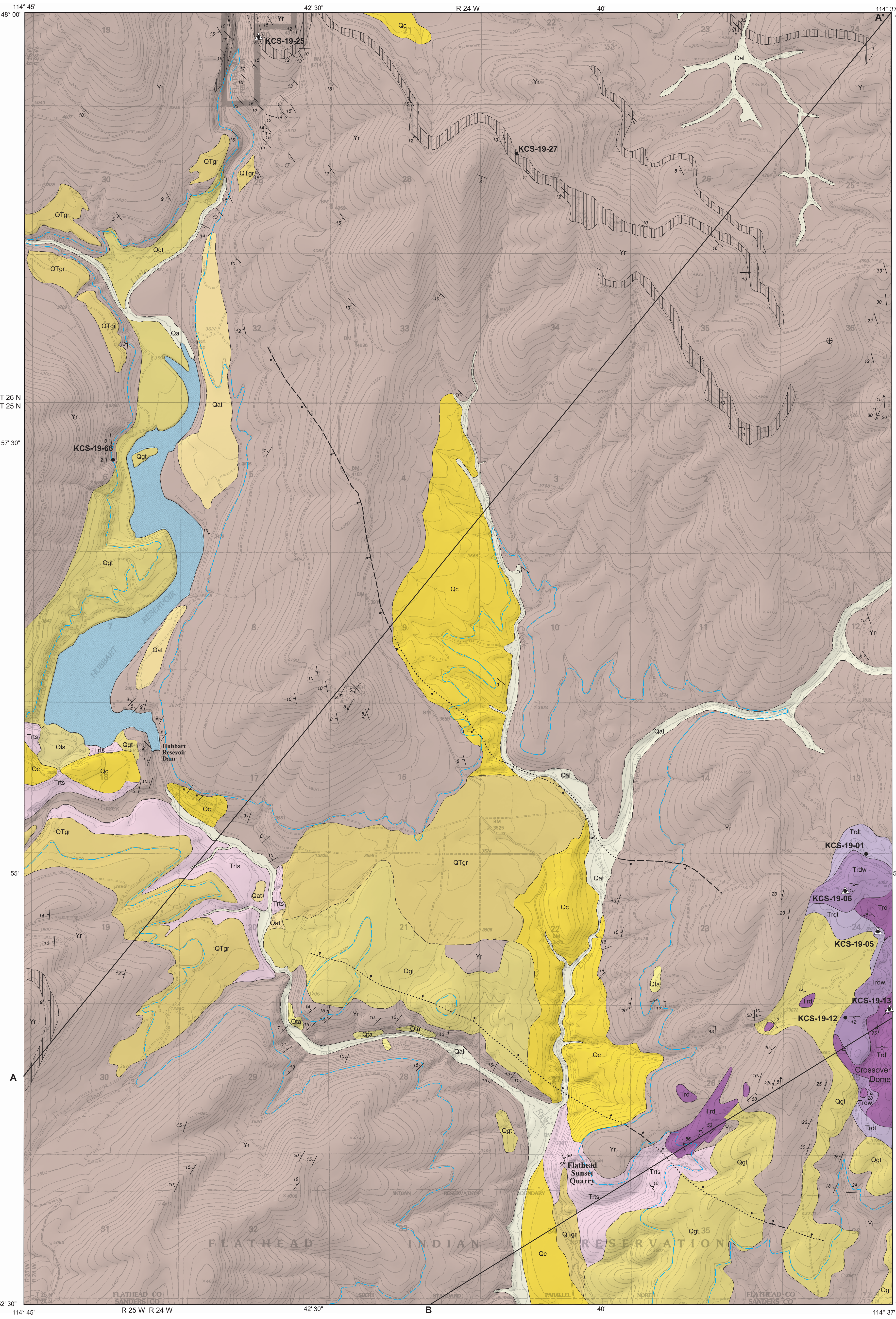
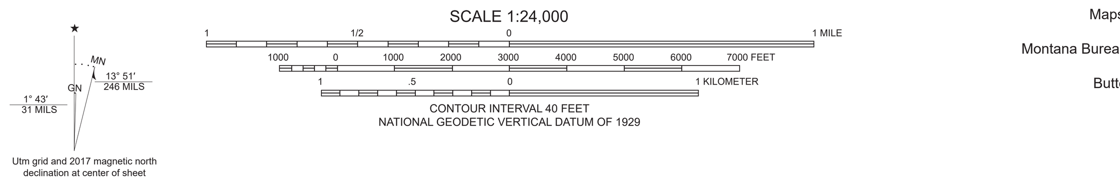


Base map produced by the United States Geological Survey
Hubbart Reservoir 1:24,000-scale quadrangle map
Areas inside forest boundaries revised by U.S. Forest Service
Control by: USGS, USC&GS, and U.S. Forest Service
Compiled from aerial photographs taken 1964.
Revised from aerial phtographs taken 1990.
Partial field check by USFS 1994.
Projection: Lambert conformal conic
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.



Maps may be obtained from:
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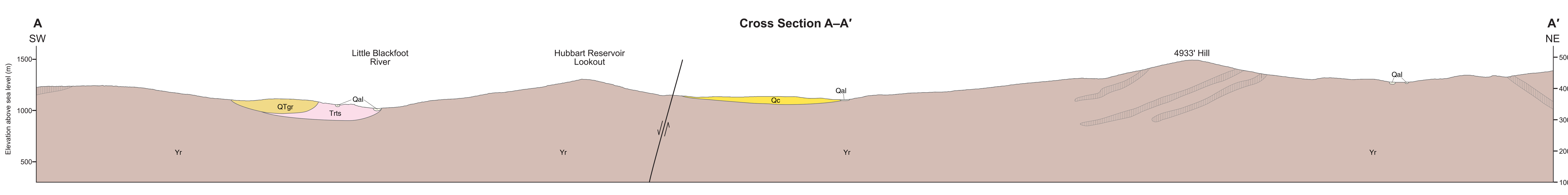
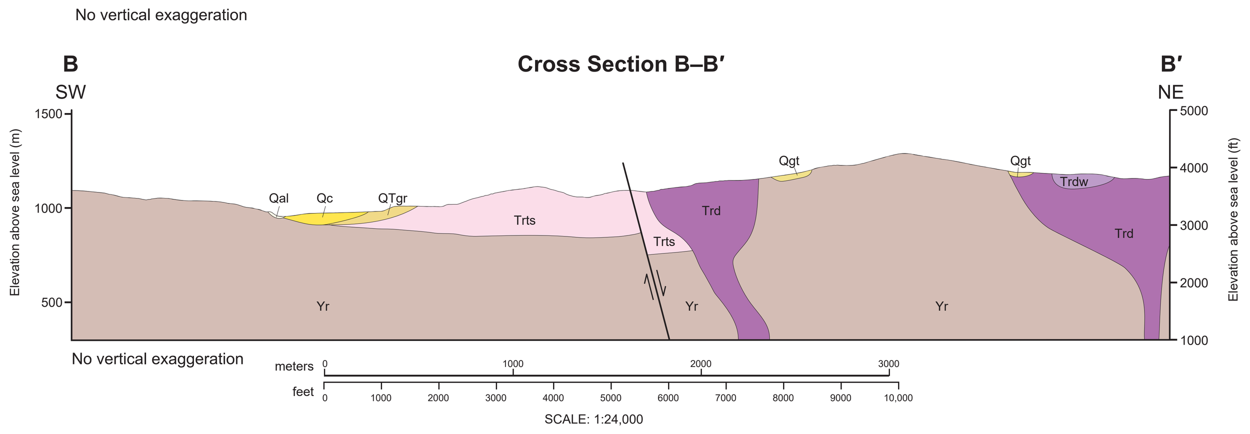
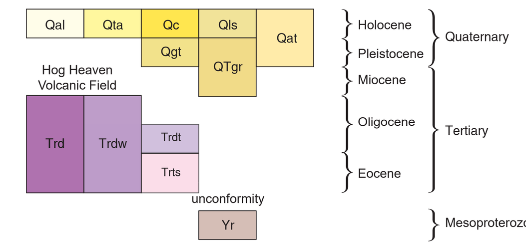




CORRELATION DIAGRAM



MAP SYMBOLS

- Contact: dashed where approximately located,
- Normal fault: dashed where approximately located, dotted where concealed, bar and ball on downthrown side
- Glacial Lake Missoula highstand, after Locke and Smith (2004)
- Horizontal bedding
- 20 Inclined bedding, showing strike and dip
- 75 Inclined pressure-solution cleavage, showing strike and dip
- Vertical pressure-solution cleavage, showing strike and dip
- 30 Inclined igneous foliation, showing strike and dip
- Vertical igneous foliation
- 15 Trend and plunge direction of bedding and pressure-solution cleavage intersections
- Adit or tunnel entrance (caved)
- Sample: bulk rock geochemistry (table 1)
- Sample: bulk rock geochemistry (table 1) and U-Pb geochronology (table 2)
- Biotite magnetite alteration zones in Belt rocks (unit Yr), also shown on cross-section

INTRODUCTION

The Hubbart Reservoir 7.5′ quadrangle is located about 40 km (25 mi) southwest of Kalispell, Montana (fig. 1). The Flathead Indian Reservation boundary lies just north of the southern boundary of the quadrangle. Dense forest covers most of the quadrangle, but a network of U.S. Forest Service, mining, and logging roads exist throughout the terrain. Elevation in the quadrangle ranges from about 920 m (3,020 ft) along the outlet of the Little Bitterroot River in the south-central part of the quadrangle, to about 1,514 m (4,966 ft) in the unnamed hilltops in the northeastern corner of the quadrangle.

Previous Mapping

The quadrangle lies within the Mesoproterozoic Belt Basin (fig. 2A). Harrison and others (1986), and Johns (1970) published regional geologic maps that cover the Hubbart Reservoir 7.5' quadrangle at scales of 1:250,000 and 1:126,720, respectively. Sears (1991) mapped the Flathead Indian Reservation in the southern part of the quadrangle at 1:100,000-scale (unpublished). Lange and Zehner (1992) mapped the Hog Heaven Volcanic Field (HHVF) in the Hubbart Reservoir quadrangle at 1:24,000 scale. Montejo (2021) mapped the Quaternary geology in the region, which included parts of McGregor Peak, Murr Peak, Marion, and Hubbart Reservoir 7.5' quadrangles (see location map).

Geologic Summary

Mesoproterozoic Belt Supergroup metasedimentary rocks (fig. 2B) form the bedrock in the Hubbart Reservoir 7.5' quadrangle. Belt Supergroup rocks formed in a northeastward-thinning clastic wedge that may represent a large alluvial fan complex (Winston, 1986a; Ryan and Buckley, 1998) that fed a subsiding, northwest-elongate intracontinental rift basin near the continental margin of Laurentia between 1,470 Ma and 1,380 Ma (Sears and Price, 2003; Evans and others, 2000). Mesozoic fold–thrust belt contraction in northwestern Montana produced a series of broad north–northwest-trending folds in the Belt metasediments (Harrison and others, 1980). The gently folded Belt rocks have limbs that generally dip less than 25° and fold-axes that trend approximately N05°W–N25°W and plunge less than 10°. Sub-vertical pressure-solution cleavage occurs in argillite throughout the quadrangle and is interpreted here to be axial planar cleavage representative of a large regional structure (Purcell Anticlinorium, fig. 1).

The Belt sequence consists of thin-bedded argillite, siltite, and minor quartzite of the Revett Formation of the Ravalli Group. These rocks correlate with mineralized Belt rocks to the west, in the Coeur d'Alene mining district (Boleneus and others, 2006), and with the Spokane Formation in the eastern part of the Belt Basin (Winston, 1986b; White and others, 1977; White, 2000; Harrison and others, 1986). Johns (1970) described magnetite-bearing alteration zones in Flathead County that are characterized by green magnetite-bearing beds apparently interstratified in the Belt rock sequence. The green beds may be an important marker interval in the Hubbart Reservoir 7.5' quadrangle and throughout the region. Rocks in the southeast map corner contain ferricrete (QTgr; fig. 3) and leisegang oxide bands, which suggests an oxidizing ore body may exist in the region at a relatively shallow depth.

The Oligocene to Late Eocene HHVF (fig. 1) contains high-K felsic rocks (Lange and others, 1994) that correlate in time with voluminous calc-alkaline, rhyodacitic ash-flow tuff volcanic deposits recognized throughout the U.S. Great Basin (e.g., Best and others, 1989; Christiansen and Yeats, 1992). These volcanic deposits formed during extensional block faulting and intrude and overlie the Belt rocks in the quadrangle. This episode of Great Basin magmatism produced volcanic-hosted precious metal deposits and mostly predates the onset of Miocene Basin and Range extension (Seedorf, 1991). HHVF mineral deposits are unique to the northern Rockies and possibly unique worldwide. The HHVF high sulfidation deposits are distinctly polymetallic (Ag-Au-Pb-Cu-Zn-As), with high base metals (Pb > Zn, Cu) and Ag, but relatively low Au (Ag:Au ratio > 2,000:1); (Lange and others, 1994).

Quaternary deposits provide ample cover for bedrock units in the quadrangle. Glacial Lake Missoula flooded the region, including the Hubbart Reservoir 7.5' quadrangle, during the northward retreat of the Pleistocene Cordilleran Ice Sheet between about 15,000 and 13,000 years ago (Pardee, 1942; Locke and Smith, 2004). Shorelines are conspicuous in the hills at elevations above about 1,097 m (3,600 ft) south of the quadrangle. Glacial lake shorelines were not mapped during the present study but a possible high stand is shown on the map (after Locke and Smith, 2004).

DESCRIPTION OF MAP UNITS

Sediments

The description of Quaternary–Tertiary sediments draws heavily from the work of Montejo (2021).

Qal **Alluvium (Holocene)**—Unconsolidated, stratified clay, silt, sand, and gravel deposited primarily along the Little Bitterroot River, its tributaries, and other modern streams and flood plains. The unit is typically less than 10 m (33 ft) thick.

Qta **Talus (Holocene)**—Coarse, poorly sorted and angular, unconsolidated metasedimentary boulders found at the base of cliffs and steep slopes in the Little Bitterroot River canyon south of Hubbart Reservoir. Thickness is likely less than 10 m (33 ft).

Qc **Colluvium (Holocene)**—Unconsolidated, locally derived slope deposits that contain angular, poorly sorted clasts, pebble size and larger. Thickness generally less than 10 m (33 ft).

Qls **Landslide deposit (Holocene)**—Slump and slope failure deposit that occurs at the southwest end of Hubbart Reservoir, near the dam (see map). This deposit is unconsolidated, poorly sorted, and consists of angular to sub-rounded pebbles to boulders in an orange-red-brown matrix of clay and sand. The landslide has a distinct crescent-shaped head scarp (Montejo, 2021).

Qat **Alluvial terrace deposits (Holocene–Pleistocene)**—Subrounded to rounded, variably sorted pebble- to boulder-sized, primarily Belt rock clasts, in a sand matrix. Montejo (2021) described three terrace surfaces in the quadrangle, located at about 50 m (164 ft), 20 m (66 ft), and 10 m (30 ft), elevation above the modern level of the Little Bitterroot River.

Qgt **Glacial deposits, undivided (Pleistocene)**—Includes glacial lacustrine and glacial till deposits. Weakly stratified deposit of clay, silt, sand, and gravel with abundant, locally derived, sub-rounded to sub-angular cobbles and boulders. The unit is exposed throughout the quadrangle. The coarseness of sediments in the unit changes gradually from northeast to southwest, perhaps reflecting a change from till-dominated deposits to Glacial Lake Missoula deposits. For example, northeast of Hubbart Reservoir the unit consists primarily of massive piles of till. Exposures of the unit along the west side of Hubbart Reservoir consist of silt up to 15 m (50 ft) thick. South of the Little Bitterroot River, in section 28, a rock quarry exposes a regolith cap of glacial and bedrock fragments that have moved due to post-glacial soil creep. In the southeast map corner, in section 26, the unit consists of 15 m (50 ft) of stratified lake-bed deposits that are oxidized, overlain by sub-rounded sand–pebble gravels, and dip about 2° to the northeast. Also includes outwash, kame terrace, and till deposits described by Montejo (2021). The unit averages 10 m (33 ft) thick adjacent to bedrock (unit Yr) and is up to 150 m (492 ft) thick near the center of the quadrangle.

QTgr **Gravels (Pleistocene to Oligocene)**—Poorly sorted, predominately pebble, to cobble-sized conglomerates composed of rounded to subrounded Belt Supergroup rocks, primarily quartzite. The gravel occurs at around 1,140 m (3,740 ft) elevation, is poorly indurated, and is up to 20 m (66 ft) thick adjacent to fluvial terrace surfaces (Qat) on the north side of Hubbart Reservoir. Includes Tertiary sediments in the southwest map corner described by Montejo (2021). Ferricrete deposits occur in the Tertiary gravels and are recognized by sub-rounded to sub-angular, semi-clast- supported pebble–cobble conglomerate cemented by iron oxide (fig. 3). Ferricrete deposits are up to 50 m (164 ft) thick and are found in the southeast map corner.

Hog Heaven Volcanic Field

Trd **Rhyodacite (Oligocene and Eocene)**—Rhyodacite is exposed in the southeastern corner of the quadrangle. The rhyodacite forms lavas and dome complexes (around 67–68 wt. percent SiO_2; table 1) that are light tan in outcrop and coarsely porphyritic in fresh hand samples. Phenocrysts typically include euhedral 1–2 mm-long (0.04–0.08 in) biotite, altered plagioclase, and growth-zoned sanidine crystals up to 6 cm (2.4 in) long. Dome complex rocks are coarsely crystalline and exhibit steep contacts with the Revett Formation (unit Yr), whereas lavas exhibit shallowly oriented igneous foliations, or flow-banding, defined by mineral alignments and planar exsolution parting surfaces. The thickness of individual lava flows is undetermined because they are not easily distinguished from the domes. A sample of coarsely crystalline rhyodacite from the north end of the Crossover Dome, in the southeast corner of the map, yielded a U-Pb age of around 34.9 Ma, and a sample of the same dome collected 0.5 mi (0.8 km) to the south, at the eastern border of the quadrangle, yielded a U-Pb age of about 35.3 Ma (table 2, samples KCS-19-05 and KCS-19-13, respectively).

Trdw **Rhyodacite, welded (Oligocene and Late Eocene)**—Moderately welded, crystal-rich (30 percent) and lithic-poor, rhyodacite tuff (around 67 wt. percent SiO_2; table 1). The tuff is yellow to brown in weathered outcrops, and white to gray on fresh surfaces. Compacted pumice in outcrops is used to measure the orientation of tuff sections, which are tilted 12° to 28° to the south in the eastern edge of the quadrangle. Welded tuff is crystal-rich with the same phenocryst assemblage (sanidine, biotite, and quartz) as rhyodacite lavas and dome complex rocks, which suggests that the former is a less viscous product of the latter. Growth-zoned sanidine megacrysts are up to 2 cm-long (3/4 in). Length to width ratios up to 12:1 in pumice form compaction foliation in outcrops. Lithophysae are present also. A sample of welded rhyodacite tuff from the southeast corner of the quadrangle yielded a U-Pb zircon age of about 35.3 Ma (sample KCS-19-06; table 2), which is considerably older than the 31.1–31.7 Ma welded tuff near the Hog Heaven Mine (Scarberry and others, 2023) in the east-adjacent Kofford Ridge 7.5' quadrangle. On this basis, the unit is assigned an Oligocene to Late Eocene age (see correlation diagram). The welded tuff is up to 60 m (197 ft) thick.

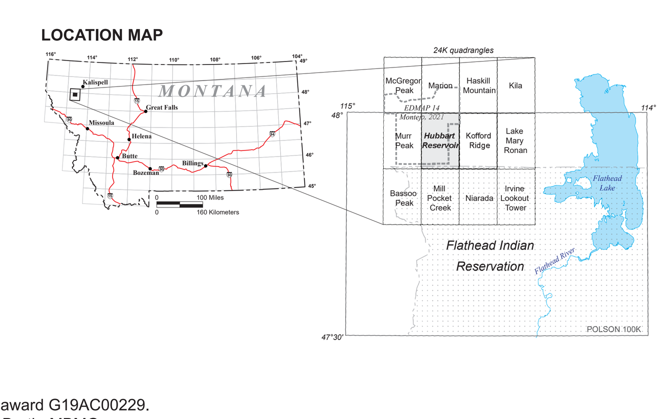
Trdt **Rhyodacite tuff (Oligocene and Late Eocene)**—Non-welded, crystal- and lithic-poor, rhyodacite tuff. The tuff sequence is white to tan to cream-colored and in places resembles mud flows. Although the sequence appears to underlie the welded tuff sequence (Trdw) in the southeastern map corner, it's possible that both sequences are relatively distal facies of the explosive eruptions that produced the welded tuff (Trdw). The silicic tuff sequence is recessive weathering and is up to 45 m (148 ft) thick.

Trts **Tuff and tuffaceous sedimentary rock (Oligocene and Late Eocene)**—Poorly welded, light gray to tan lithic-bearing dacite (63.8 wt. percent SiO_2; table 2; Lange and others, 1994). Lithic rip-ups are typically Belt rock fragments. The base of the tuff sequence consists of sand-size equigranular deposits of 30–40 percent lithic fragments in an igneous matrix. Excellent exposures of the sequence occur at, and adjacent to, the Flathead Sunset Quarry in the southeastern part of the quadrangle (see map). Here the sequence consists of Belt river cobbles in a liesengang-banded tuff matrix. East of the Flathead Sunset Quarry, the tuff sequence contains fragmental Belt Supergroup clasts up to 5 cm (2 in) long. Also includes units "Trts" and "Ta" of Montejo (2021), who described poorly welded, sediment-rich ash flow tuff deposits south of Hubbart Reservoir. The tuff sequence is up to 500 m (1,640 ft) thick.

Belt Supergroup

Although the Ravalli Group is not subdivided on previous maps, the metamorphosed siltite, argillite, and quartzite deposits in the quadrangle most resemble the middle and upper part of the Revett Formation (fig. 2B), as described by Ryan and Buckley (1998) at Revais Creek, located about 80 km (50 mi) south of the quadrangle.

Yr **Revett Formation (Mesoproterozoic)**—Grayish green, grayish red, and grayish blue, laminated to very thinly bedded argillite, siltite, and massive quartzite. The siltite is characterized by climbing ripple cross-beds, scoured beds, cut-and-fill structures, troughs, cross-beds, mega-ripples, and lenticular quartzite beds; the argillite exhibits a conspicuous steeply oriented pressure-solution cleavage, mudcracks, and ripples (Ryan and Buckley, 1998). The quartzite beds are flat-laminated to cross-bedded and often sericitic. The unit is well exposed in the peaks of most hills throughout the quadrangle, along the walls of Hubbart Reservoir (fig. 4), and in the Little Bitterroot River canyon in the northern part of the map. A section of the Revett Formation at elevations ranging between 1,113 m (3,650 ft) and 1,494 m (4,900 ft) in the northeast corner of the quadrangle (see cross-section A–A′) consists of (north to south, bottom to top) two sequences. (1) A bottom sequence that is 150 m (492 ft) thick and consists of grayish blue, mud-cracked and finely laminated (2–5 cm; 0.08–2 in) argillite. This sequence gradually transitions up-section to siltite intervals that are characterized by white to tan, subcentimeter siltite–argillite couplets, quartzite beds that are up to 5 cm (2 in) thick, and purple mud-cracked argillite that contains rip-up "breccia" beds. This bottom sequence is similar to the "coupled purple argillite" unit described in the Revett Formation by Mauk (1983). (2) A top sequence that is 250 m (820 ft) thick and is characterized by finely laminated siltite and mud-cracked argillite couplets, and quartzite with interstratified green-colored quartzite and argillite intervals (pattern on map and cross-section A–A′) that are found primarily in the northeast map corner but also in the southwest map corner. The green intervals contain biotite, magnetite, and secondary Cu-minerals and are around 60 m (197 ft) thick. Sample KCS-19-25 suggests that some of these beds have elevated Cu concentrations (table 1). At Elk Mountain, 105 km (65 mi) northeast of the quadrangle in the Flathead Range, Johns (1970) described similar green intervals of quartzite and argillite that contained biotite, magnetite, and limonite. A green bed sample collected from the northwestern map corner yielded a U-Pb maximum depositional age of around 1,465 Ma (1.46 Ga); (sample KCS-19-25, table 2). The age distribution in this sample shows zircon inheritance, with peaks at about 1.8 Ga and 2.5 to 2.7 Ga (fig. 5). The unit is up to 700 m (2,297 ft) thick in the quadrangle.



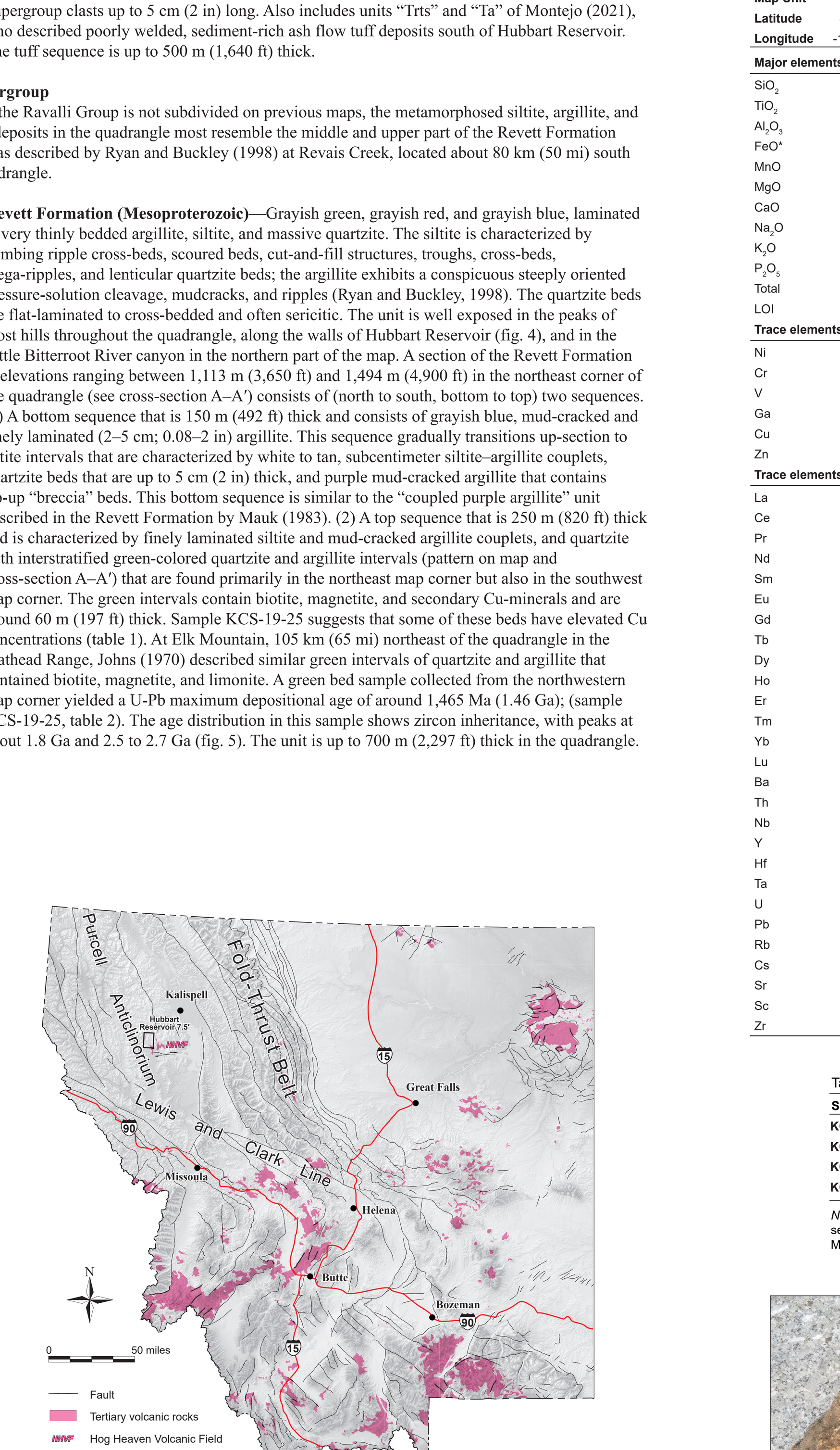


Figure 1. Location of the Hubbart Reservoir 7.5' quadrangle and distribution of major faults and Tertiary volcanic rocks in western and central Montana, after Vuke and others (2007).

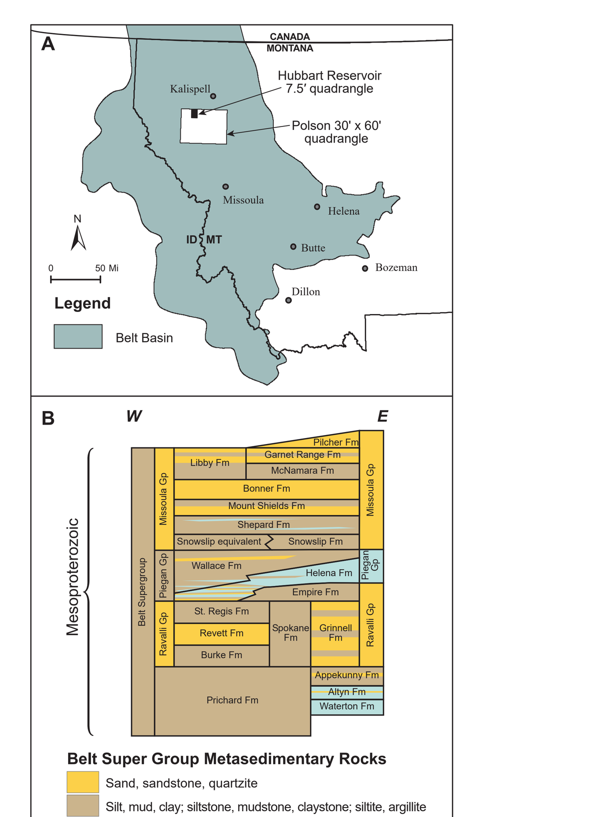


Figure 2. (A) Location of the quadrangle with respect to the Mesoproterozoic Belt Basin in Idaho and Montana. (B) Mesoproterozoic Belt Supergroup stratigraphy in north-western Montana (Vuke and others, 2007).

Table 1. Raw bulk rock geochemical data.

Sample ID	KCS-19-06	KCS-19-12	KCS-19-05	KCS-19-01	KCS-19-13	KCS-19-66	KCS-19-25	KCS-19-27
Map Unit	Trdw	Trdw	Trd	Trd	Trd	Yr	Yr	Yr
Latitude	47.91495	47.90270	47.91102	47.91854	47.90357	47.95668	47.99759	47.98631
Longitude	-114.63272	-114.63273	-114.62802	-114.62970	-114.62542	-114.73819	-114.71724	-114.68005
Major elements (wt. % oxide)								
SiO_2	67.43	67.60	67.59	67.77	67.65	82.34	63.82	69.82
TiO_2	0.52	0.53	0.52	0.51	0.51	0.26	0.54	0.50
Al_2O_3	15.77	15.54	15.74	16.05	16.30	9.19	14.71	14.08
FeO*	3.39	3.24	3.04	2.69	2.87	1.71	4.82	4.46
MnO	0.04	0.02	0.02	0.02	0.03	0.02	0.16	0.09
MgO	0.80	0.72	0.64	0.50	0.54	0.43	3.10	1.96
CaO	2.77	2.22	2.29	2.69	2.50	0.05	3.86	0.76
Na_2O	4.07	4.00	3.96	4.49	4.32	2.37	1.45	1.80
K_2O	2.96	3.15	3.07	2.93	3.04	1.79	3.48	3.60
P_2O_5	0.23	0.27	0.21	0.19	0.19	0.02	0.12	0.20
Total	96.97	97.30	97.08	97.85	97.95	98.18	96.05	97.27
LOI	2.47	2.25	2.42	1.62	1.60	1.34	3.71	2.33
Trace elements (ppm)(XRF)								
Ni	7	7	7	8	6	7	22	17
Cr	15	12	14	12	7	18	54	43
V	51	51	40	40	47	22	83	61
Ga	18	19	18	19	19	9	18	18
Cu	10	9	9	7	8	7	158	6
Zn	53	65	50	36	42	29	79	75
Trace elements (ppm)(ICP-MS)								
La	35.8	44.6	34.8	33.9	38.5	35.2	39.0	40.2
Ce	62.9	73.5	62.6	59.3	69.0	44.5	80.4	82.4
Pr	7.2	8.6	6.8	6.3	7.5	7.6	9.4	9.1
Nd	25.6	30.2	23.8	21.2	26.6	28.6	35.3	33.3
Sm	4.1	4.7	3.6	3.1	4.1	5.4	7.4	7.1
Eu	1.2	1.4	1.1	1.0	1.2	1.1	1.2	1.4
Gd	3.1	3.5	2.5	2.0	2.8	4.7	6.4	6.4
Tb	0.4	0.5	0.4	0.3	0.4	0.7	1.0	1.1
Dy	2.4	2.8	1.8	1.5	2.0	4.2	6.4	6.8
Ho	0.5	0.6	0.3	0.3	0.4	0.9	1.3	6.8
Er	1.2	1.5	0.9	0.8	1.0	2.4	3.5	3.9
Tm	0.2	0.2	0.1	0.1	0.1	0.3	0.6	0.6
Yb	1.1	1.5	0.9	0.7	1.0	2.2	3.5	3.7
Lu	0.2	0.2	0.1	0.1	0.2	0.4	0.6	0.6
Ba	1,942	2,004	1,811	1,964	1,810	413	711	727
Th	6.3	7.5	6.8	6.8	7.1	7.2	13.1	13.2
Nb	24.4	26.2	24.5	24.7	24.6	6.2	12.5	11.3
Y	12.3	17.4	8.9	7.6	9.9	24.3	34.2	37.0
Hf	3.9	4.0	3.9	3.9	3.9	4.5	5.8	6.0
Ta	1.7	1.8	1.7	1.7	1.7	0.5	0.9	0.9
U	2.7	2.3	2.5	2.7	2.5	1.8	3.0	3.6
Pb	19.4	19.2	20.9	22.0	20.4	16.8	20.5	18.1
Rb	62.3	62.6	60.1	56.1	60.8	76.2	149.1	160.6
Cs	4.0	2.0	2.8	3.0	2.7	4.1	9.2	10.0
Sr	917	788	716	984	862	77	125	104
Sc	4.9	4.0	4.0	3.4	3.9	4.9	13.1	11.8
Zr	151	159	154	153	153	168	203	212

Table 2. U-Pb LA-ICPMS geochronology.

Sample ID	Map Unit	Latitude	Longitude	Age (Ma)	2 σ	MSWD
KCS-19-06	Trdw	47.91495	-114.63272	35.25	0.20	0.89
KCS-19-05	Trd	47.91102	-114.62802	34.90	0.18	0.99
KCS-19-13	Trd	47.90357	-114.62542	35.25	0.20	0.89
KCS-19-25	Yr	47.99759	-114.71724	1,465.00	13.00	0.23

Note: Reported ages are the weighted mean of ^{206}Pb-^{238}U ages obtained for each sample. Zircon separates were prepared by Ethan Coppage in the rock laboratory at the Montana Bureau of Mines and Geology, and analyzed by Jesse Mosolf at the University of California-Santa Barbara.

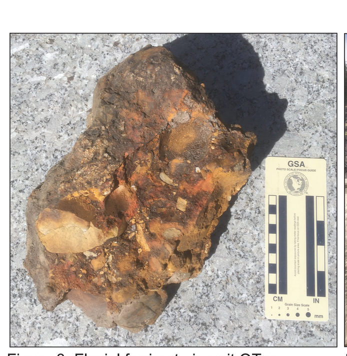


Figure 3. Fluvial ferricrete in unit QTgr.

Figure 4. The Revett Formation (unit Yr) exposed at the Hubbart Reservoir Dam at the southern end of Hubbart Reservoir (see map).

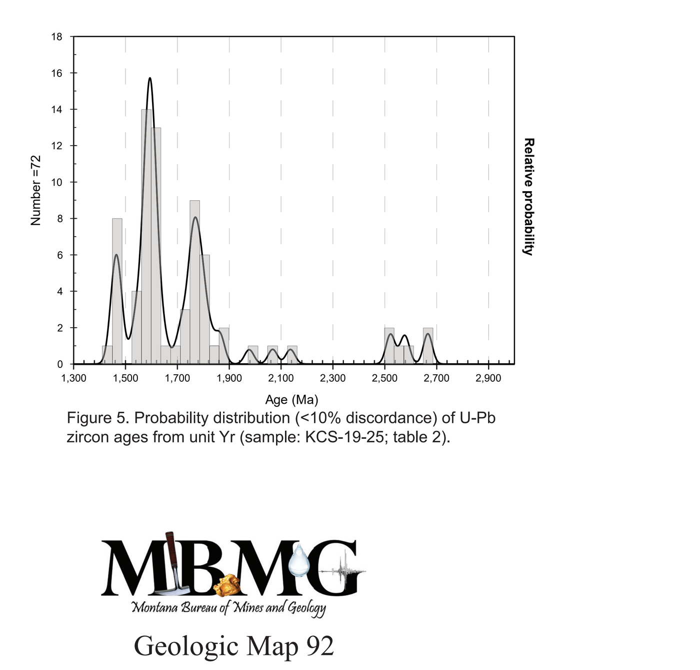


Figure 5. Probability distribution (<10% discordance) of U-Pb zircon ages from unit Yr (sample: KCS-19-25; table 2).

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Geologic Map 92

Geologic Map of the Hubbart Reservoir 7.5' Quadrangle, Flathead and Sanders Counties, Montana

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2023

https://doi.org/10.59691/DKUV6756

Research supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award G19AC00229.
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