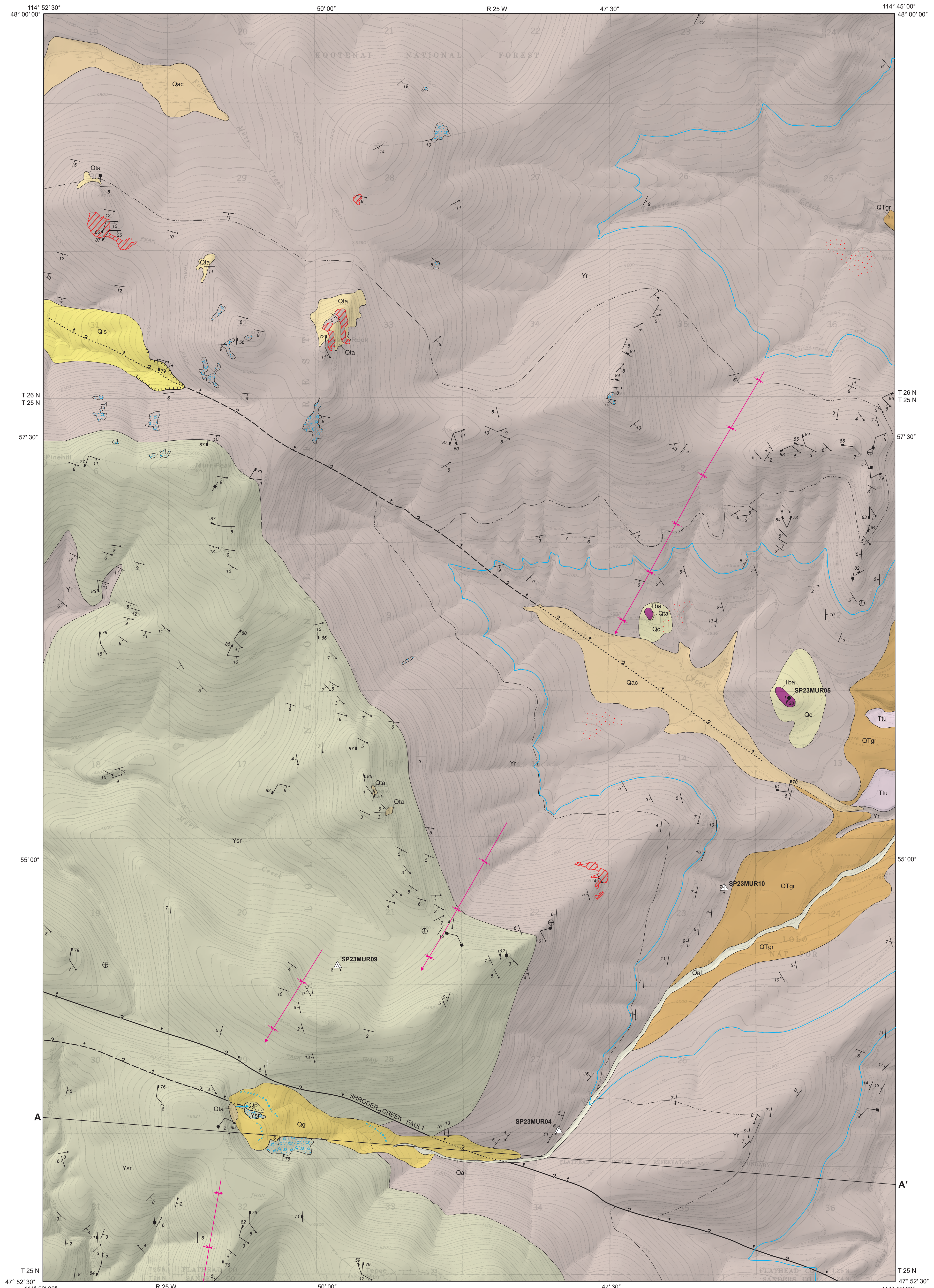


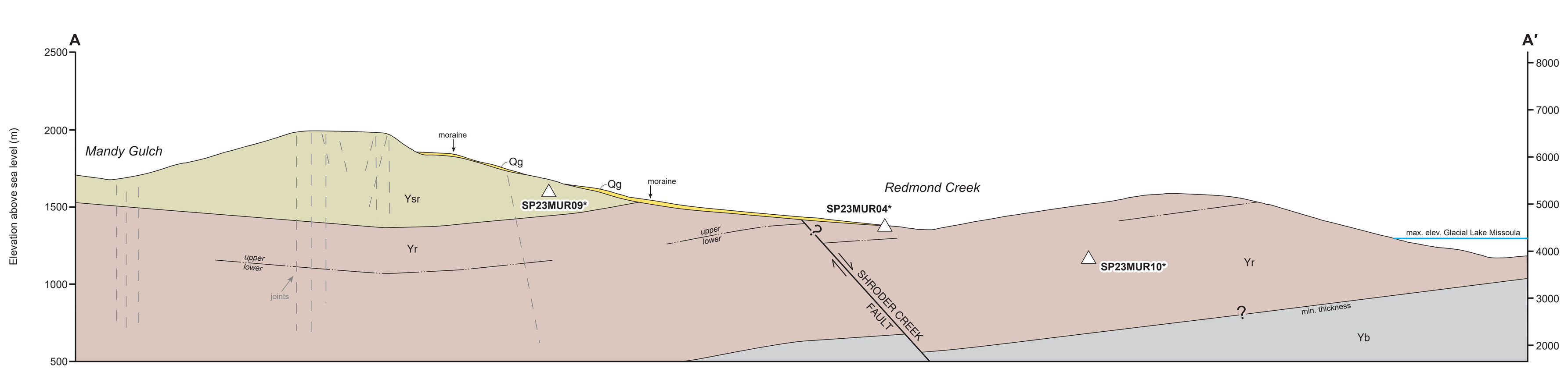
Base map produced by the United States Geological Survey
Murr Peak 1:24,000-scale quadrangle map
Control by: USGS and USC&GS
Compiled from aerial photographs taken in 1964
Field checked 1964
Projection: polyconic
Grid:1000 meter Universal Transverse Mercator Zone 11
Vertical Datum: National Geodetic Vertical Datum of 1929
Horizontal Datum: 1927 North American Datum
Shaded relief created from 10 meter digital elevation model from U.S. Geological Survey National Elevation Dataset

UTM GRID AND 2019 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
http://mbmg.mtech.edu



No vertical exaggeration

Yb Burke Formation (cross-section only)

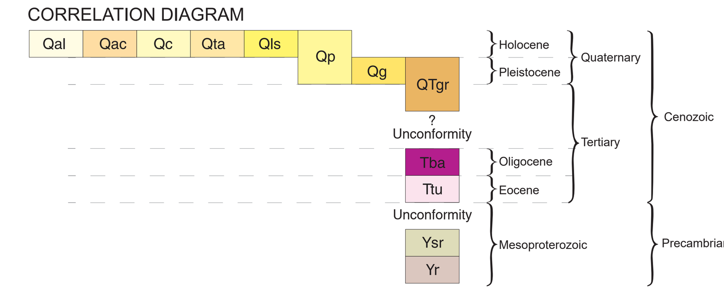
Internal contact between informal upper and lower parts of Revett Formation (see unit description)

Schematic joint sets

SCALE 1:24,000

*Approximate stratigraphic position of sample, based on projection onto the cross-section

CORRELATION DIAGRAM



MAP SYMBOLS

Contacts and Faults (? = Identity or existence questionable; Accurate, Approximate, Concealed, Internal)

Contact

Normal fault—Ball and bar on downthrown block

Structure Lines

Syncline: showing trace of axial plane and plunge direction where known

Geologic Lines

Main scarp of landslide; hachures point down scarp

Crest line of moraine

Maximum Glacial Lake Missoula extent

Orientation Points

Glacial striation or groove—Showing general bearing and direction of flow

Horizontal bedding

Inclined bedding—Showing strike and dip

Inclined 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 vertical joint—Showing strike

Inclined layering igneous rock—Showing strike and dip

Multiple Observations at One Locality

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 and dip

Inclined bedding, for multiple observations at one locality—Showing strike and dip

Inclined bedding, where top direction of beds is known from local features, for multiple observations at one locality—Showing strike and dip

Sample Points

U-Pb geochronology (table 2, fig. 4)

Whole rock geochemistry

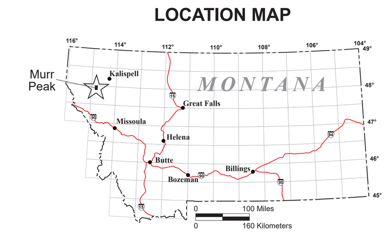
Overlay Polygons

Felsenmeer—Unconsolidated blockfields of moderately sorted angular boulders on flat or gentle slopes

Ferricrete—Thin lag deposit of iron oxide-cemented colluvial breccia

Quarry—Extensive amount of mapped geologic unit has been removed or exposed

LOCATION MAP



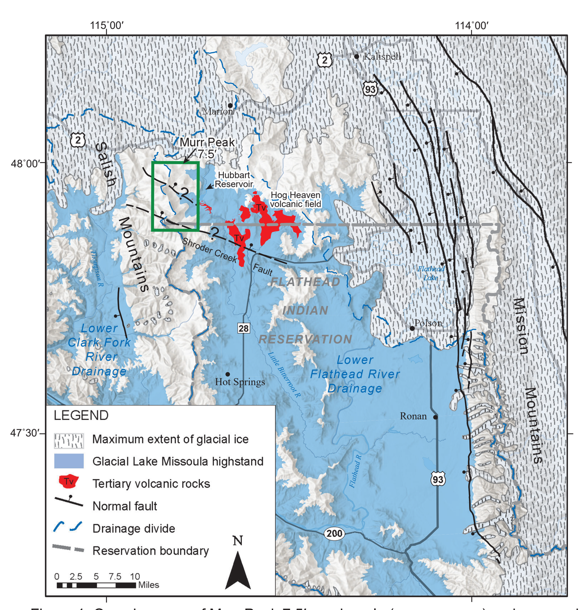
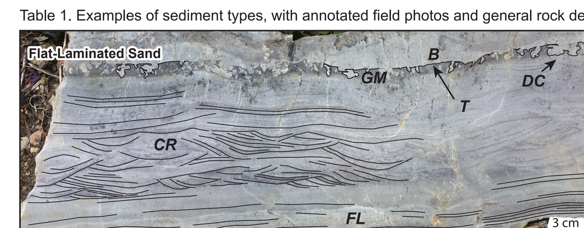
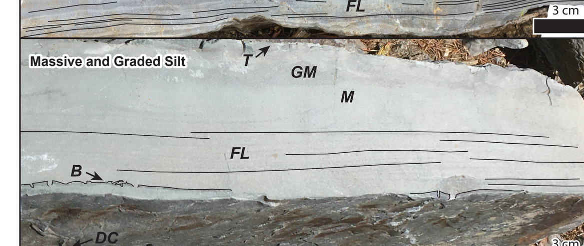
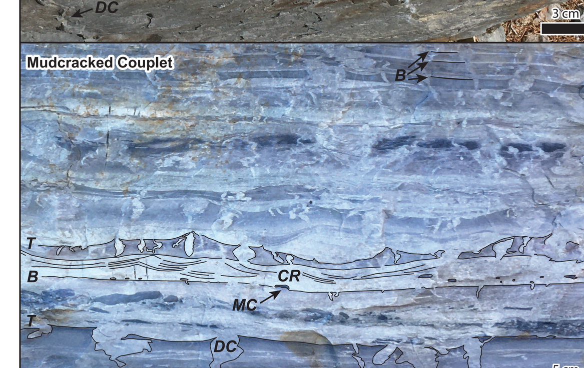


Figure 1. Overview map of Murr Peak 7.5′ quadrangle (green square) and surrounding area. Active faults and speculative faults mentioned in the text are shown. Maximum extent of glacial ice and highstand of Glacial Lake Missoula modified from Smith and others (2021).

Table 1. Examples of sediment types, with annotated field photos and general rock descriptions.

	Description
	Tabular bedded fine/very fine sand with massive to flat-laminated bases, climbing-ripple tops, and rare mud drapes with desiccation cracks.
	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.
	Even to wavy, continuous very fine sand/silt to clay couples and couplets with common desiccation cracks and mud chips.
	Oscillation-rippled, very fine sand/silt lenses capped by clay with common crinkle cracks. KEY T top of event B base of event GM graded mud DC desiccation crack CR climbing ripple FL flat lamination M massive MC mud chip

INTRODUCTION

The Murr Peak 7.5′ quadrangle is in the Salish Mountains, about 25 mi (40 km) southwest of Kalispell (fig. 1). The northwestern corner of the Flathead Reservation is near the southern boundary of the quadrangle. A drainage divide bisects the quadrangle, separating the lower Clark Fork and lower Flathead river drainages. Much of the quadrangle is forested and unglaciated, located less than a half mile south of the Cordilleran ice sheet margin during the last glacial maximum (e.g., Alden, 1953). While the higher elevations can be thickly vegetated, a dense network of decommissioned U.S. Forest Service and logging company roads makes travel relatively easy within the quadrangle. Outcrops are generally limited to gentle ridgelines and active or abandoned quarries. Extensive low-relief erosional surfaces occur at all elevations, often trapping thick deposits of non-calcareous loess. Elevations range from 6,770 ft (2,063 m), at the high point of Murr Peak, to about 3,500 ft (1,065 m), at the low point along Briggs Creek. The highstand of Glacial Lake Missoula, at about 4,250 ft (1,295 m; e.g., Alden, 1953; O'Connor and others, 2020), projects into the quadrangle but shorelines are not apparent.

PREVIOUS MAPPING AND METHODS

Early maps of the quadrangle were completed as part of a geologic study and mineral assessment of Lincoln and Flathead Counties (Johns, 1964, 1970, 1:126,720 scale). Harrison and others (1986, 1:250,000 scale) later subdivided the Belt Supergroup into formations, using a combination of stratigraphic names from the western and eastern edges of the basin. Ryan and Buckley (1993, 1:24,000 scale) refined the stratigraphy of the Ravalli Group and mapped informal members of the Revett Formation, as part of a larger mapping project of the Flathead Reservation (Buckley, 1994, 1:100,000 scale). These maps were never published at full scale, but were included as less-detailed figures in other reports (Ryan and Buckley, 1993; Buckley, 1994). Buckley's (1994, 1:100,000 scale) unpublished map was later revised by Sears (1991, unpublished, 1:100,000 scale). Lange and Zehner (1992, 1:50,000 scale) mapped sparse outcrops of Tertiary volcanic rocks and dikes (Tba of this study) in the eastern part of the quadrangle. Montejo (2021, 1:24,000 scale) mapped surficial deposits in detail near Hubbart Reservoir.

Rock samples collected during the mapping effort for whole-rock geochemistry and U-Pb geochronology were processed at the MBMG mineral separation laboratory. A ~100 to 200-g split of the crushed material was prepared for bulk-rock geochemical analysis and subsequently analyzed by X-ray fluorescence (XRF) and inductively coupled plasma mass spectrometry (ICP-MS) at the Peter Hooper GeoAnalytical Lab, Washington State University. Zircon was isolated from selected samples 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 Stuart Parker, at the University of California, Santa Barbara. All data is reported in Brennan and others (in press) and Mosolf and others (in press).

GEOLOGIC SUMMARY

Deposition of the Revett and St. Regis Formations occurred during the Mesoproterozoic, between ca. 1470 and 1430 Ma (Hirtz and others, in press). Sediment types in both formations (table 1, fig. 2) have been interpreted as different parts of idealized sheetflood, playa, and lacustrine complexes (fig. 4 of Winston, 1986). The Revett Formation was deposited by sheetfloods that entered a flat intracratonic playa of the Belt Basin from the west during episodic rainstorms (Winston, 2016). Deposition occurred on the toes of nearly flat alluvial aprons, forming extensive sand- and mudflats, which slowly migrated across the playa in response to punctuated sediment transport events during rainstorms. The St. Regis Formation was deposited in a wetter climate, as the intracratonic Belt Sea episodically expanded and contracted. During drier periods, deposition occurred as the distal edges of muddy sheetfloods filled the playa, creating extensive sand- and mudflats similar to those in the Revett. Once flooded, sand was transported along the margin of the shallow intracratonic sea by fair weather and storm waves. Mud settled out from the turbid water during calm weather. Predominantly east–west oscillatory waves passed through the elastic fluid mud along the lake bottom, periodically opening and closing small tension cracks that trapped the overlying sand bedload ("crinkle cracks" of Winston and Smith, 2016). Rising and falling lake levels and episodic drying of the muddy playa produced the characteristic cycles ("type 1 cycle" of Winston and Lyons, 1997) of the St. Regis Formation (fig. 2). Burial, diagenesis, and ultimately greenschist metamorphism overprinted the Belt sediments, resulting in the various colors that loosely correspond with these cycles.

During the Cretaceous to early Eocene Cordilleran (i.e., Sevier) Orogeny, Belt rocks were thrust up and out of their basin as part of the Lewis thrust plate (e.g., Sears and Hendrix, 2004; Fuentes and others, 2012). This large thrust panel was translated to the northeast by at least 70 mi (115 km) over younger, flat-lying rocks in its footwall (e.g., Sears and Buckley, 1993; Sears and Hendrix, 2004). Minor folding of the brittle Belt rocks produced pervasive joints parallel and orthogonal to mapped fold hinges. Fold geometries are irregular and often non-cylindrical. Fold hinges are poorly defined, difficult to trace, and seem to change position based on stratigraphic level. In drainage bottoms, flat-lying erosional surfaces (pediments) were established by the late Eocene to early Oligocene. Near Briggs Creek, basaltic lavas and dacite tuffs flowed down a pediment, likely from eruptive centers in the nearby Hog Heaven volcanic field (fig. 1; Lange and others, 1994; Scarberry and others, 2023; Scarberry, 2023). Coeval extension may have been locally accommodated by cryptic down-to-the-northeast normal faults, including the Shroder Creek and unnamed faults of Johns and others (1963), and the Little Bitterroot fault of Lange and Zehner (1992). However, the faults lack evidence of deformation and are only tentatively inferred from stratigraphic relationships and projected contacts, which suggest no more than 500 ft (150 m) of apparent normal offset. An alternative interpretation of the Shroder Creek fault as a gentle syncline is permissible, requiring dips of only about 2º more than shown on the cross section.

During the Pleistocene, the Cordilleran ice sheet advanced from the north, stopping just short of the map area (fig. 1; Alden, 1953). Blowing dust from the ice sheet and the surrounding glacial deposits settled on the topography, accumulating as loess in flat and protected areas. Glacial Lake Missoula likely flooded the lowlands near the Little Bitterroot River, up to an elevation of about 4,250 ft (1,295 m; O'Connor and others, 2020), but apparently left no record in the map area. A small glacier in the head of Redmond Creek scoured a cirque, leaving behind small moraines and a tarn. Glacial outwash flowed down toward the Little Bitterroot River, depositing fluvial gravels on the older Tertiary volcanic rocks at a time when the map area was not inundated by Glacial Lake Missoula. In the highlands, above about 4,800 ft (1,460 m), ongoing freezing and thawing of jointed bedrock resulted in isolated pockets of blockfields or felsenmeer. Post-glacial (Holocene) incision advanced upstream from both sides of the drainage divide. In the Little Bitterroot River drainage basin near Hubbart Reservoir, steep-sided and narrow drainages have been incised into glacial deposits. In the Thompson River drainage basin, impressive canyons with waterfalls have been carved into bedrock (e.g., Mandy Gulch). Several quarries have modified natural outcrops of the Revett Formation.

DESCRIPTION OF MAP UNITS

Qal **Alluvium (Holocene)**—Unconsolidated, poorly sorted to moderately sorted deposits of stream-rounded cobbles and gravel. Deposited by modern streams from local Belt Supergroup sources (Revett and St. Regis Formations). Unit is inset within older glacial deposits and bedrock along Redmond Creek, in the southern part of the map. Mapped only where thickness approaches 30 ft (10 m).

Qac **Alluvium and colluvium (Holocene)**—Unconsolidated, poorly sorted 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 valley bottoms by sheetwash and gravity processes from adjacent hillsides. Includes minor paludal and fine-grained deposits of moderately sorted sand to clay, deposited in marshy areas by sheetwash processes. Thickness generally less than 30 ft (10 m).

Qc **Colluvium (Holocene)**—Unconsolidated, angular to subangular basalt gravel and boulders. Forms scattered lag on gentle hillslopes below basalt outcrops. Deposited by rockfall and topple, with reworking by sheetwash and gravity processes. Thickness generally less than 30 ft (10 m).

Qta **Talus deposit (Holocene)**—Unconsolidated deposits of poorly sorted angular boulders. Deposited by rockfall in fan-shaped rubble piles beneath steep slopes and cliffs. Thickness is likely less than 50 ft (15 m).

Qls **Landslide deposit (Holocene?)**—Mass-wasting deposit that consists of large, unsorted boulders and a fine-grained matrix. Deposit consists of a headwall breakaway zone of toppled bedrock, a smooth to hummocky slope with large rotated blocks, and a hummocky toe of poorly sorted boulders and finer-grained debris. Variable thickness, likely less than 100 ft (30 m).

Qp **Paludal deposit (Holocene to Pleistocene)**—Unconsolidated silt, clay, and organic sediments accumulated in an ephemeral pond or marsh. Sediment deposited by settling ouf of standing water and by accumulation of organic material. Occurs only in the small tarn at the head of Redmond Creek in the southwestern part of the map area. Likely rests unconformably on glacially scoured bedrock, dammed behind a small moraine. Thickness is likely less than 30 ft (10 m).

Qg **Glacial deposit (Pleistocene)**—Unconsolidated glacial till deposits of poorly sorted subangular boulders, cobbles, pebbles, sand, and tan loess with lesser glacial outwash deposits of subrounded boulders, cobbles, pebbles, and sand. Boulders rarely have glacial striations and grooves. Rests unconformably on glacially scoured bedrock, draping bedrock benches and forming small moraines below the cirque at the head of Redmond Creek in the southwestern part of the map area. Thickness likely less than 100 ft (30 m).

QTgr **Gravel (Pleistocene to Oligocene?)**—Unconsolidated deposits of poorly sorted subangular to rounded pebbles, cobbles, and boulders in a silty-sand matrix. Forms a thin lag deposit that thickens towards the valley bottom. Correlative with glacial outwash deposits (Qg) near the headwaters of Redmond Creek, based on shared clast provenance with local bedrock sources (Ysr, Yr). Deposited by glacial outwash streams draining Redmond Creek. Inferred Pleistocene age. Rests on ash-fall tuff and tuffaceous sedimentary rock (Ttu) along the drainage canal that diverts Briggs Creek into Hubbart Reservoir. Gravels near this basal contact are more consolidated, making it possible that fluvial gravels as old as Oligocene may be included in the lower part of the unit. Where the basal contact is exposed, the unit is about 25 ft (8 m) thick.

Tba **Basalt (Oligocene to late Eocene)**—Black basalt (49.1–50.7 wt. percent SiO_2; Lange and Zehner, 1992; Mosolf and others, in press) that weathers tan to light reddish-brown. Mostly aphanitc, with uncommon vugs, vesicles, amygdules, and columnar joints. Columnar joints are inclined up to about 40º from vertical, yet the basal contact is flat and consistently at an elevation of around 4,080 ft (1,245 m), suggesting deposition as a flow with irregular cooling margins. Basal contact with the underlying Revett Formation is covered but is near the same elevation as a pediment with a ferricrete lag. An Oligocene to late Eocene age is based on a whole-rock K-Ar date of 33.8 ± 1.6 Ma (Lange and others, 1994). Paleomagnetic data from this unit suggest minor clockwise rotation and flattening since emplacement (Sheriff, 1989). Correlative with the Hog Heaven volcanic field (fig. 1), which is centered about 8 mi (13 km) to the east (Lange and others, 1994; Scarberry and others, 2023). Thickness is about 50–60 ft (15–18 m).

Ttu **Tuff and tuffaceous sedimentary rock (Oligocene to late Eocene)**—Tan to yellowish tan, poorly welded ash-flow tuff of dacite composition (66.8 wt. percent SiO_2; Lange and others, 1994). Quartz, plagioclase, sanidine, and biotite phenocrysts are common. Correlative with units "Ta" of Montejo (2021) and "Trts" of Scarberry (2023), which are better exposed in the neighboring Hubbart Reservoir 7.5′ quadrangle. Lower contact is an inferred unconformity, resting on lower Revett Formation. Unconformable upper contact with Pleistocene or older gravels (QTgr) is exposed along the drainage canal that diverts Briggs Creek into Hubbart Reservoir, where the unit is at least 50 ft (15 m) thick.

BELT SUPERGROUP

The Belt Supergroup is a very thick succession of low-grade metasedimentary rocks that have well-preserved primary sedimentary structures. Formations are defined by the characteristics of their sedimentary rock protoliths, with gradational contacts between formations. For accuracy and clarity, the descriptions on this map sometimes 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; layers approximately 1–4 in (3–10 cm) thick are termed couples. Layers greater than 4 in (10 cm) thick are termed beds; greater than about a foot (30 cm) are termed thick beds.

Common associations of primary grain sizes, layer scales, bed geometry (bedforms), and sedimentary structures define sediment types (e.g., Winston and Link, 1993; Winston, 2016). Associations of key sediment types provide the most diagnostic description for formations of the Belt Supergroup. Unit descriptions include associations of key sediment types, which are summarized in table 1. The general proportions of sediment types can be used to accurately identify formations and infer depositional environment (fig. 2).

Ysr **St. Regis Formation (Mesoproterozoic)**—Alternating 15 to 50 ft-thick (5 to 15 m) intervals of gray to purple, dark gray weathering, mudcracked, very fine sand to clay couplets and gray to green, tan weathering, lenticular, fine or very fine sand to clay couples (table 1; fig. 2; "type 1 cycle" of Winston and Lyons, 1997). Mudcracked couplets range from about ¼–1½ in (½–4 cm) thick, with common polygonal desiccation cracks and mud chips with upturned cusps. Lenticular couples range from about ¼–4 in (½–10 cm) thick. Isolated, aligned to intersecting spindle-shaped, sand-filled subaqueous shrinkage cracks ("crinkle cracks" of Winston and Smith, 2016) are common. Lenticular couples range from indistinct, wavy 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. Mud chip breccia lags, about ½–4 in (1–10 cm) thick, often mark the top of the mudcracked couplet to lenticular couple cycles ("type 1 cycle" of Winston and Lyons, 1997). Interbedded tabular couples and beds of flat-laminated sand, massive silt, and graded silt (table 2) are also common, particularly near the lower part of the unit. Unit forms resistant outcrops due to the general lack of partings in the siltite and argillite. Lower contact is gradational, placed below the lowest lenticular couple interval. Upper contact is not exposed in the map area. U-Pb dating of zircon yielded a maximum depositional age of 1468 ± 10 Ma (table 2, fig. 3, Brennan and others, in press), which overlaps with results from the Ravalli Group in Glacier National Park (Hirtz and others, 2024). Apparent thickness is at least 2,500 ft (760 m).

Yr **Revett Formation (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. 2) and interbedded gray-blue to gray-purple, dark gray weathering, mudcracked, very fine sand/silt to clay 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 (fig. 4), 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 (2016) are rare, typically occurring near the gradational upper contact. Where possible, Formation is divided into informal upper and lower parts. The upper part contains bed sets around 30 ft (10 m) thick that alternate between flat-laminated sand/massive silt and mudcracked couplet/graded silt sediment types (table 2). In the poorly exposed lower part, 1- to 3-ft (1/3-1 m) thick 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. Internal contact is placed 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. U-Pb dating of zircon constrains maximum depositional ages of 1469 ± 9 Ma for the upper part and 1474 ± 9 Ma for the lower part (table 2, fig. 3, Brennan and others, in press), both of which overlap with results from the Ravalli Group in Glacier National Park (Hirtz and others, 2024). Thickness of the upper part is about 980 ft (300 m). Lower part is at least 2,500 ft (760 m) thick. Lower contact is not exposed.

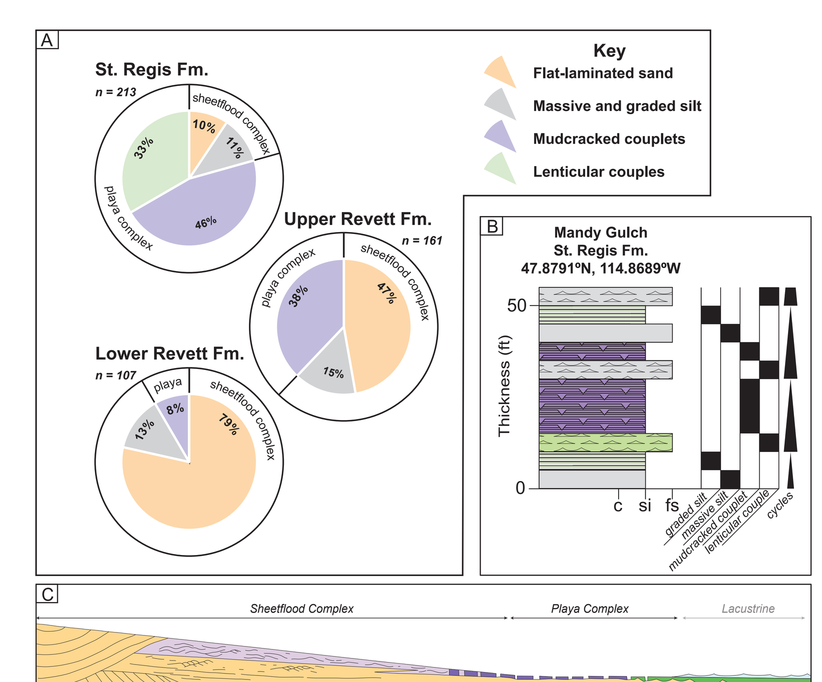


Figure 2. Stratigraphic, vertical, and lateral distribution of sediment types in the study area. (A) Relative proportions of sediment types within the St. Regis and Revett formations, based on outcrop observations *(n = 481)*. Massive and graded silt sediment types were combined based on their resemblance to one another and relative lack of abundance. (B) Generalized stratigraphic column shows typical succession of sediment types from the lower part of the St. Regis Formation, measured in Mandy Gulch (see cross-section). Colors represent the general color of the rocks. (C) Depositional model of common sediment types within the Ravalli Group, with attention drawn to sediment types in the St. Regis and Revett Formations. Modified from Winston (1986). Not drawn to scale.

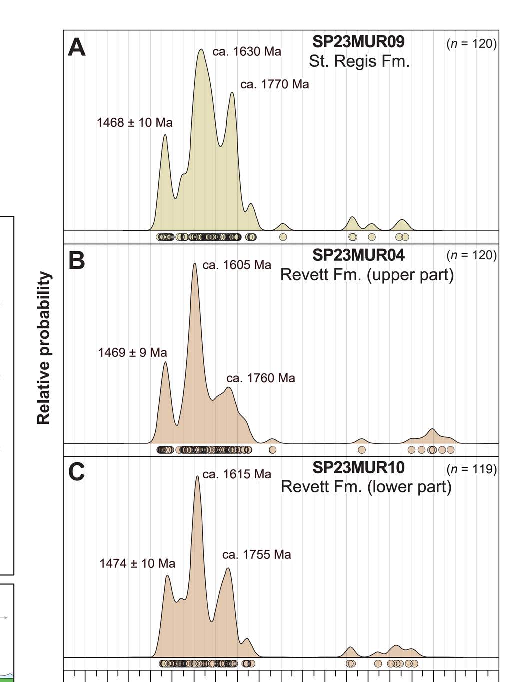


Figure 3. Kernal density estimate (KDE) plots of $^{207}Pb/^{206}Pb$ zircon ages with <10% discordance. Bandwidths of 20 m.y. and bin widths of 50 m.y. were used. Circles show individual age analyses. See table 2 for more information regarding maximum depositional ages. Data reported in Brennan and others (2025).

Figure 4. Example of cross-cutting diagenetic banding and depositional layering in the Revett Formation. Horizontal layers generally follow depositional layering of the flat-laminated sand sediment type, which are cross-cut by more steeply dipping diagenetic bands.

Table 2. U-Pb zircon geochronology.

Sample	Sediment type	Unit	Latitude (°N)	Longitude (°W)	# of spot analyses[a]	Maximum depositional age (Ma)	2σ	MSWD
SP23MUR09	lenticular couple	Ysr	47.9061	-114.8328	16/120	1468.3	9.8	0.4
SP23MUR04	mudcracked couple (muddy antidune)	Yr (upper)	47.8899	-114.8005	20/120	1468.9	8.7	0.4
SP23MUR10	flat-laminated sand	Yr (lower)	47.9138	-114.7761	15/119	1474.3	10.1	0.2

Reported maximum depositional ages are the weighted mean of $^{206}Pb/^{238}U$ ages, with <10% discordance, that define the youngest graphical peak (fig. 4). MSWD is the Mean Square Weighted Deviation. 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 used to calculated the maximum depositional age; denominator denotes the total number of concordant analyses in the sample.

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Geologic Map 107

Geologic Map of the Murr Peak 7.5′ Quadrangle, Flathead and Sanders Counties, Montana

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