dark argillite caps, interlayered with tan- to orange-brown-weathering dolomitic intervals with pervasive molartooth structure. Pinch-and-swell couple sediment type and tabular molartooth lithotype are most common (table 1, fig. 4). Pinch-and-swell couples have sharp basal contacts with wavy, continuous to discontinuous, fine sand layers that grade up to dark mud. Couples are most commonly around 2 in (5 cm) thick, but graded layering ranges from couplet to bed scale. Scoured bases, soft-sediment deformation, ripple cross-lamination, hummocky cross-stratification, and sand-filled subaqueous shrinkage cracks (“crinkle cracks” of Winston and Smith, 2016) are common. Gutters filled with mud chips are rare. Dolomite cement commonly overprints primary depositional features, often forming massive intervals about 1 m (3 ft) thick, with pervasive molartooth structure (tabular molartooth lithotype, table 1, fig. 2). Carbonate forms rare intervals of gray recessive nodules. Interbedded even couples and lenticular couples are uncommon in the upper part, and rare in the lower part. Correlative with the “sandy member of the Wallace Fm.” of Grotzinger (1981), and the “middle Helena member,”, “upper Helena member,” and “Wallace Fm.” of Winston (2007). Lower gradational contact is concealed, defined by stratigraphically lowest pinch-and-swell couple. Upper gradational contact placed below the lowest cracked couple/t of the Snowslip Formation. About 2,600 ft (790 m) thick.

Ypnl **Piegan Group, lower (Mesoproterozoic)**—Dark gray to greenish gray, tan- to pink-weathering, thick-bedded dolostone with pervasive molartooth structure, and even silt to clay couples and couplets (table 1, fig. 4). Tabular molartooth lithotype is common (table 1, fig. 2), with bedding about 3 ft (1 m) thick, and a general lack of recognizable depositional layering. Poorly exposed but easily recognized by orange- to red-weathering, chippy float containing molartooth structure. Even couple sediment type is uncommon (table 1, fig. 4). Couplets are continuous, ranging from even parallel to wavy, sometimes with dolomitic mud tops. Rarely contains limestone beds, about 8 in (20 cm) thick, with elongate nodules of dolostone. Lower contact with the St. Regis Formation is gradational, placed just below the stratigraphically lowest float of the tabular molartooth lithotype. Gradational upper contact is concealed, defined by the stratigraphically lowest pinch-and-swell couple. Correlative with the “cyclic member of the Wallace Fm.” of Grotzinger (1981), and the “lower Helena member” of Winston (2007). Thickness is poorly constrained in the map area, but is likely about 800–1500 ft (240–460 m) thick, based on nearby measured sections (Grotzinger, 1981; Winston, 2007).

Ysr **St. Regis Formation of the Ravalli Group (Mesoproterozoic)**—Gray to green, tan-weathering, lenticular and even, fine or very fine sand to clay couples and couplets, and gray to purple, dark gray weathering mudcracked very fine sand to clay couplets and couples (table 1, fig. 4). Lenticular and even couples range from about ¼ to 4 in (½ to 10 cm) thick. Lenticular couples range from indistinct, wavy, and continuous layers with subtle grading to distinct rippled layers of white, well-sorted fine 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 couplets range from about ¼ to 1½ in (½ to 4 cm) thick, with common polygonal desiccation cracks and mud chips with upturned 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 mudcracked and green lenticular couples and couplets (type 1 cycle of Winston and Lyons, 1997). Middle part consists mostly of green to gray, tan-weathering lenticular couples and even continuous couples and couplets, sometimes with partly dolomitic cement (type 2 cycle of Winston and Lyons, 1997). Upper gradational contact with Piegan Group contains common molartooth structure and small-scale couplets and rare microcouplets (type 3 cycle of Winston and Lyons, 1997). Gradational upper contact placed above the stratigraphically highest microcouplet section or just below float of the molartooth lithotype. Internal contact is placed at the base of the gradational upper transition zone, below the stratigraphically lowest molartooth structure. Lower contact is gradational, placed below the lowest lenticular couple interval. The green and purple lower part was correlated to the upper St. Regis Formation by Winston and Lyons (1997). The green and tan middle and upper part was correlated to the Empire and Helena Formations by Winston and Lyons (1997) and the “green member of the Wallace Formation” by Grotzinger (1981). About 2,400 ft (730 m) thick, near the northern map border.

Yr **Revett Formation of the Ravalli Group (Mesoproterozoic)**—Blue-gray to white, rusty- to tan-weathering very fine sericitic quartzite and siltite (flat-laminated sand and massive silt sediment types, table 1, fig. 4) and interbedded gray-blue to gray-purple, dark gray-weathering mudcracked, very fine sand or silt to clay couples and couplets (table 1). Quartzite and siltite beds are tabular, ranging from about 4 in (10 cm) to 6 ft (2 m) thick. Characteristic blue-gray to white, tan-weathering, thick quartzite beds have well-rounded, well-sorted fine quartz sand, commonly with flat laminations near the base and climbing ripple sets (straight crested and lunate) near the top of beds. Diagenetic banding, thin mud drapes, and load structures are common. Couplets are often even and continuous, with desiccation cracks and mud chips. Wavy and continuous couplets matching descriptions of muddy antidunes described by Winston and Smith (2016) are rare, typically occurring near the gradational upper contact. Where possible, the formation is divided by an internal contact into informal upper and lower parts on the map. The upper part contains bed sets around 30 ft (10 m) thick that alternate between flat-laminated sand or massive silt and mudcracked couplet or graded silt sediment types (table 1). In the poorly exposed lower part, 1- to 3-ft thick (1/3–1 m) quartzite beds are often poorly cemented, with a grainy texture. The upper part corresponds with the informal upper and middle Revett of Ryan and Buckley (1993), the lower part with the informal lower Revett. Upper contact is gradational, placed below the lowest lenticular couple interval. Upper internal contact is placed at the base of the gradational upper transition zone, approximately above the highest thick (>3 ft; 1 m), fine-grained quartzite bed and below the lowest thick (>30 ft; 10 m) set of mudcracked couplets. Lower contact is not exposed. About 4,750 ft (1,450 m) thick in the northern part of the map.

ACKNOWLEDGMENTS

Lab assistance was provided by Andrew Kylander-Clark, Ray Salazar, Henry Stahl, Dan Brennan, Connie Thomson, and Amanda Willingham. Thoughtful reviews by Katie McDonald, Skyler Mavor, and Jesse Mosolf and discussions with Larry Smith helped clarify and improve this report.

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

Sediment Type	Description	Interpretation
Pinch-and-swell couples	Wavy, discontinuous layers and lenses of fine sand to clay. Layers are couplet, couple, and bed scale, with sharp contacts. Bases commonly have irregular 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 uncommonly dolomitic. Hummocks are common in the thicker sand lenses.	Sand bed load is transported, and deposited on a scoured and/or loaded muddy perennial lake bottom by storm waves. Mud settles out of suspension after or during the waning storm, in a perennial lake.
Tabular molartooth	Beds and thick beds, about ½–2 m thick, of tan to brown weathering massive dolostone with pervasive molartooth structure (fig. 2). Recessive, often found as blocky float.	Diagenetic overprint, where dolomitic or calcitic cement precipitates in saturated, shallowly buried mud. Molartooth structure may form very early, just beneath the surface, as biogenic gas escaped wet mud during compaction (Furniss and others, 1998). Calcite cement later replaces the fill of the molartooth structure.
Even couples	Even to wavy, continuous very fine sand/silt to clay couples and couplets with sharp, planar contacts. Commonly purple or green and tan weathering.	Mud settles out from turbid water, below wave base or in still, protected water, after or during storms, in a perennial lake.
Microcouplets	Even, continuous silt to clay microcouplets and couplets, less than about 1/2 cm thick. Sometimes layers are continuous but contorted. Mudcracks uncommon. Usually black, light purple, or green, sometimes tan weathering. Recessive.	Mud settles out from slightly turbid water. Deposited either below wave base or in still, protected water. May be deposited along a perennial lake bottom or where a distal sheetflood meets a ponded playa.
Lenticular couples	Couple or couplets. Sharp planar bases with oscillation-rippled, fine sand/silt lenses capped by clay with common crinkle cracks. Commonly green, tan weathering. Sandy ripple crests are often recessive weathering.	Sand bed load is transported, and deposited on a muddy perennial lake bottom by gentle storm or fair weather waves. Mud settles out from turbid water after or during storm or increased wave action in a perennial lake or flooded playa.
Mudcracked couples	Even to wavy, continuous very fine sand/silt to clay couples and couplets with common desiccation cracks and mud chips. Commonly purple or green.	Coarse bed load is transported and deposited during sheetflood. Mud settles out from turbid water during the waning flood waters. Mud subsequently dries out and cracks. Deposited in a playa.
Massive and graded silt	Tabular very fine sand/silt beds and couples, with sharp bases, massive to flat-laminated interiors, uncommon graded muddy silt tops, and rare, very thin (mm-scale) 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 is transported and deposited during sheetflood. Trace amounts of mud settles out from turbid water as the flood passes. Most mud bypasses deposition. Mud subsequently dries out and cracks. Deposited low 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 is transported and deposited during a decelerating and shallowing sheetflood. Trace amounts of mud settles out from turbid water as the flood passes. Most mud bypasses deposition. Mud subsequently dries out and cracks. Deposited on a gently sloping alluvial apron.

Table 2. U-Pb zircon geochronology.

Sample	Sediment Type	Unit	Latitude (°N)	Longitude (°W)	# of Spot Analyses^a	Maximum Depositional Age (Ma)	2σ	MSWD
SP24SC03	Pinch-and-swell couples	Ypnu	47.9878	-114.9875	34/36	NA	—	—

Note. Low yield precludes interpretation of maximum depositional age. 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.
^{a}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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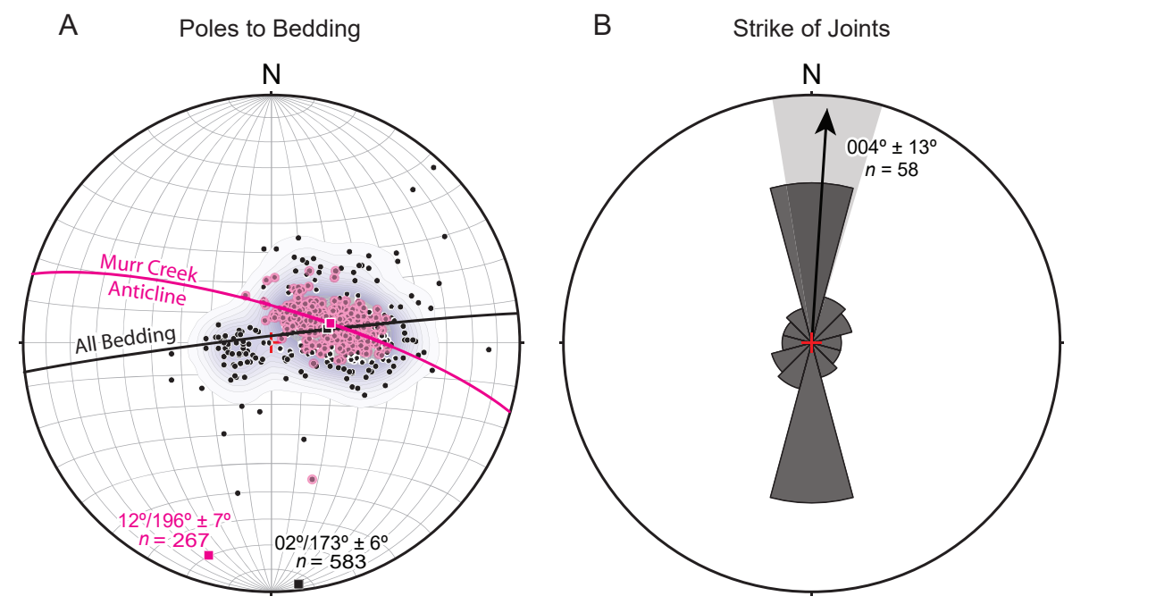

Figure 3. Lower hemisphere stereographic projection and rose diagram showing measured bedding planes and joints within the map area. Shading denotes Kamb contouring with 2σ-uncertainty envelopes. (A) Poles to bedding with calculated best fit girdle, mean pole, and fold hinge and uncertainty labeled. Pink annotations show statistics from the subset of highlighted measurements taken near the Murr Creek Anticline. (B) Rose diagram showing strike of high-angle joints. Arrow shows mean vector and 2σ-uncertainty envelope. Data are treated as axes, with 30° bins.

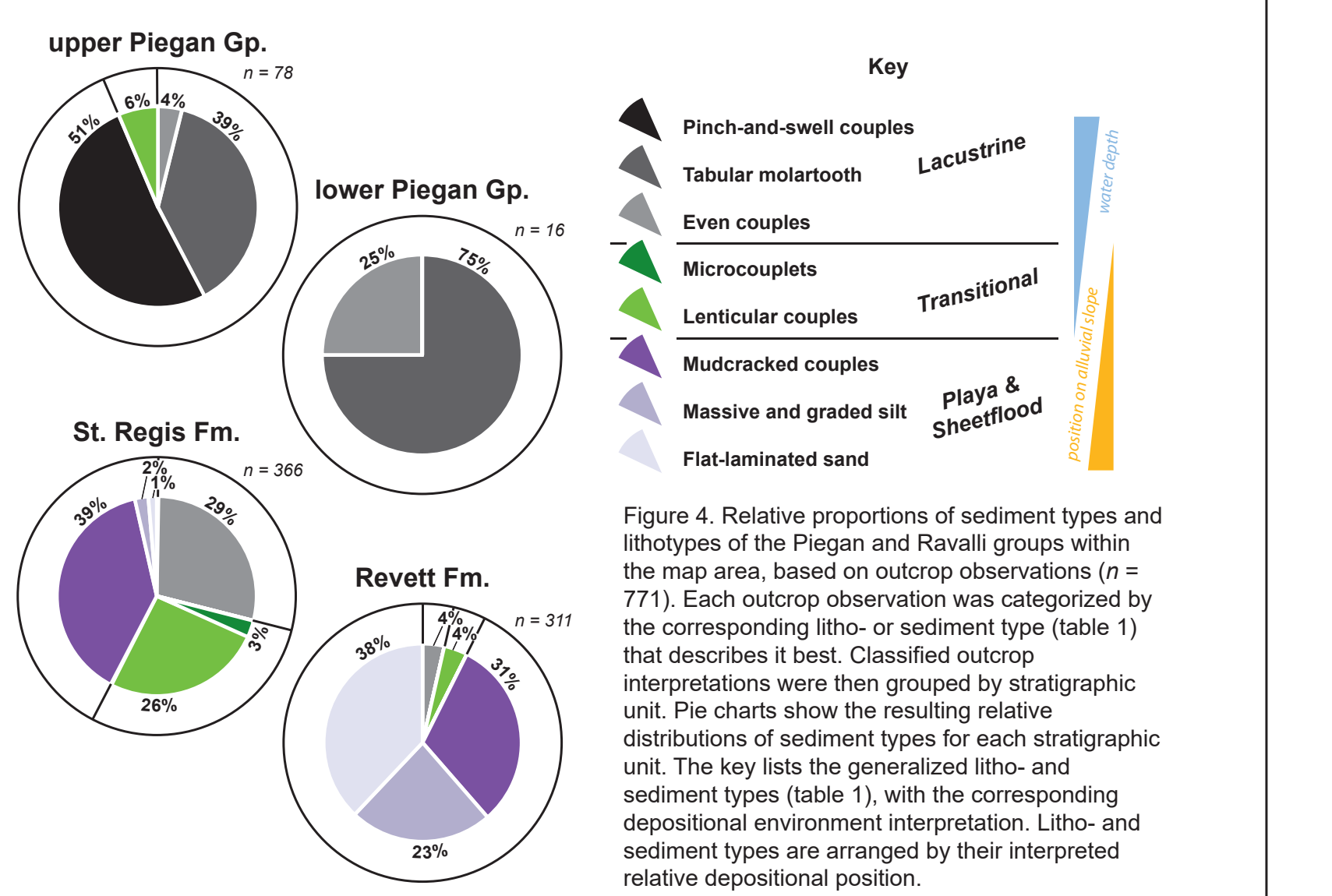

Figure 4. Relative proportions of sediment types and lithotypes of the Piegan and Ravalli groups within the map area, based on outcrop observations (n = 771). Each outcrop observation was categorized by the corresponding litho- or sediment type (table 1) that describes it best. Classified outcrop interpretations were then grouped by stratigraphic unit. Pie charts show the resulting relative distributions of sediment types for each stratigraphic unit. The key lists the generalized litho- and sediment types (table 1), with the corresponding depositional environment interpretation. Litho- and sediment types are arranged by their interpreted relative depositional position.

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Geologic Map 113

Geologic Map of the Shroder Creek 7.5′ Quadrangle, Flathead and Sanders Counties, Montana

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2026

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