Geologic Map of the Bohannon Spring Quadrangle, Lemhi County, Idaho, and Beaverhead County, Montana

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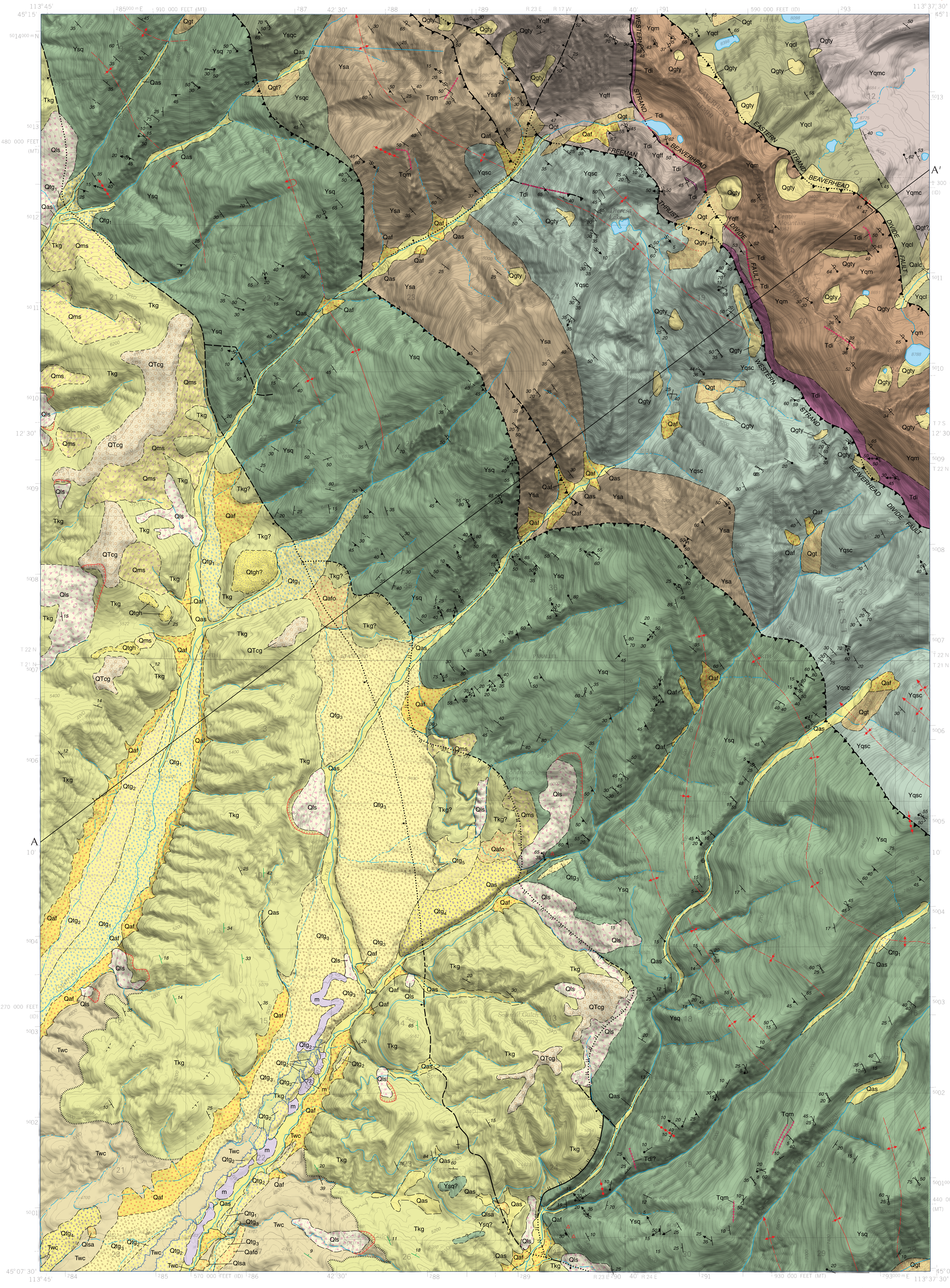
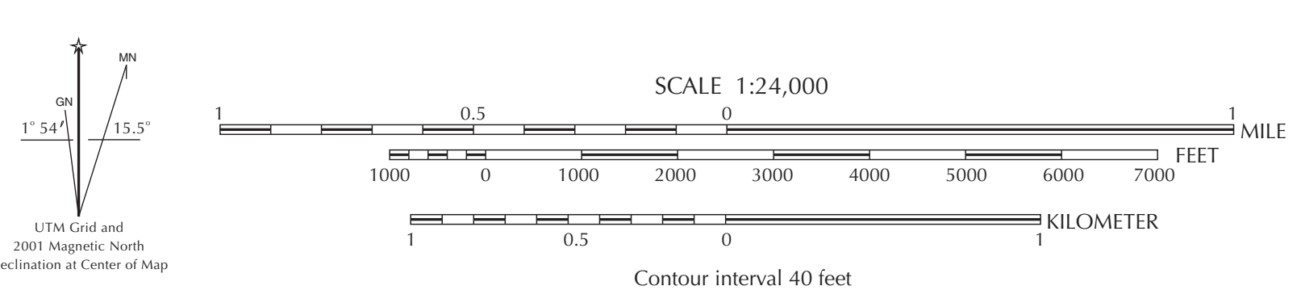
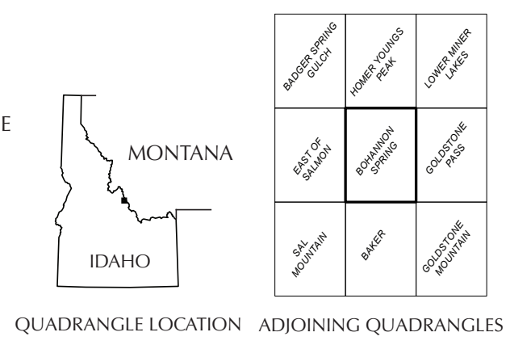
2009



Base map scanned from USGS film positive, 1997.
Shaded elevation from 10 m DEM, vertically exaggerated 2x.
Topography compiled 1985. Planimetry derived from imagery taken 1995.
Projection: Idaho coordinate system, central zone (Transverse Mercator). 1927 North American Datum.
10,000-foot grid ticks based on Idaho coordinate system, central zone.
1000-meter Universal Transverse Mercator grid ticks, zone 12.



Contour interval 40 feet



QUADRANGLE LOCATION   ADJOINING QUADRANGLES

[1]Idaho Geological Survey
[2]Montana Bureau of Mines and Geology

Field work conducted 2008-2009.

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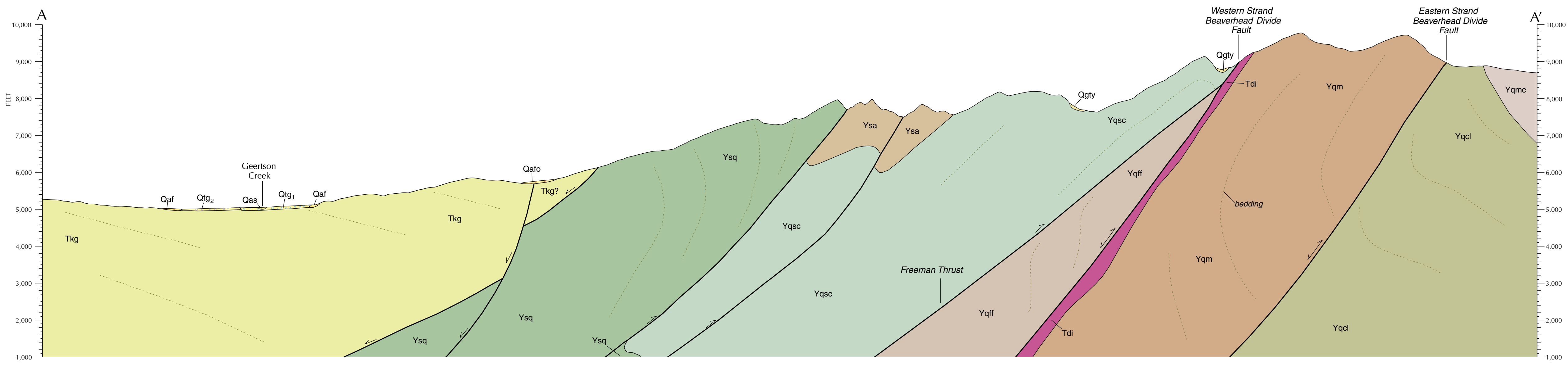
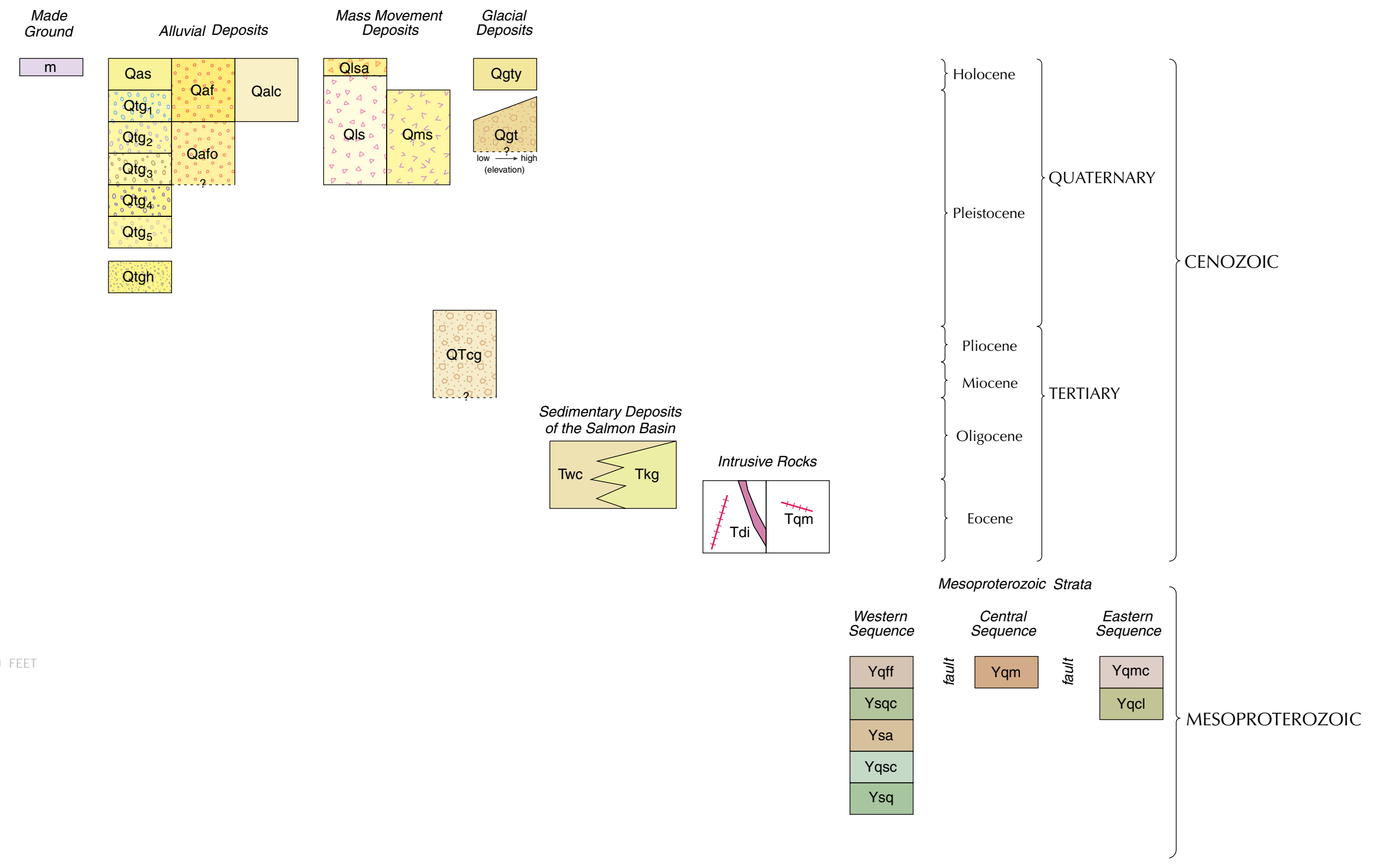
Digital cartography by Loudon R. Stanford at the Idaho Geological Survey's Digital Mapping Lab.

Map version 12-09-2009.

PDF (Acrobat Reader) map may be viewed online at www.idahogeology.org and www.mbmg.mtech.edu.



CORRELATION OF MAP UNITS



INTRODUCTION

The Montana Bureau of Mines and Geology (MBMG) and the Idaho Geological Survey (IGS) selected the Bohannon Spring 7.5' quadrangle in the northern Beaverhead Mountains along the Montana-Idaho border for a 1:24,000-scale collaborative mapping project because of its excellent exposures of two different Mesoproterozoic sedimentary rock packages. To the east and northeast, in the West Pioneer Mountains and Anaconda Range (Figure 1), are exposures of known Belt Supergroup rocks (Ruppel and others, 1993; Lonn and McDonald, 2004a, 2004b), whereas to the southwest in the Lemhi Range and Salmon River Mountains are the reference sections of the Lemhi Group, Swauger Formation, and Yellowjacket Formation (Ross, 1934; Ruppel, 1975). In the intervening Beaverhead Mountains, both the stratigraphic and structural interpretations have been controversial among previous workers (MacKenzie, 1949; Tucker, 1975; Ruppel and others, 1993; Winston and others, 1999; Evans and Green, 2003; O'Neill, 2005; Tysdal and others, 2005). The MBMG and IGS mapped the Homer Youngs Peak quadrangle to the north in 2007 (Lonn and others, 2008) and our collaborative team plans to continue 1:24,000-scale mapping southward to Lemhi Pass in an attempt to resolve some of the long-standing controversies. Bedrock mapping in 2008 by Lewis, Burmester, Lonn, and McFadden followed reconnaissance work by Lonn, Burmester, and Lewis in 2007. Tertiary and Quaternary deposits were mapped in 2008 by Othberg and Stanford. Attitudes from previous mapping by Anderson (1957 and unpublished mapping) and Tucker (1975) were used to supplement the structural data collected by the authors.

DESCRIPTION OF MAP UNITS

Mineral modifiers are listed in order of increasing abundance. Grain size classification of unconsolidated and consolidated sediment is based on the Wentworth scale (Lane, 1947). Bedding thicknesses and lamination type are after McKee and Weir (1953), and Winston (1986). Distances and bed thicknesses are given in abbreviation of metric units (e.g., dm=decimeter). Formation thickness and elevation are listed in both meters and feet. Multiple lithologies within a rock unit description are listed in order of decreasing abundance.

MADE GROUND

m **Made land (Holocene)**—Gold placer tailings of Bohannon Creek valley. Dredge tailings northeast of East Fork confluence with Bohannon Creek. Tailings from hydraulic mining southwest of confluence form "alluvial" fans deposited into the flood plain of Bohannon Creek. Includes dredge tailings near confluence of Bohannon Creek and its East Fork.

ALLUVIAL DEPOSITS

Qas **Side-stream alluvium (Holocene)**—Cobble to boulder sandy gravel in alpine stream valleys in the Beaverhead Mountains. Pebble to cobble sandy gravel from mountain front to confluences with the Lemhi River. Includes fine-grained deposits in local foothill drainages. Thickness 2-10 m (5-30 ft).

Qaf **Alluvial and debris-flow fan deposits (Holocene to late Pleistocene)**—In the Beaverhead Mountains, steep valley-side alluvial and debris-flow fans are composed of angular to subangular poorly sorted, primarily clast-supported boulder gravel and sand. Along the mountain front, alluvial fans are composed of angular to subrounded poorly sorted, primarily matrix-supported pebble to boulder gravel in a sand, silt, and clay matrix. In the foothill slopes alluvial fans are primarily composed of sand, silt, and clay with common matrix-supported gravel clasts. Thickness highly varied, ranging from 30 cm to 15 m (1-50 ft).

Qafo **Older alluvial deposits (Pleistocene)**—Angular to subrounded, poorly sorted, primarily matrix-supported pebble to boulder gravel in a sand, silt, and clay matrix. Thickness highly varied ranging from 30 cm to 15 m (1-50 ft).

Qalc **Fine-grained alluvial and lacustrine deposits in glaciated uplands (Holocene-Pleistocene)**—Siltand sand deposited behind end moraines and in glacially scoured depressions.

Qtg_1 **Gravel of first terrace (Holocene to late Pleistocene)**—Subrounded to well-rounded pebble to cobble sandy gravel, mostly clast supported. Forms terrace 3-5 m (10-15 ft) above modern streams. Weakly developed soils. Thickness 3-6 m (10-20 ft). Overlies stream-cut surface on Tertiary sediments.

Qtg_2 **Gravel of second terrace (Pleistocene)**—Subrounded to well-rounded pebble to cobble sandy gravel, mostly clast supported. Forms terrace 18-24 m (60-80 ft) above modern streams. Soils have well-developed calcic horizons. Thickness 3-6 m (10-20 ft). Overlies stream-cut surface on Tertiary sediments.

Qtg_3 **Gravel of third terrace (Pleistocene)**—Sandy gravel; clasts vary from subangular to rounded pebbles, cobbles, few boulders at mountain front, to subrounded to rounded pebbles and cobbles near the confluence with the Lemhi River. Forms terrace 24-30 m (80 to 100 ft) above modern streams. Thickness 3-6 m (10-20 ft); thicker near the mountain front where form is more like an alluvial fan. Overlies stream-cut surface on Tertiary sediments.

Qtg_4 **Gravel of fourth terrace, (Pleistocene)**—Sandy gravel; clasts vary from subangular to rounded pebbles, cobbles, and boulders at mountain front, to subrounded to rounded pebbles and few cobbles near the confluence with the Lemhi River. Forms terrace 30-61 m (100 to 200 ft) above modern streams. Thickness 3-6 m (10-20 ft); thicker near the mountain front where form is more of an alluvial fan. Overlies stream-cut surface on Tertiary sediments.

Qtg_5 **Gravel of fifth terrace (Holocene to late Pleistocene)**—Moderately to poorly sorted sandy pebble to boulder gravel. Remnant is 37 m (120 ft) above *Qtg_3* and 30 ft above *Qtg_4*, and may be an alluvial fan. Thickness unknown, but probably less than 15 m (50 ft).

Qtgh **High-elevation terrace gravel deposits (Pleistocene)**—Moderately to poorly sorted sandy pebble to boulder gravel. Forms terrace remnants approximately 122 m (400 ft) above modern streams. Thickness approximately 12 m (40 ft).

MASS MOVEMENT DEPOSITS

Qlsa **Deposits of active landslides (late Holocene)**—Unstratified, poorly sorted silty clay and gravelly silty clay. Deposited by slumps, slides, and debris flows from slope failures in Tertiary sediments. Directly related to and formed after development of water ditches and irrigation.

Qls **Landslide deposits (Holocene to Pleistocene)**—Unstratified, poorly sorted silty clay and gravelly silty clay. Deposited by slumps, slides, and debris flows that primarily occur in Tertiary sediments, but also in Mesoproterozoic siltite near the range-front fault. Map may also show the landslide scarp and the headwall (steep area adjacent to and below the landslide scarp) from which material broke away (see Symbols).

Qms **Mass-movement deposits (Holocene to Pleistocene)**—Angular to subangular poorly sorted silty and clayey gravel. Deposit includes solifluction slumps, colluvium, and some alluvial-fan gravel.

GLACIAL DEPOSITS

Qgty **Young glacial and periglacial deposits (Holocene to Pleistocene?)**—Poorly sorted angular to subangular boulder gravel and till. Sandy boulder till on some ramparts and moraines. Includes pro-talus ramparts, inactive rock glaciers, and moraines. Deposits in cirques and northeast-facing protected areas mostly above 2500 m (8200 ft). Lichens common on all but youngest (uppermost) deposits. MacKenzie (1949) classified the larger deposits as rock glaciers, but well developed lateral moraines of some deposits indicate a glacial component to their origin. Lateral moraines found in the largest deposits are tree covered on distal slopes. Today, deposits appear inactive; debris-covered ice is found only in protected areas above youngest ramparts or moraines at or above 2800 m (9300 ft).

Qgt **Glacial till of last local glacial maximum (Pinedale) (Pleistocene)**—Poorly sorted sandy to clayey boulder till. Clasts subangular to subrounded. Also includes younger till deposited near or just below cirque floors up to 2500 m (8200 ft). Includes end moraine, recessional moraine, and some outwash. Thickness up to 35 m (120 ft).

QTcg **Colluvial and glacial deposits (Pleistocene to Miocene?)**—Pebble, cobble, and boulder gravel that caps highest foothill ridges; primarily colluvium with large, lag surface boulders; original deposits probably include till, pediment gravel, and creep and lag deposits derived from Tertiary conglomerates (*Tkg*).

TERTIARY SEDIMENTARY DEPOSITS
OF THE SALMON BASIN

Janecke and Blankenau (2003) interpreted the Salmon basin as one of several superdetachment basins that formed in east-central Idaho and western Montana between 46 and 31 Ma (late middle Eocene to early Oligocene). Blankenau (1999) studied the structure and stratigraphy of an area just south of the quadrangle. He described and mapped coarse-grained basin-margin facies near the mountain front and suggested they formed in response to movement along the Salmon basin detachment fault. Previously, sedimentary rocks of the Salmon basin were described, subdivided, and mapped by Anderson (1957) and Tucker (1975). Harrison (1985) studied the sedimentology of the basin-filling sediments, identified a series of gradational facies, and described several lithostratigraphic units. In contrast to Anderson's ideas, she demonstrated that the basin sediments are conformable, and their lithologic distribution resulted from depositional environments that varied by proximity to the active, basin-bounding fault. The sediments were deposited in alluvial fan, braided stream, and mixed stream-channel and flood-plain environments. Harrison (1985) defined the two formations shown on this map (*Tkg* and *Twc*) that represent laterally gradational and interfingering, coarser and finer grained lithostratigraphic units. The units are local and therefore informal.

Twc **Wimpey Creek formation (Oligocene and Eocene)**—Vitric siltstone, bentonite, mudstone, and carbonaceous shale with interbeds of conglomerate and sandstone. Colors vary from white to greenish gray and pinkish brown. Carbonaceous and bentonitic beds are the chief distinguishing feature of the unit. Bed thicknesses range from a few centimeters to several meters. Conglomerate and sandstone beds are commonly lenticular and increase in frequency over fine-grained beds as the unit grades and interfingers with the Kriley Gulch formation. Depositional environments vary from flood-basin swamps and ponds, to sandy mixed-load streams, to proximal mixed-load streams (Harrison, 1985). Forms gently sloping, low-relief, and "bad land" topography that is prone to erosion and landsliding when wet.

Tkg **Kriley Gulch formation (Oligocene and Eocene)**—Matrix-poor breccia, matrix-supported conglomerate, and clast-supported conglomerate interbedded with beds of volcanic ash, vitric siltstone and sandstone. Colors are gray, white, and red. Silica and hematite cement are common. Clast sizes commonly pebbles and cobbles, but boulders as large as 3 meters in diameter locally occur as lag deposits from weathered and eroded beds. Beds are predominantly breccia and matrix-supported conglomerate lower in the unit, but transition upward to better sorted and cross-stratified clast-supported conglomerate. Clast compositions are primarily Mesoproterozoic quartzite, siltite, and argillite derived from the adjacent Beaverhead Mountains. Percentage of fine-grained beds increases laterally as the unit grades and interfingers with the Wimpey Creek formation. Depositional environments vary from proximal fan and fan head at the base of the unit to mid fan and proximal braided stream in the upper part (Harrison, 1985). Forms steep slopes with coarse gravelly soils and resistant ridges capped with lag pebbles and cobbles, and rare lag boulders.

INTRUSIVE ROCKS

Tqm **Quartz monzonite(?) dikes (Eocene)**—Fine-grained intermediate (to mafic?) intrusions with distinct acicular green hornblende. Quartz content is low. Potassium feldspar probably present, but if absent, dikes would be andesite.

Tdi **Diorite dikes and sills (Eocene)**—Medium- to fine-grained hornblende diorite. Similar rocks to the north described by MacKenzie (1949) as meladiorite composed of altered hornblende, albite, biotite, chlorite, and clinozoisite, with andesine and orthoclase in some of the less altered rocks. Locally contains abundant magnetite. Occurs both along the Beaverhead Divide fault, where it is locally foliated or has sheared margins and chloritized fractures, and within the country rock near that fault, where it is less deformed. Eocene age from a body in Goldstone Pass quadrangle to the east (Lonn and others, 2009) using LA-ICPMS dating of zircons.

MESOPROTEROZOIC STRATA

Low metamorphic grade metasedimentary rocks of Mesoproterozoic age are exposed over most of the Bohannon Spring quadrangle. These rocks have been variously assigned by previous workers to the Belt Supergroup, the Lemhi Group, and (or) the Yellowjacket Formation. We describe three main metasedimentary rock packages in the quadrangle: 1) poorly sorted, medium- to coarse-grained quartzite northeast of the eastern strand of the Beaverhead Divide fault (eastern sequence); 2) quartzite found between the eastern and western strands of the Beaverhead Divide fault (central sequence); and 3) siltite, argillite, and fine-grained quartzite southwest of the western strand of the Beaverhead Divide fault (western sequence).

Eastern Sequence

Northeast of the eastern strand of the Beaverhead Divide fault is an east-facing stratigraphic sequence of poorly sorted, feldspathic, medium- to coarse-grained quartzite. This sequence is tentatively correlated with the Missoula Group of the Belt Supergroup because of similarities to known upper Missoula Group rocks east and northeast of the map area in the western Anaconda Range (Lonn and McDonald, 2004a) and West Pioneer Mountains (Ruppel and others, 1993; Lonn and McDonald, 2004b). This correlation is in agreement with Evans and Green (2003), but conflicts with Tysdal and others (2005) assignment of it to the Gunsight Formation of the Lemhi Group. To the north in the Homer Youngs Peak quadrangle we divided this thick sequence into four informal units based on grain size and sedimentary structures (Lonn and others, 2008). Only two of those units are exposed in the Bohannon Spring quadrangle.

Yqmc **Multi-colored quartzite (Mesoproterozoic)**—White, purple, dark gray, and green, fine- to coarse-grained quartzite and siltite. Characterized by intervals of white to dark gray (biotite-bearing?), flat-laminated, fine- to medium-grained quartzite in beds 30-60 cm thick alternating with intervals of thin bedded quartzite, purple siltite, and black and green argillite in beds 1-3 cm thick. Ripple marks are common. Some bedding planes contain small pebbles. Finer grained intervals contain some green calc-silicate minerals and scapolite. Outcrops have a tabular-bedded appearance. Thickness approximately 2100 m (7000 ft).

Yqcl **Conglomeratic quartzite (Mesoproterozoic)**—White to light gray, poorly sorted, medium- to coarse-grained, trough and planar crossbedded, feldspathic quartzite in beds as much as 180 cm thick. Matrix-supported pebbles as much as 2.5 cm in diameter of quartz, quartzite, and hornblende granite are abundant. Granitic pebbles are angular; quartzite pebbles are rounded. Conglomeratic beds are as much as 60 cm thick. Contains black argillite interbeds as much as 8 cm thick with desiccation cracks. Some carbonate cement present, and some beds exhibit soft-sediment deformation. Similar quartzite along strike to the northwest in the adjoining quadrangle contains more potassium feldspar than plagioclase (Lonn and others, 2008). Base of unit not exposed. Minimum thickness is 1800 m (6000 ft).

Central Sequence

Between the eastern and western strands of the Beaverhead Divide fault is an east-facing stratigraphic sequence of feldspathic quartzite and subordinate siltite. Correlation of this sequence to units either west or east is uncertain. To the east in the Goldstone Pass quadrangle we divided the central sequence into four informal units based on grain size, color, and sedimentary structures (Lonn and others, 2009). Only the lowest unit is exposed in the Bohannon Spring quadrangle. Most of the central sequence is similar to the western sequence described below, but the lowest unit (*Yqm*, medium-grained quartzite) is more similar to rocks of the eastern sequence.

Yqm **Medium-grained quartzite (Mesoproterozoic)**—White to medium-grained quartzite in upward-fining sequence. Upper part is 15 to 30-cm-thick flat laminated quartzite beds interbedded with 7 to 15-cm-thick green argillite and siltite. Lower part is more thickly bedded white quartzite. Sample from southwest of Timberline Lake contains about 15 percent potassium feldspar and 1 percent plagioclase. Top and base of unit faulted, but thickness at least 1200 m (4000 ft).

Western Sequence

West of the western strand of the Beaverhead Divide fault is a complexly folded and faulted sequence consisting of siltite, fine- to very fine-grained feldspathic quartzite, and argillite. Carbonate cement is present locally. This sequence is tentatively correlated with the Lemhi Group of the Belt Supergroup because of similarities to known Lemhi Group rocks in the Lemhi Range south of Salmon. This correlation is in agreement with Evans and Green (2003), although we have been conservative by applying lithologic unit assignments and only offer tentative correlations to specific Lemhi Group formations. We divided this sequence into five informal units based on grain size, presence of carbonate, and sedimentary structures.

Yqff **Fine-grained feldspathic quartzite (Mesoproterozoic)**—Fine-grained, medium- to thick-bedded, light-weathering feldspathic quartzite and minor darker siltite and argillite. Despite well-developed cleavage or foliation, dark specular hematite laminations in layers 1-2 mm thick define large, high-angle planar cross bedding, ripple and climbing ripple cross lamination as well as flat lamination. Some steep laminations (30°-60°) truncate underlying laminations; some define loads that apparently grew during deposition. Argillite is present as thin layers or skins (some discontinuous) on quartzite parting surfaces, rarely as mud chips, and as graded tops of some quartzite- and darker siltite-based couples. Two samples contained plagioclase as the only feldspar, constituting 40-50 percent of the rock; a third contained 25 percent plagioclase and 1 percent potassium feldspar and a fourth contained up to 10 percent potassium feldspar in some layers. Tentatively correlated with the type Gunsight Formation of the Lemhi Group (Ruppel, 1975) based on similarity with rocks in the type section. Top and base faulted, but a minimum thickness of 1500 m (5000 ft) likely.

Ysqc **Carbonate-bearing siltite and quartzite (Mesoproterozoic)**—Pale green dm-thick siltite with subordinate cm to dm beds of carbonate-bearing white quartzite and rare cm-thick dark gray argillite. Siltite is strongly cleaved and phyllitic, with obscure internal laminations. Quartzite is fine to very fine-grained and feldspathic, with internal mm-scale wavy laminations and uneven scoured(?) bases. Carbonate content within the quartzite varies from orange calcitic spots and wisps to distinct brown-weathering calcitic banded beds. Two samples of very fine-grained quartzite contained roughly 40 percent plagioclase and appreciable magnetite. Tentatively correlated with the Yellow Lake unit of the Apple Creek Formation of the Lemhi Group (Tysdal, 2000) based on uniformly fine grain size, thin bedding, and interpretation of original carbonate. Top faulted, but a minimum thickness of 800 m (2600 ft) likely.

Ysa **Siltite and argillite (Mesoproterozoic)**—Laminated to thin-bedded dark gray siltite and darker gray argillite. Siltite layers cm-scale approximately equal in volume to cm-scale siltite and argillite couplets. Some zones characterized by graded siltite and argillite couples. Commonly cleaved to foliated (schistose). Some cleavage and schistosity is axial planar to tight folds. Lower parts of unit included in Big Creek Formation and upper part in Apple Creek Formation by Evans and Green (2003). Stratigraphic position suggests that it is a carbonate-poor interval between the Yellow Lake and Big Creek units of Tysdal (2003). Thickness uncertain due to folding, but likely on the order of 900 m (3000 ft).

Yqsc **Carbonate-bearing quartzite and siltite (Mesoproterozoic)**—Pale greenish-gray to uncommon pale pink very fine-grained to rarely medium-grained quartzite and subordinate siltite. Orange to white weathering. Locally contains carbonate cement or voids between silicate grains probably formerly occupied by carbonate, particularly near the upper part of the unit and, in places, appreciable magnetite. Finer grained and more sheared (phyllitic) lower in section near the western strand of the Beaverhead Divide fault. Five quartzite samples contained 13-45 percent plagioclase and no potassium feldspar. One quartzite from 1.5 km west-southwest of Timberline Lake contained about 20 percent plagioclase and 13 percent potassium feldspar and a sample from the West Fork of Wimpey Creek contained 19 percent plagioclase and 10 percent potassium feldspar. Thickness approximately 700 m (2300 ft). Tentatively correlated with the Big Creek Formation of the Lemhi Group (Ruppel, 1975) based on similarity with rocks described in the type section. Similarly correlated by Evans and Green (2003).

Ysq **Siltite, quartzite, and argillite (Mesoproterozoic)**—Mixed unit dominated by siltite and argillite in the northern part of the map and siltite and quartzite in the south. Finer grained intervals to the north contain laminated to thin bedded dark siltite and darker argillite, with some thin-bedded and rare thick-bedded quartzite. Decimeter-scale siltite layers approximately equal in volume to cm-scale siltite and argillite couplets. Argillite both green and dark gray. Some zones characterized by graded siltite and argillite couples. Thick siltite beds have more diffuse multi-mm to cm laminations that are planar, gently undulating (hummocky), or disturbed by soft sediment deformation. Coarser intervals to the south contain thick to thin bedded white quartzite, dark siltite, and darker argillite. Quartzite as thin (cm) quartzite bases of thin graded beds and thick beds, commonly in groups of several beds. Thicker beds commonly have bedding defined by dark mm-scale laminations most commonly planar, but dm stacks of cm-scale ripple cross lamination are more common in this unit than in any other, as are loads and convolute laminations. Nine quartzite samples contained about 35-40 percent plagioclase and 0-8 percent potassium feldspar. Where present in these samples, potassium feldspar is patchy, interstitial, and likely not detrital. One sample from ridge east of the West Fork of Wimpey Creek near the southern map boundary contained only 6 percent plagioclase and about 8 percent detrital(?) potassium feldspar. Another sample from the next ridge to the east contained about 30 percent plagioclase and 18 percent potassium feldspar, some of which may have been detrital. Highly folded, commonly cleaved to foliated, with cleavage in graded beds curving toward bedding-parallel in argillitic tops. Cleavage in finer beds is axial planar to similar folds of the siltite and argillite couplets. Thickness uncertain because of folding, but a minimum of 2400 m (8000 ft) likely. Tentatively correlated with the type Inyo Creek Formation of the Lemhi Group (Ruppel, 1975) and rocks below the Inyo Creek that are not exposed in the Lemhi Range. Shown as Apple Creek Formation on the Salmon National Forest map (Evans and Green, 2003).

SYMBOLS

Contact: dashed where approximately located.

Gradational contact between interfingering units: placed where change in erosional resistance is expressed topographically.

Detatchment fault: hatchures on downthrown side; dashed where approximately located; dotted where concealed.

Thrust fault: teeth on upper plate; dashed where approximately located; dotted where concealed.

60 Reactivated thrust fault: teeth on upper plate; bar and ball on downthrown side on reactivated fault segments; dashed where approximately located; dotted where concealed; arrow indicates dip of shear or fault plane.

Normal fault: ball and bar on downthrown side; dashed where approximately located; dotted where concealed.

Anticline axial trace: approximately located; dotted where concealed; arrow indicates plunge direction.

Syncline axial trace: approximately located; dotted where concealed; arrow indicates plunge direction.

Overturned anticline axial trace: approximately located; dotted where concealed.

20 Strike and dip of bedding.

Strike of vertical bedding.

65 Strike and dip of bedding: ball indicates bedding known to be upright.

50 Strike and dip of bedding, strike variable.

45 Strike and dip of bedding, strike approximate.

75 Strike and dip of bedding known to be overturned.

80 Strike and dip of bedding interpreted to be overturned.

10 Strike and dip of compositional layering.

14 Strike and dip of bedding determined from 3-point analysis on bed traced in Google Earth 3-D imagery.

Strike and direction of bedding dip: approximated from air-photo stereopairs.

30 Strike and dip of compositional layering, strike variable.

⊕ Horizontal bedding.

24 Strike and dip of foliation.

55 Strike and dip of mylonitic foliation.

55 Strike and dip of foliation where present with bedding or layering.

50 Strike and dip of cleavage.

60 Strike and dip of joint.

60 Strike and dip of crenulation cleavage.

8 Bearing and plunge of lineation, type unknown.

30 Bearing and plunge of mylonitic lineation.

7 Bearing and plunge of intersection lineation.

15 Bearing and plunge of mineral lineation.

5 Bearing and plunge of asymmetrical small fold showing counterclockwise rotation viewed down plunge.

5 Bearing and plunge of asymmetrical small fold showing clockwise rotation viewed down plunge.

15 Bearing and plunge of small fold axis.

70 Bearing and plunge of crenulation lineation.

Vein.

Dike.

Fault breccia.

Headwall scarp of landslide; ticks on top of scarp.

Extent of placer-pit excavations; exposes map units *Twc* and *Tkg*.

STRUCTURE

Several faults, both contractional and extensional, and folds traverse the quadrangle north-northwest to south-southeast. A few minor faults strike northeast. The major faults and the intervening swaths of rock are described below from northeast to southwest.

The Beaverhead Divide fault (BDF), which crosses the northeast part of the quadrangle, was first described by MacKenzie (1949) who referred to the structure as the Miner Lakes fault. Tucker (1975) mapped it southeast into this quadrangle. Ruppel and others (1993) interpreted the BDF as a major structure separating the Missoula Group to the northeast from the Mesoproterozoic Yellowjacket Formation and Lemhi Group to the southwest. Evans and Green (2003) mapped it as a thrust reactivated as a normal fault, separating Missoula Group from Lemhi Group. More recently, O'Neill (2005) interpreted the BDF as a low-angle normal fault that has been rotated to vertical, with unmetamorphosed upper plate rocks now to the northeast and metamorphosed lower plate rocks now to the southwest.

Our mapping indicates that the Beaverhead Divide fault consists of two strands, both southwest-dipping, that diverge at a slight angle as the fault crosses the map from northwest to southeast. Fault activity may span a long time (Proterozoic to Eocene). A third structure, the southwest dipping Freeman thrust, merges with the western strand of the BDF near Center Mountain. A fourth, unnamed and more poorly defined southwest dipping fault, is postulated to cross the central part of the map approximately parallel to the BDF. The two strands of the BDF separate the map area into three major structural packages, termed here the eastern, central, and western domains. The western domain is further subdivided into three structural packages (Freeman footwall, Freeman hanging wall, and westernmost strata separated from the rest by an extensional fault system).

Northeast of the eastern strand of the BDF is an east-facing panel of quartzitic strata (*Yqmc*, *Yqcl*), tentatively assigned to the Missoula Group. It is interpreted as the west limb of a giant east-verging syncline similar to the gigantic folds mapped by Tysdal (2002) in the Lemhi Range southwest of the map area. The eastern strand of the BDF, characterized by chloritic breccia, dips 60º-65º southwest. It separates weakly foliated strata of the eastern sequence to the northeast from strongly foliated strata of the central sequence to the southwest. The breccia contains randomly oriented clasts of strongly foliated and non-foliated quartzite. Mylonitic zones approximately parallel to the fault zone are developed southwest of the brittle fabrics.

Rocks of the central domain are strongly foliated and, in this quadrangle, consist of only the medium-grained quartzite unit (*Yqm*) of the central sequence. To the southeast, the central sequence contains three additional units that appear to be higher stratigraphically than these on this map. In this quadrangle, the strata of the central domain are everywhere overturned to the east. The western strand of the BDF is a zone of 50° southwest-dipping mylonitic foliation that approximately parallels the strike of foliation in the zone. Lineation within the fault plunges west. The fault is dominated by ductile fabrics that contrast with the brittle deformation along the eastern strand. This ductile shear zone contains tabular mafic bodies (*Tdi*) that exhibit foliation parallel to that of the shear zone and tops to the southwest S-C fabric. Thus it appears that at least some of the mafic magma intruded this zone during Eocene extension. Strata in the hanging wall of the western (ductile) strand of the BDF consist of strongly foliated, fine-grained quartzite (*Yqff* unit) that is tentatively correlated with the Gunsight Formation of the Lemhi Group. Beds are generally overturned to the east and exhibit a strong southwest dipping foliation.

The Freeman thrust (Lonn and others, 2008) carries highly folded and cleaved *Ysa* and *Yqsc* units, tentatively assigned to the Apple Creek and Big Creek formations, in its hanging wall. It is a low angle, southwest dipping zone of mylonite west of the Beaverhead Divide fault that merges southeastward with or is cut by the western strand of the BDF near Center Mountain. It varies from a thin mylonite zone to a thick (100 m) zone with multiple thrust faults in broken folds of its hanging wall. It merges southeastward with the western strand of the BDF near Center Mountain. Steeply dipping, foliated mafic bodies associated with the western strand of the BDF are present in both the hanging wall and footwall of the Freeman thrust, suggesting the western strand of the BDF postdates or is coeval with the Freeman thrust.

An ill-defined zone of faulting has been traced across the west-central part of the range, separating the *Ysq* unit from units to the east. The trace of this zone is characterized by well-foliated rock and an apparent reversal in top directions. Rocks in the footwall face west and those in the hanging wall face east along all but the extreme northwestern and southeastern parts of the structure. Lack of lithologic symmetry this zone (quartzite of *Yqsc* unit was not found to the southwest) rules out the presence of a syncline. Structural style changes along the structure with ductile (thrust-related?) deformation dominant in the central and northwestern part of the map, but quartz veining and possibly more brittle deformation present to the southeast. There the fault may have had later normal motion. Complexly folded strata along the lower parts of the range front complicate the relatively simple picture of a southwest-facing stratigraphic sequence in this quadrangle depicted by Evans and Green (2003).

The Beaverhead Range front fault, which marks the southwestern margin of the range, was mapped by Tucker (1975). The fault is covered by colluvium and landslide deposits along most of its length and is poorly characterized. Breccia near the base of the range is indicative of brittle deformation. A low-angle normal fault dipping about 15° southwest is exposed west of the West Fork of Wimpey Creek in section 24, T.21N, R.23E. It is probable that the fault across the section 22-27 line, T.22N, R.23E, although within Ysq, is part of the same system. Whether the entire length of the range is bounded by such a low-angle structure is uncertain. On the basis of the relatively straight trace of the range front across much of the quadrangle, we suspect that a steeper normal fault cuts this low-angle structure (section A-A'). A northeast-striking brittle fault along the upper part of Geertson Creek postdates the ductile fabrics and offsets the Freeman thrust with down-to-the-northwest motion.

Large-scale folds can only be traced for relatively short distances in this part of the Beaverhead Range. We suspect this is a result of truncation by thrust faults and associated folds that strike at an acute angle to the large-scale folds.

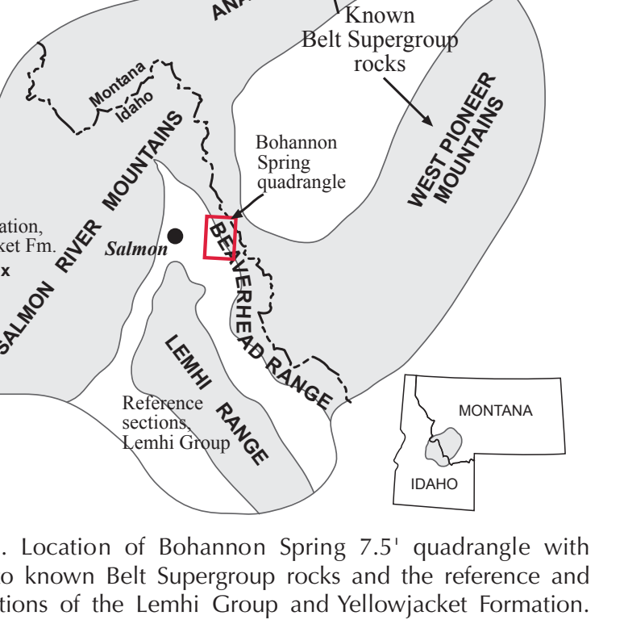


Figure 1. Location of Bohannon Spring 7.5' quadrangle with respect to known Belt Supergroup rocks and the reference and type sections of the Lemhi Group and Yellowjacket Formation. Shaded areas represent mountain ranges containing Mesoproterozoic sedimentary rocks.

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