Geologic Map of the Kitty Creek Quadrangle, Lemhi County, Idaho, and Beaverhead County, Montana

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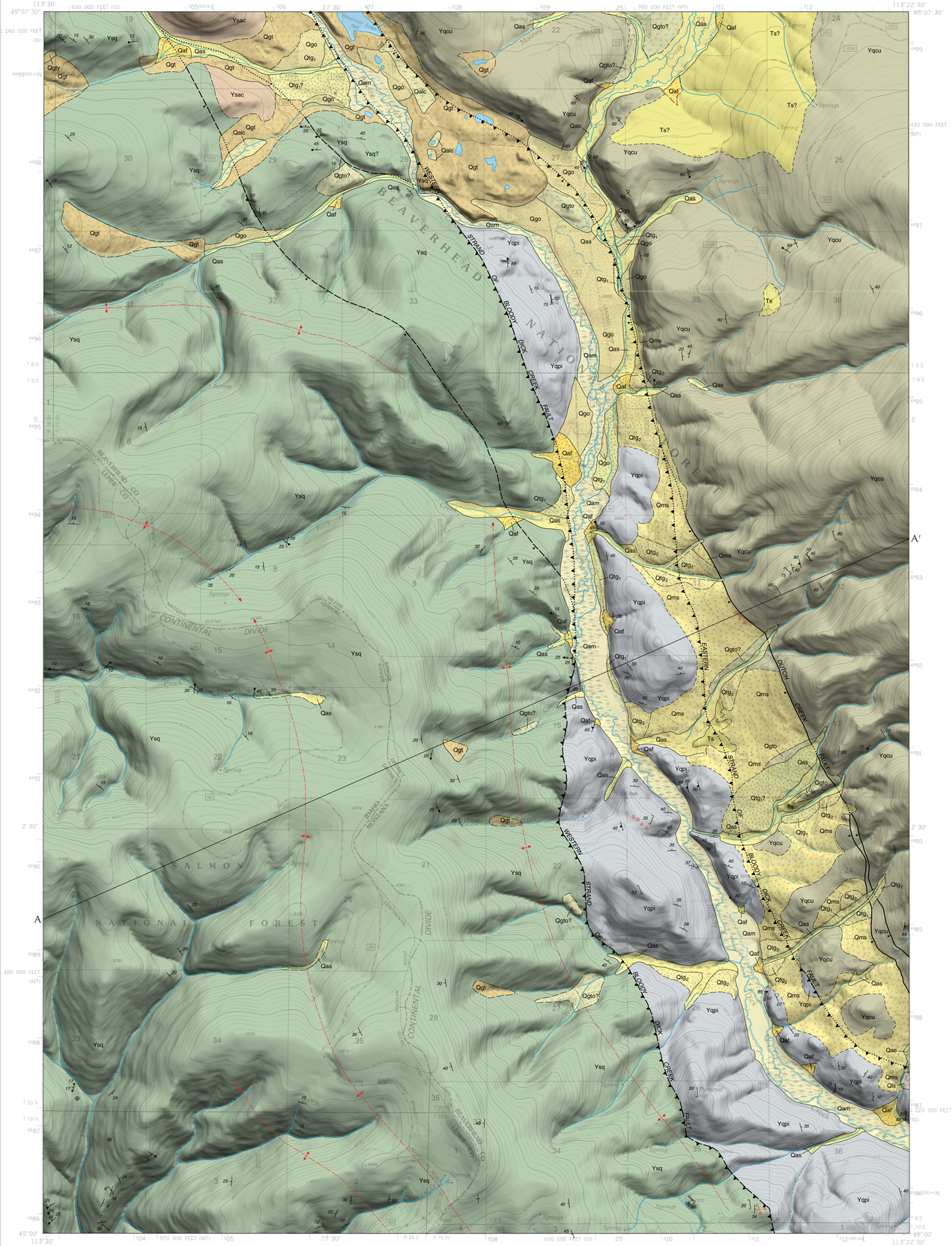

Base map scanned from USGS film positive, 1997.

Shaded elevation from 10 m DEM, vertically exaggerated 2x.

Topography compiled 1967. Planimetry derived from imagery taken 1995 and other sources.

Projection: Idaho coordinate system, central zone (Transverse Mercator). 1927 North American Datum.

10,000-foot grid ticks based on Idaho coordinate system, central zone, and Montana coordinate system, south zone.

1000-meter Universal Transverse Mercator grid ticks, zone 12.

UTM Grid and 2001 Magnetic North Declination at Center of Map

SCALE 1:24,000

Contour interval 40 feet

QUADRANGLE LOCATION

ADJOINING QUADRANGLES

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

Field work conducted 2008.

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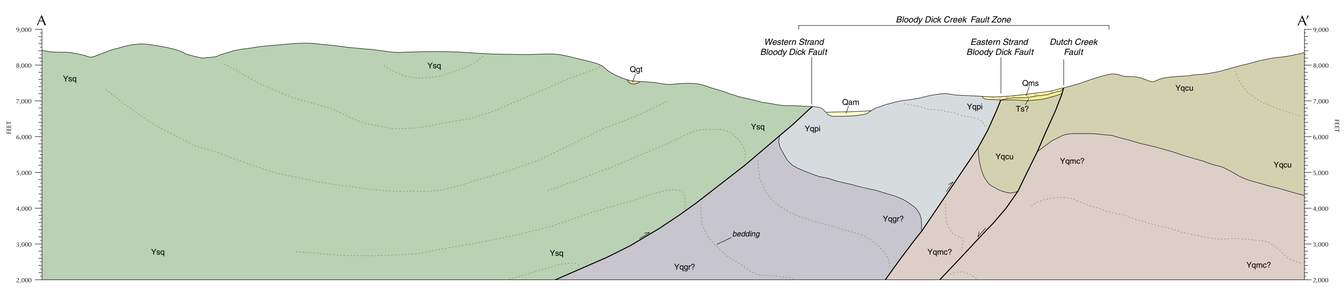
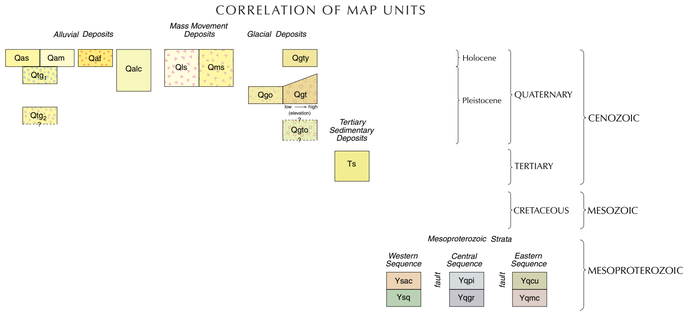
Digital cartography by Loudon R. Stanford at the Idaho Geological Survey's Digital Mapping Lab.

Map version 12-10-2009.

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 Kitty Creek 7.5' quadrangle in the Beaverhead Mountains along the Montana-Idaho border for a 1:24,0000-scale collaborative mapping project because of its 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 (Coppinger, 1974; Tucker, 1975; Hansen, 1983; Ruppel and others, 1993; Winston and others, 1999; Evans and Green, 2003; Tysdal and others, 2005; O'Neill and others, 2007). 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 along the Beaverhead Range in an attempt to resolve some of the long-standing controversies.

Bedrock mapping in 2008 by Lewis, Lonn, Burmester, and McFaddan followed reconnaissance work in 2004 and 2007 by Lonn and Lewis. Quaternary and Tertiary deposits were mapped in 2008 by Stanford and Othberg. Attitudes from previous mapping by Coppinger (1974) and Hansen (1983) were used to supplement the data collected by the authors.

DESCRIPTION OF MAP UNITS

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.

ALLUVIAL DEPOSITS

Qas **Side-stream alluvium (Holocene)**—Rounded to subrounded cobble to boulder gravel and sand. In glaciated valleys, derived from re-worked till and outwash gravels. Thickness 1-3 m (3-10 ft).

Qam **Main-stream alluvium (Holocene)**—Rounded to subrounded cobble to boulder gravel and sand. Mostly derived from re-worked till and outwash gravels. Thickness 1-5 m (3-16 ft).

Qaf **Alluvial and debris-flow fan deposits (Holocene)**—Angular to subangular poorly sorted boulder gravels and sand. Found on steep valley walls. Thickness highly varied, up to 6 m (20 feet).

Qalc **Fine-grained deposits in glaciated uplands (Holocene-Pleistocene)**—Silt and sand deposited behind end moraines. Thickness 1-4 m (3-12 ft).

Qtg_1 **Gravel of first terrace (Holocene)**—Cobble to boulder gravel. Mostly derived from re-worked till and outwash gravels. Forms terrace 1-1.5 m (3-5 ft) above modern flood plain. Thickness less than 1.5 m (5 ft).

Qtg_2 **Gravel of second terrace (Pleistocene)**—Cobble to boulder gravel locally covered by a wedge of alluvial and debris-flow fan deposits. Forms terrace 12-15 m (40-50 ft) above modern flood plain. Thickness 4-5 m (12-15 ft).

MASS MOVEMENT DEPOSITS

Qls **Landslide deposits (Holocene)**—Angular to subangular poorly sorted gravels. Thickness less than 12 m (40 ft).

Qms **Mass movement deposits (Holocene-Pleistocene)**—Angular to subangular poorly sorted gravel. Deposit includes solifluction slumps, colluvium, and some fan gravel. Thickness highly varied, up to 18 m (60 ft).

GLACIAL DEPOSITS

Qgty **Young glacial and periglacial deposits (Holocene)**—Poorly sorted angular to subangular boulder gravel deposited in pro-talus ramparts. Deposits in cirques and northeast-facing protected areas above 2475 m (8120 ft). Thickness less than 6 m (20 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).

Qgto **Older glacial till (Pleistocene)**—Deposits older than last local glacial maximum. Poorly sorted bouldery till. Mostly subangular to subrounded quartzite clasts. Offset by the Dutch Creek Fault. Thickness 1-5 m (3-15 ft).

Qgo **Glacial outwash gravels of last local glacial maximum (Pinedale) (Pleistocene)**—Subrounded to rounded, sorted sandy cobble to boulder gravel. Deposit on terrace 3 meters (10 ft) above *Qam*. Thickness at least 2 m (6 ft).

TERTIARY SEDIMENTARY DEPOSITS

Ts **Sedimentary rocks and sediment (Oligocene to Eocene)**—Light yellowish brown siltstone to claystone in exposure along Dutch Creek, and pebbleeе-rich sediment in northeast part of map. Dutch Creek exposure probably is basin fill in the hanging wall of the Dutch Creek fault.

MESOPROTEROZOIC STRATA

Low metamorphic grade metasedimentary rocks of Mesoproterozoic age underlie most of the Kitty Creek 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 Bloody Dick Creek fault (eastern sequence); 2) medium- to fine-grained quartzite found between the eastern and western strands of the Bloody Dick Creek fault (central sequence); and 3) fine-grained quartzite, siltite, and argillite southwest of the western strand of the Bloody Dick Creek fault (western sequence).

Eastern sequence

Northeast of the eastern strand of the Bloody Dick Creek fault is a generally 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). To the northwest in the Homer Youngs Peak quadrangle we divided a more extensively exposed part of this sequence into four informal units based on grain size and sedimentary structures (Lonn and others, 2008). Only one of those units are exposed in the Kitty Creek quadrangle.

Yqcu **Upper coarse-grained quartzite (Mesoproterozoic)**—White to light gray, poorly sorted, medium- to coarse-grained, trough and planar crossbedded feldspathic quartzite. Contains subangular granule-sized grains and sparse floating pebbles low in the section. Lavender quartz grains and rare granule-sized aggregates of lavender grains are present. Potassium feldspar typically in excess of plagioclase. Eight quartzite samples contained 5-16 percent potassium feldspar and 4-8 percent plagioclase. One sheared sample near the mouth of Camp Creek lacked potassium feldspar and one sample from the upper part of East Creek contained plagioclase in excess of potassium feldspar (15 versus 10 percent). Tysdal and others (2005) cited relatively low feldspar content (5-16 percent as reported by Coppinger, 1974) as evidence that this quartzite differs from quartzite on the east side of the Beaverhead Divide fault to the north in the Beaverhead Range. We found higher concentrations of feldspar (13-25 percent) and did not see significant differences between the quartzite in this quadrangle and what we consider equivalent quartzite east of the Beaverhead Divide fault in the Homer Youngs Peak quadrangle (Lonn and others, 2008). Top and bottom not exposed, but thickness at least 1500 m (5000 ft).

Yqmc **Multi-colored quartzite (Mesoproterozoic)**—White, purple, dark gray, and green, fine- to coarse-grained quartzite and siltite. In cross section only.

Central Sequence

Between the eastern and western strands of the Bloody Dick Creek fault is an east-facing sequence of feldspathic, very fine- to medium-grained quartzite and subordinate siltite. Correlation of this sequence to units either west or east is uncertain. To the northwest in the Goldstone Pass quadrangle we divided a more extensively exposed central sequence into four informal units based on grain size, color, and sedimentary structures (Lonn and others, 2009). As a result of faulting, only the uppermost of those units is exposed in the Kitty Creek quadrangle.

Ypi **Pink quartzite (Mesoproterozoic)**—Medium- to fine-grained, moderately well sorted feldspathic quartzite that has a pinkish cast on fresh surfaces. Typically flat-laminated m to dm beds with little siltite or argillite. Plagioclase content greater than or sub-equal to potassium feldspar. Nine quartzite samples contained 5-16 percent potassium feldspar and 12-28 percent plagioclase. Three samples lacked potassium feldspar and contained 19-35 percent plagioclase. Top and bottom of unit not exposed, but thickness at least 900 m (3000 ft).

Yqgr **Green quartzite (Mesoproterozoic)**—Pale green fine-grained feldspathic quartzite. In cross section only.

Western Sequence

West of the western strand of the Bloody Dick Creek fault is a gently folded sequence of uncertain thickness consisting of siltite, fine- to very fine-grained feldspathic quartzite, and argillite. Carbonate cement is present locally. This sequence is 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. To the northwest in the Bohannon Spring quadrangle (Lewis and others, 2009) we divided this sequence into five informal units based on grain size, presence of carbonate, and sedimentary structures. Only the two lowest of those units are exposed in the Kitty Creek quadrangle.

Ysac **Siltite, argillite, and quartzite (Mesoproterozoic)**—Laminated to thinly bedded dark and dull green siltite and argillite, and white, fine-grained feldspathic quartzite. Poorly exposed in map area, but along strike just off the map to the north siltite and argillite occur as distinct, laterally discontinuous laminae and graded couplets and dm beds, quartzite as discontinuous and irregular cm, rare dm layers. Sedimentary structures include cm and dm loads and channels, ripples, climbing ripples, dark mud chips in quartzite and rare mud cracked light argillite tops of graded couplets. Correlated with *Ysac* to the northwest in the Goldstone Pass and Goldstone Mountain quadrangles where manganiferous carbonate is characteristic of the lower part, and minimum thickness is estimated to be 800 m (2600 ft). Tentative correlation with the West Fork Formation of the Lemhi Group (Ruppel, 1975).

Ysq **Siltite, quartzite, and argillite (Mesoproterozoic)**—Laminated to thin-bedded dark green siltite and dark argillite with coarser intervals of light quartzite as thin (cm-scale) bases of graded beds, and as thick layers commonly in groups of several beds. Decimeter-scale siltite layers-approximately equal in volume to cm-scale siltite and argillite couplets. Thick siltite beds have diffuse multi-mm to cm laminations that are planar or gently undulating as if hummocky cross laminations, in addition to soft sediment deformed laminations. Some zones characterized by graded siltite and argillite couples. Argillite both green and dark gray. Zones with green argillite tend to have more but rare mud chips and coarse quartz lag deposits a few cm thick. Quartzite commonly has bedding defined by dark, even mm-scale laminations. Planar lamination most common, load, convolute, and cm-scale ripple cross lamination in stacks to dm thickness less common; the last are more common in this unit than in any other. Plagioclase typically well in excess of potassium feldspar. Six quartzite samples contained 5-15 percent potassium feldspar and 18-40 percent plagioclase. Seven lacked potassium feldspar and contained 10-30 percent plagioclase. One relatively coarse-grained quartzite lag from the ridge north of the upper part of Kitty Creek contained subequal potassium feldspar and plagioclase (9 versus 8 percent). Highly folded and commonly cleaved to foliated, with cleavage in graded beds curving to become nearly beddingg-parallel in argillitic tops. Similar to, but overall coarser than, *Ysac* unit. Thickness highly uncertain, but minimum of 2400 m (8000 ft) likely. Tentatively correlated with the type Inyo Creek Formation of the Lemhi Group (Ruppel, 1975) along with rocks below the Inyo Creek that are not exposed in the Lemhi Range.

SYMBOLS

- Contact: dashed where approximately located.
- Thrust fault: teeth on upper plate; dashed where approximately located; dotted where concealed.
- Reactivated thrust fault: teeth on upper plate; bar and ball on downthrown side on reactivated fault segments; dashed where approximately located; dotted where concealed.
- 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.
- 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.
- 75 Strike and dip of bedding known to be overturned.
- 80 Strike and dip of bedding interpreted to be overturned.
- Horizontal bedding.
- 24 Strike and dip of foliation.
- 55 Strike and dip of foliation where present with bedding or layering.
- 50 Strike and dip of cleavage.
- 8 Bearing and plunge of lineation, type unknown.
- 30 Bearing and plunge of mylonitic lineation.
- 5 Bearing and plunge of asymmetrica l small fold showing clockwise rotation viewed down plunge.
- Fault breccia.

STRUCTURE

Two major structures, the Beaverhead Divide fault and the Bloody Dick Creek fault, converge just northwest of the Kitty Creek quadrangle. We believe these faults are part of a continuous zone of deformation that extends at least 70 km from southeast of Lemhi Pass north-northwest to the North Fork of the Salmon River. Because both faults are part of the same large structure, assigning names to the northern and southern portions is arbitrary. Like the Beaverhead Divide fault to the northwest, the Bloody Dick Creek fault zone consists of two major parallel strands. We use the term eastern strand of the Bloody Dick Creek fault for the structure that separates quartzite of the *Yqcu* unit from finer grained pink quartzite of the *Ypi* unit. To the northwest, this structure is equivalent to the eastern strand of the Beaverhead Divide fault (Lonn and others, 2009). The fault that separates the *Ypi* unit from siltite and quartzite to the west (*Ysq* unit) is here termed the western strand of the Bloody Dick Creek fault. It is equivalent to the western strand of the Beaverhead Divide fault to the north, although the mafic intrusions common to the fault have not been observed in the Kitty Creek quadrangle. These two fault strands separate three structural and stratigraphic domains (eastern, central, and western). A third fault that forms the range front east of Bloody Dick Creek is within the eastern domain and may have had relatively recent down-on-the-west normal motion. It is referred to here as the Dutch Creek fault, but is considered part of the Beaverhead Divide-Bloody Dick Creek fault system.

The Bloody Dick Creek fault zone was first described in detail by Coppinger (1974) who reported a width for the zone as much as 3.2 km and interpreted the structure as a thrust or high-angle reverse fault. Ruppel and others (1993) interpreted it as a major structure separating the Missoula Group to the northeast from the Mesoproterozoic Yellowjacket Formation and Lemhi Group to the southwest. More recently, Tysdal and others (2005) interpreted it as long-fived structure with multiple movements, some with opposite sense of displacement. O'Neill and others (2007) have suggested that the fault is a vertical structure that is part of a 500 km-long left-lateral megashear. Our mapping suggests that the Bloody Dick Creek fault is a southwest-dipping zone approximately 2-3 km in width. The eastern strand is apparently steeper than the western strand. Both ductile and brittle deformation has occurred along this zone, and may have been recurrent from the Proterozoic to the Quaternary.

A 7 km-long splay of the Bloody Dick Creek fault system is referred to here as the Dutch Creek fault. It is described separately because of evidence for Quaternary motion along this portion of the fault system. The fault is along the range front east of Bloody Dick Creek where its morphology is clearly visible for several kilometers on air photos and Google Earth 3-D imagery. At Dutch Creek the fault is expressed by a 2-3 meter scarp on a moraine crest composed of older till (*Qgto*). Breccia occurs along strike to the north between Terrell and Hopps creeks. Janecke and others (2001) classified this portion of the fault as an active or potentially active normal fault in the current tectonic regime and noted that the age of initial slip is uncertain. Two kilometers off the map to the south the fault may continue as the western boundary of a sliver of Paleoproterozoic(?) basement rocks caught up in the Bloody Dick Creek fault system.

The eastern strand of the Bloody Dick Creek fault is poorly exposed in the quadrangle, largely following the trace of Bloody Dick Creek or under Tertiary and Quaternary cover just east of it. Its mapped location is based on the change from white, medium- to coarse grained quartzite in the east to medium-grained pink quartzite to the west. West-dipping foliations that may be the result of faulting are locally present west of the structure. Strata strike into the fault at moderate to high angles in the southern part of the map and parallel the fault in the north. During regional compressional deformation in the Cretaceous this was likely an east-directed thrust or reverse fault, with a possible component of left-lateral motion. Northwest of the quadrangle, the equivalent eastern strand of the Beaverhead Divide fault is characterized by chloritic breccia and separates weakly foliated, east-facing vertical strata on the northeast from strongly foliated and tightly folded rocks on the southwest (Lonn and others, 2008). Northeast of the eastern strand of the Bloody Dick Creek fault is a thick, largely east-facing and locally overturned panel of quartzitic strata (*Yqcu*), tentatively assigned to the Missoula Group. To the northwest in the Homer Youngs Peak quadrangle (Lonn and others, 2008) correlative rocks are interpreted to form 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 western strand of the Bloody Dick Creek fault is a poorly exposed shear zone several hundred meters in width that is largely confined to the west side of Bloody Dick Creek. At one locality north of the mouth of Brenneis Creek a mylonitic foliation within the fault dips 25 degrees west and a mylonitic lineation there is down dip. Breccia is present along the western strand near the south map boundary. We interpret the structure in this quadrangle to be an east-directed thrust fault. The central domain east of the fault consists of northeast- to east-facing, moderately dipping strata of the *Yqpi* unit. The western strand of the Bloody Dick Creek fault carries the units *Ysq* and *Ysac* of the Lemhi Group in its hanging wall. Bedding is well preserved and the rocks are gently folded. A large syncline-anticline pair is subparallel to the western strand of the Bloody Dick Creek fault in the south but diverges from the fault to the north.

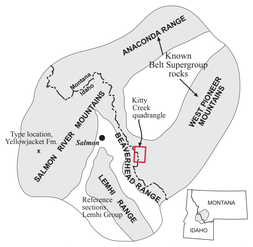


Figure 1. Location of Kitty Creek 7.5' quadrangle with respect to known Belt Supergroup rocks and the reference and type sections of the Lemhi Group and Yellowjacket Formation. Shaded areas represent mountain ranges containing Mesoproterozoic sedimentary rocks.

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