Geologic Map of the Goldstone Mountain Quadrangle, Lemhi County, Idaho, and Beaverhead County, Montana

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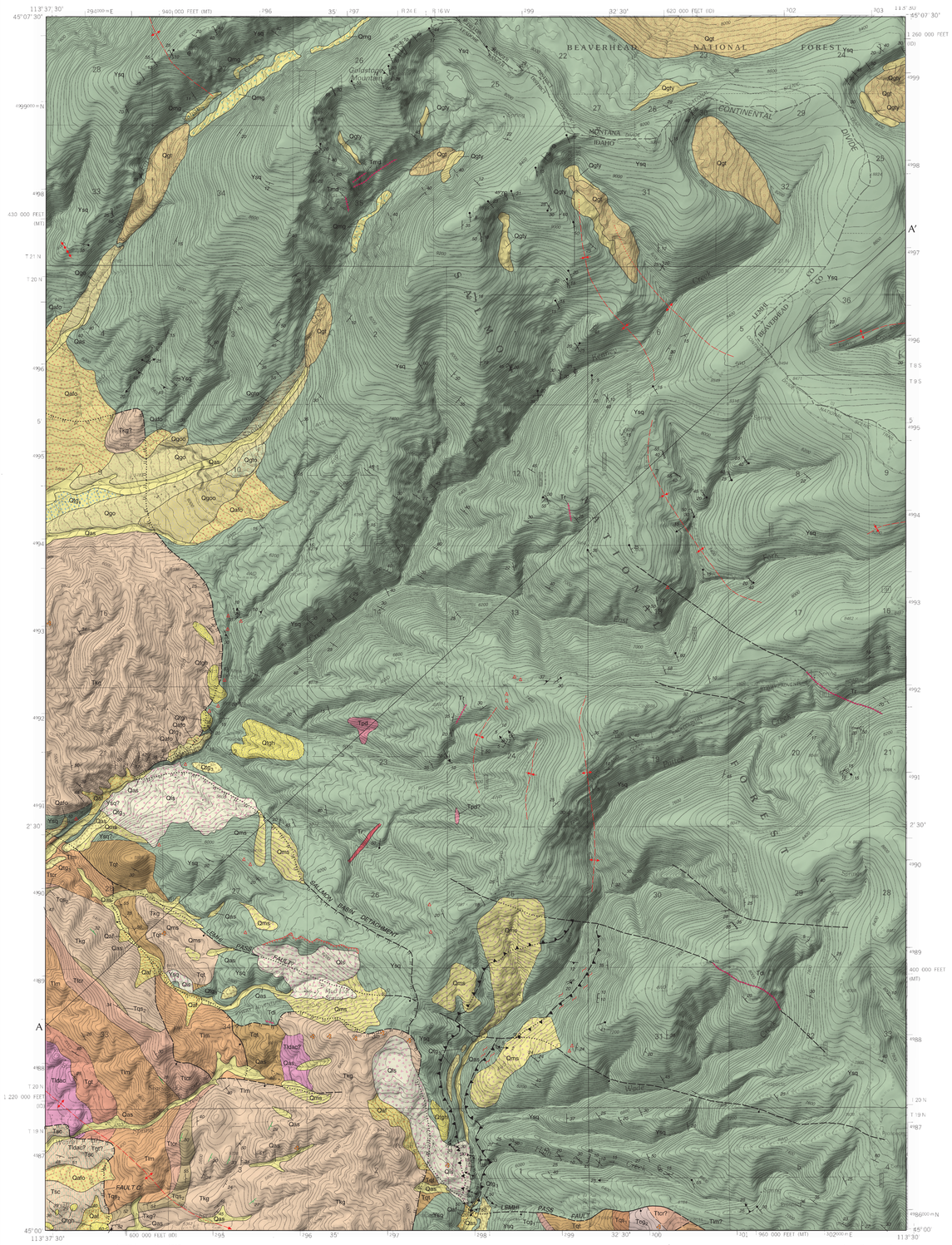
2011



Base digitally scanned from USGS film positive, 1997.

Shaded elevation from 10 m DEM.

Topography compiled 1983. Planimetry derived from imagery taken 1995. Public Land Survey System and survey control current as of 1999.

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.

SCALE 1:24,000

1 0.5 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 0.5 0 1 KILOMETER

Contour interval 40 feet

UTM Grid and 2001 Magnetic North Declination at Center of Map

IDAHO

QUADRANGLE LOCATION

ADJOINING QUADRANGLES

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

Field work conducted 2006-2010.

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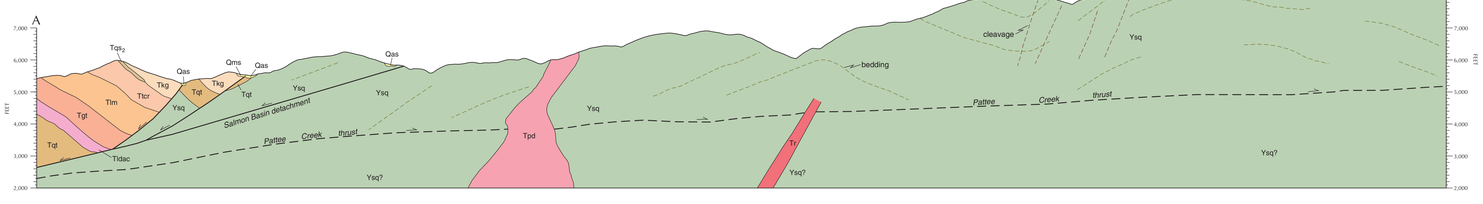
Map version 10-11-2011.

PDF (Acrobat Reader) map may be viewed online at www.idahogeology.org.



Correlation of Map Units

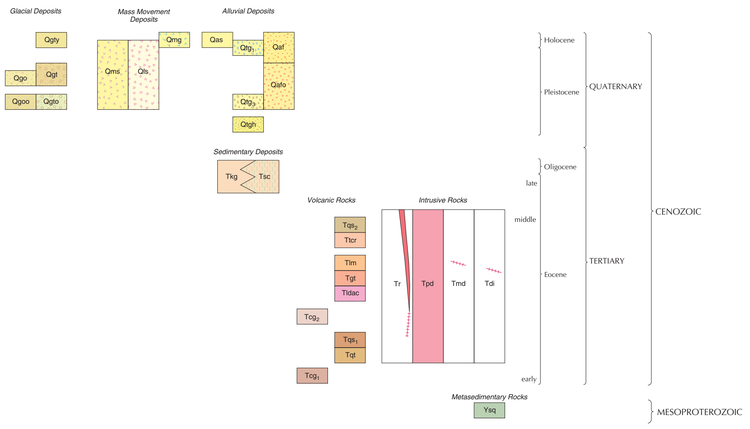


Figure 1. Location of Goldstone Mountain 7.5' quadrangle with respect to known Belt Supergroup rocks and the reference and type sections of the Lemhi Group and Yellowjacket Formation. Shaded areas represent mountain ranges containing Mesoproterozoic sedimentary rocks.

Introduction

The Idaho Geological Survey (IGS) and the Montana Bureau of Mines and Geology (MBMG) selected the Goldstone Mountain 7.5' quadrangle in the central Beaverhead Mountains along the Montana-Idaho border for a 1:24,000-scale collaborative mapping project as part of a larger project to understand the structural and stratigraphic relationships between two different Mesoproterozoic sedimentary rock packages. To the east and northeast, in the West Pioneer and Pintler Mountains (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; and O'Neill and others, 2007). In 2008 the MBMG and IGS mapped the Goldstone Pass quadrangle to the north (Lonn and others, 2009) and the Kitty Creek quadrangle to the east (Lewis and others, 2009a) 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 2009 by Lewis, Burmester, Lonn, and McFaddan followed reconnaissance work by Lonn, Burmester, and Lewis in 2006-2008. Mapping in 2009 and 2010 of Tertiary strata was by Lewis, Stanford, Othberg, and McFaddan, and of Quaternary deposits 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. Mapping and unit descriptions by Blankenau (1999) were used extensively to supplement our work in the Tertiary units in the southern part of the map. Soils information is from Hipple and others (2006).

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 metric units. 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)**—Pebble to boulder sandy gravel in stream valleys emanating from the Beaverhead Mountains. Silty and clayey in foothill stream valleys and localized bottomlands where sheet wash and colluvium are included. Soils undeveloped to weakly developed. Thickness 1-6 m (3-20 ft).

Qaf **Alluvial-fan and debris-flow fan deposits (Holocene to late Pleistocene)**—Angular to subrounded, poorly sorted, primarily matrix-supported pebble to boulder gravel in a sand, silt, and clay matrix. Soils undeveloped to weakly developed. Commonly grades into side-stream alluvium (Qas). Thickness highly varied, ranging 1 to 15 m (3-50 ft).

Qafo **Older alluvial-fan deposits (Pleistocene)**—Angular to subrounded, poorly sorted, primarily matrix-supported pebble to boulder gravel in a sand, silt, and clay matrix. Soils moderately to well developed. Thickness highly varied, ranging 1to15 m (3 to 50 ft).

Qaf_1 **Gravel of first terrace (Holocene to late Pleistocene)**—Subrounded to well-rounded pebble to boulder sandy gravel; moderately sorted and clast supported. Forms terrace 3 m (10 ft) above Sandy Creek. Soils weakly developed. Thickness 3-6 m (10-20 ft). Overlies stream-cut surface on bedrock.

Qaf_2 **Gravel of third terrace (Pleistocene)**—Subrounded to well-rounded pebble to boulder sandy gravel; moderately sorted and clast supported. Soil horizons well developed. Forms terrace 24-37 m (80-120 ft) above modern streams. Probably age-equivalent to outwash gravels older than last local glacial maximum (Qgoo). Thickness 3-6 m (10-20 ft). Overlies stream-cut surface on bedrock.

Qtgh **High-elevation terrace gravel deposits (Pleistocene)**—Subrounded to well-rounded pebble to boulder sandy gravel. Forms terrace remnants at least 100 m (300 ft) above modern streams. Thickness unknown but probably ranges 1 to 12 m (3 to 40 ft).

Mass Movement Deposits

Qmg **Mass movement and glacial deposits undifferentiated (Holocene)**—Angular unsorted to poorly sorted boulder to large boulder gravels. Forms protalus ramparts and slumps derived from moraine remnants and frost-wedged debris on high, glaciated valley walls. Includes some alluvial-fan gravel and young glacial and periglacial deposits. Thickness as much as 15 m (50 ft).

Qls **Landslide deposits (Holocene and Pleistocene)**—Unstratified, poorly sorted silty clay and gravelly silty clay. Deposited by slumps, slides, and debris flows. 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 and Pleistocene)**—Angular to subangular, poorly sorted, silty and clayey gravel. Includes solifluction deposits, colluvium, and some alluvial-fan gravel.

Glacial Deposits

Qgfy **Young glacial and periglacial deposits (Holocene?)**—Poorly sorted angular to subangular boulder gravel and till. Includes pro-talus ramparts, inactive rock glaciers, and moraines deposited in cirques and northeast-facing protected areas above 2,500 m (8,200 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. Soils undeveloped. Thickness as much as m 25 m (80 ft).

Qgt **Till deposits of last local glacial maximum (Pleistocene)**—Poorly sorted sandy to clayey boulder till. Clasts subangular to subrounded. Forms end moraines and recessional moraines. Primarily late Pinedale Glaciation equivalent. Includes younger till deposited in or just below cirque floors up to 2,650 m (8,700 ft) and local deposits of outwash. Soils weakly developed. Thickness as much as 36 m (120 ft).

Qgto **Till deposits older than the last glacial maximum (Pleistocene)**—Poorly sorted bouldery till. Mostly subangular to subrounded clasts. Found only by Sandy Creek at mountain front. Early Pinedale Glaciation or older. Soils moderately well developed. Thickness 15 m (50 ft).

Qgo **Outwash gravels of last local glacial maximum (Pleistocene)**—Subrounded to rounded, well sorted sandy cobble to boulder gravel. Primarily Pinedale equivalent; traceable to terminal moraine deposits of *Qgt*. Forms outwash terrace 12 m (40 ft) above Sandy Creek. Soils weakly developed. Thickness 3-9 m (10-30 ft). Probably overlies stream-cut surface on bedrock.

Qgoo **Outwash gravels older than last local glacial maximum (Pleistocene)**—Subrounded to rounded, well-sorted sandy cobble to boulder gravel. Forms outwash terrace 18-24 m (60-80 ft) above Sandy Creek. Traceable to old moraine deposits (Qgto). Early Pinedale or older. Shows evidence of relict meltwater channels. Soils moderately well developed. Thickness 3-12 m (10-40 ft). Probably overlies stream-cut surface on bedrock. Probably age-equivalent to gravel of third terrace (*Qtg*$_3$).

Tertiary Sedimentary Deposits of the Salmon Basin

Tkg **Kriley Gulch formation (Oligocene and Eocene)**—Matrix- and clast-supported pebble to boulder conglomerate interbedded with lithic sandstone and minor tuff. Forms steep slopes with coarse gravelly soils and resistant ridges capped with common lag pebbles and cobbles, and infrequent lag boulders as long as to 3 m (10 ft). Outcrops of cemented beds are common lower in the section but rare higher in the section. Exposures along Kenney Creek described by Tucker and Birdseye (1989) show primarily matrix-rich, poorly sorted conglomerate with highly angular clasts typical of proximal facies in alluvial fans that are dominated by debris-flow deposition. Volcanic clasts are common near the base, but are absent near the top where quartzite and siltite dominate. Granite cobbles and boulders are present in the middle part of the section, and are likely from a Mesoproterozoic pluton northwest of Salmon (Evans and Green, 2003). Along Kenney Creek, Blankenau (1999) identified a basal matrix-poor breccia composed of poorly sorted angular quartzite clasts. Higher in the section, more rounded, clast-supported clasts in the conglomerate indicate increasing braided-stream deposition in a more distal part of the fan complex. Harrison (1985) included the Kenney Creek rocks in her Kriley Gulch formation, and noted a similar upward transition to better sorted and clast-supported sediment. The unit grades into the Salmon City formation (*Tsc*); both are informal lithostratigraphic units named and described by Harrison (1985). Tucker and Birdseye (1989) included the Kenney Creek rocks in the Challis Volcanic Group and interpreted a western source for the deposits, noting as evidence the retrograde alluvial fan sequence and the diverse clast lithologies that include volcanic, granitic, and rare clasts of biotite gneiss in addition to the ubiquitous quartzite. However, Harrison (1985) and Blankenau (1999) interpret the Kenney Creek deposits as forming in proximal fan, mid fan, and proximal braided stream environments during activity along the Salmon Basin detachment. Includes portions of Blankenau's (1999) middle conglomerate of the sedimentary rocks of Tendoy, and the conglomerate of Kenney Creek of the sedimentary rocks of Sacagawea.

Tsc **Salmon City formation (Oligocene and Eocene)**—Interbedded sandstone, siltstone, shale, and minor conglomerate. Sandstone is a vitric quartz arenite. Shale is thin-bedded tuffaceous silt to massive bentonite. Locally, well-cemented conglomerate beds form fins. Depositional environments mostly distal sandy stream and lake shore deposits. In adjacent quadrangles unit grades into and interfingers with the Kriley Gulch formation (Tkg). Includes Blankenau's (1999) Tertiary sandstone and shale units of the sedimentary rocks of Tendoy. Blankenau (1999) places age between 46 and 31 Ma, late middle Eocene to early Oligocene.

Challis Volcanic Group

Tqs_c **Younger quartz-sanidine welded tuff (Eocene)**—White to pale green or gray-green with euhedral chatoyant sanidine and smoky quartz in a fine ash matrix (Tqs, of Blankenau, 1999).

Ttcr **Tuff of Curtis Ranch (Eocene)**—White to greenish white tuff containing abundant biotite and lesser amounts of smoky quartz, plagioclase, and angular volcanic and quartzite lithics (Tcr of Blankenau, 1999). Pumice is abundant to rare and typically concentrated at the top of the unit. Sandstone present locally at base. Typically poorly welded, but densely welded in places.

Tim **Mafic lava flows (Eocene)**—Black to dark green-gray or dark brown-black aphanitic to porphyritic lava flows; locally vesicular. Probably andesitic to basaltic composition (TI of Blankenau, 1999). Interbedded with the flows are thin biotitic tuffs and volcaniclastic sandstones. Secondary chalcedony and calcite are common.

Tgt **Green tuff (Eocene)**—Green to light green biotite tuff containing abundant euhedral biotite, smoky quartz, minor subhedral sanidine, and pumice in a white to light green ash matrix. Also contains chert-bearing siltstone. (Tgt of Blankenau, 1999).

Tidac **Dacite lava flows (Eocene)**—Purple to purple-gray or dark brown dacite or andesite lava flows containing phenocrysts of euhedral biotite, hornblende, and plagioclase along with minor amounts of quartz and augite(?) in a fine crystalline groundmass (TIdac of Blankenau, 1999). Near the top of the sequence are aphanitic layers like those of the *Tim* unit. Includes tuff northeast of Sharkey Hot Springs containing abundant volcanic lithic clasts. Clasts typically contain hornblende, but matrix apparently does not.

Tcg_2 **Granite-clast conglomerate (Eocene)**—Poorly sorted, well-rounded, cobble and boulder gravel consisting of quartzite clasts and rarer (fewer?) boulders of Proterozoic porphyritic rapakivi granite (Tcg, of Blankenau, 1999, but not previously mapped in the area immediately south of the Lemhi Pass fault).

Tqs_1 **Older quartz-sanidine welded tuff (Eocene)**—Tan-orange to light pink welded tuff containing pumice fragments and euhedral to subhedral crystals of sanidine and smoky quartz in a fine crystalline groundmass (Tqs_1 of Blankenau, 1999). Quartzite lithics are present in minor amounts. Differs from *Tqs_2*, in that it is typically more densely welded and more tan to orange in color.

Tqt **Quartzite-bearing ash-flow tuff (Eocene)**—White, pinkish red, white-gray, or pink-gray welded tuff containing abundant angular gray quartzite lithics and less abundant smoky quartz and plagioclase (Tqt of Blankenau, 1999). Poorly to densely welded.

Tcg_1 **Basal conglomerate (Eocene)**—Subrounded to well-rounded cobble to boulder, clast-supported conglomerate with a fine white to gray ash matrix. Clasts are entirely quartzite (Tcg_1 of Blankenau, 1999, but not previously mapped in the area immediately south of the Lemhi Pass fault).

Intrusive Rocks

Tr **Rhyolite dikes (Eocene)**—Tan, iron-stained dikes with quartz phenocrysts in an aphanitic groundmass.

Tpd **Porphyritic dacite (Eocene)**—Small stock in central part of map. Contains 2-4 mm phenocrysts of plagioclase, quartz, hornblende, and biotite in an aphanitic groundmass.

Tmd **Monzodiorite dikes and sills (Eocene)**—Dark gray fine- to medium-grained to porphyritic hornblende monzodiorite concentrated south-southwest of Goldstone Mountain. Hornblende acicular. Wide textural and possibly compositional variation on decimeter to meter scale. Overall less malic than *Tdi* dikes. Locally contains xenoliths of vein quartz aligned with flow fabric suggesting intrusion into quartz vein system. Intrusion and (or) quartz vein system may be related to local mineralization.

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. Sample 08RB057 from Goldstone Pass quadrangle to the north has U-Pb age of 46 ± 2 Ma (Richard Gaschnig, written commun., 2009). Records Eocene or later faulting where it is foliated or has sheared margins, such as north of Wade Creek.

Mesoproterozoic Strata

Low metamorphic grade metasedimentary rocks of Mesoproterozoic age underlie most of the Goldstone Mountain quadrangle. These rocks have been variously assigned by previous workers to the Lemhi Group and (or) the Yellowjacket Formation. All are fine-grained quartzite, siltite, and argillite located southwest of the western strand of the Bloody Dick Creek fault (4 km (6.5 mi) east of map; Lewis and others, 2009a) and part of what we consider the "western sequence" in the Beaverhead Range. This sequence is here correlated with the Lemhi Group of the Belt Supergroup because of similarities to type 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, 2009b), we divided this sequence into five informal units based on grain size, presence of carbonate, and sedimentary structures. Only the lowest of those units is exposed in the Goldstone Mountain quadrangle.

Ysq **Siltite, quartzite, and argillite (Mesoproterozoic)**—Dominated by laminated siltite and argillite, the unit contains coarser and thicker intervals. Finer grained intervals have graded couplets and couples of dark siltite and darker, gray to green argillite. Up to about one third of these intervals is white (weathering) very fine-grained feldspathic quartzite that gives the rock a candy striped appearance. These quartzite layers commonly are discontinuous and preserve hummocky and ripple drift cross laminations, some of which are distorted in loads, and rarely have lag bases that have more and coarser quartz. Thick siltite beds have more diffuse multi-mm to cm laminations that are planar, gently undulating (hummocky), disturbed by soft sediment deformation, or deformed into similar folds where cleavage development is extreme. Intervals contain sets of several to tens of dm to m thick white very fine- to fine-grained feldspathic quartzite beds with bases loaded into dark argillite tops of underlying beds. Thick beds typically have bedding defined by dark mm-scale laminations. Most laminations are planar, but load and convolute lamination and dm thick stacks of cm-scale ripple cross lamination are common. Attempts to map coarse intervals across the terrane were unsuccessful. This possibly indicates that they are channels, not sheets, but structural dissection of the stratigraphy probably contributed to their discontinuity. Thickness uncertain because of deformation, 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.
- Thrust fault: teeth on upper plate; dashed where approximately located; dotted where concealed.
- Detachment fault: hachures on upper plate; 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.
- 65 Strike and dip of bedding; ball indicates bedding known to be upright.
- 60 Strike and dip of bedding, strike approximate.
- 50 Strike and dip of bedding, strike variable.
- Horizontal bedding.
- 30 Strike and dip of bedding determined from 3-point analysis on bed trace in Google Earth 3-D imagery.
- 24 Strike and dip of foliation.
- 60 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.
- 20 Bearing and plunge of lineation, type unknown.
- 15 Bearing and plunge of small fold axis.
- 30 Bearing and plunge of mylonitic lineation.
- 5 Bearing and plunge of asymmetrical small fold showing clockwise rotation viewed down plunge.
- 5 Bearing and plunge of asymmetrical small fold showing counter-clockwise rotation viewed down plunge.
- 70 Bearing and plunge of crenulation lineation.
- Vein.
- Dike.
- Location of Mesoproterozoic granite boulder.
- Fault breccia.
- Headwall scarp of landslide; ticks on top of scarp.
- Mylonite.

Structure

Several faults, both contractional and extensional, and folds traverse the quadrangle. The extension faults are discussed in detail by Blankenau (1999) and are shown in a simplified map by Janecke and others (2001). These faults typically bound Tertiary units and controlled their distribution.

Pattee Creek Thrust

A mylonite zone exposed in the canyon of Pattee Creek is termed here the Pattee Creek thrust. The fault is characterized by a subhorizontal mylonite zone a few hundred feet thick developed in both Mesoproterozoic rocks and pegmatite. Lineations bear almost due east. This mylonitic zone shows tops-to-the-east kinematic indicators and is locally folded. Proterozoic rocks in the footwall appear to be finer grained than those in the hanging wall, but less than 100 m (300 ft) of section is exposed and so they have not been subdivided on this map. We suspect that this structure is part of a major east-vergent thrust system that may daylight again on the east side of the Beaverhead Mountains as the western strand of the Bloody Dick Creek fault in the adjacent Kitty Creek quadrangle (Lewis and others, 2009a). Locally within *Ysq* there are sheared out asymmetrical folds and stretching lineations on axial-surface cleavage that are consistent with this motion being distributed above the mylonite as well.

Other Faults within Proterozoic Rocks

Faults within the *Ysq* package are probable but difficult to document due to the lack of stratigraphic control. Likely locations are where bedding attitudes change abruptly and cleavage is best developed, but proving that these are faults and not just sharp folds is difficult. One such zone east of Goldstone Mountain contains steep, tight folds and vein quartz; another crosses the East Fork Kenney Creek in the center of section 18. Neither juxtaposes rocks sufficiently different to map as different units, so they could be minor ramps in the east-vergent thrust system.

Lemhi Pass Fault

The Lemhi Pass fault can be traced westward from Lemhi Pass to the southern edge of the map. VanDenburg (1997) and Blankenau (1999) interpret the structure as a 22-24° south-dipping detachment fault. Blankenau speculates that the Lemhi Pass fault is offset to the north by the Salmon basin detachment, an interpretation tentatively adopted for this map, although we place the western segment slightly farther north than he did.

Salmon Basin Detachment and Fault "C"

The range front fault was mapped by Tucker (1975) and later interpreted as a low-angle detachment fault by Blankenau (1999). It is well exposed along Kenny Creek where conglomerate is in contact with cataclasite formed from Proterozoic rocks. There the detachment has a dip of less than 15 degrees. The fault in Kenny Creek is also described by Tucker and Birdseye (1989) who interpret the hanging-wall deposits as an Eocene synvolcanic alluvial fan complex. The "C" fault of Blankenau (1999) is postulated to cross the southwest corner of the map. The fault is poorly exposed, but is interpreted to form the northeast margin of a second (more southwesterly) Tertiary basin.

Folds

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.

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