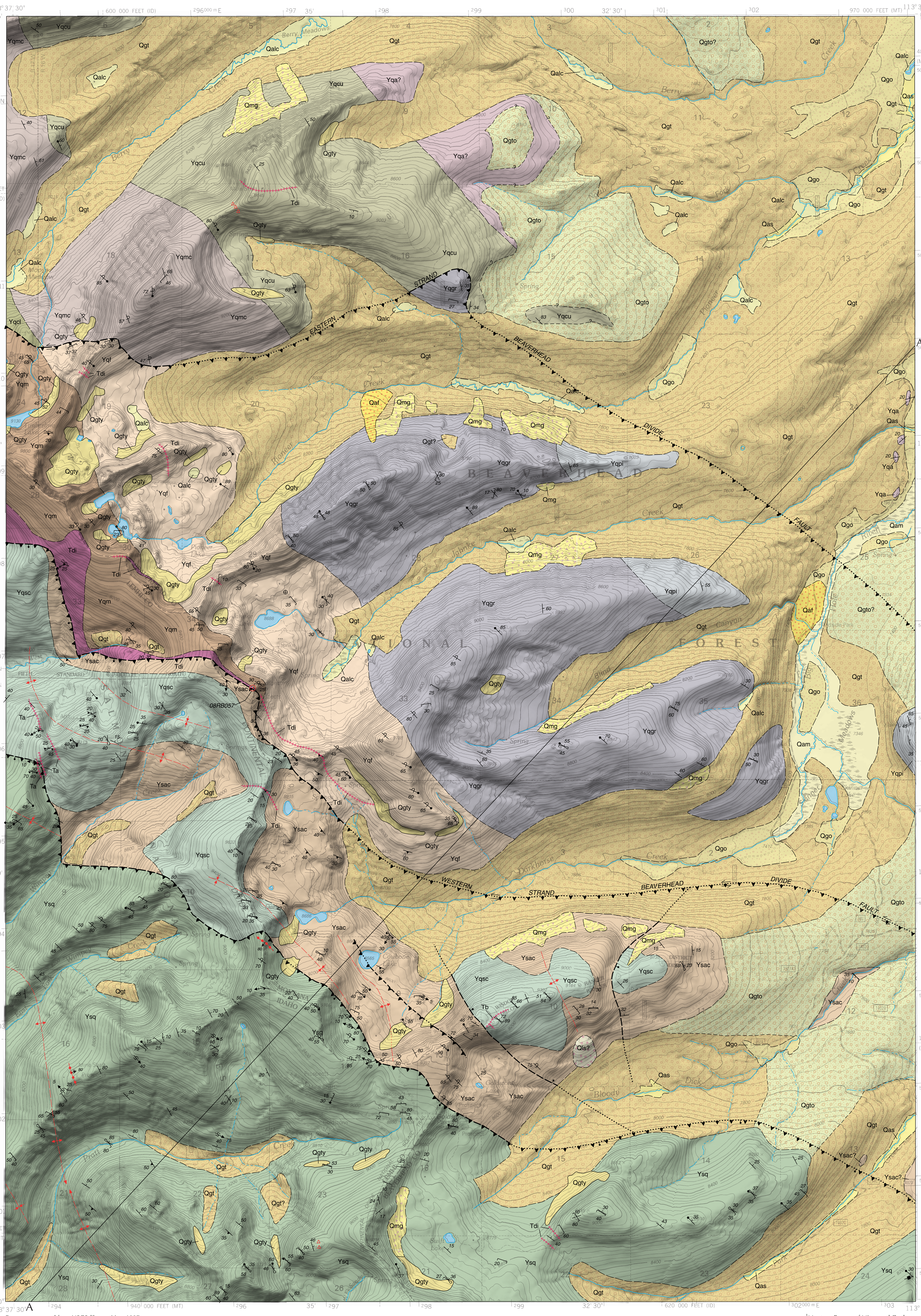
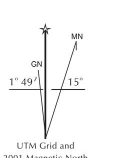
Geologic Map of the Goldstone Pass Quadrangle, Lemhi County, Idaho, and Beaverhead County, Montana

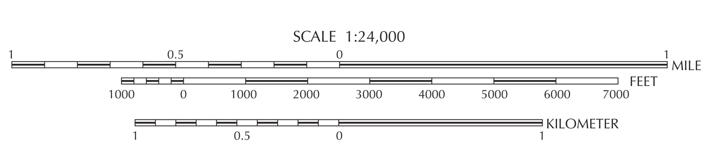
Jeffrey D. Lonn[1], Loudon R. Stanford[2], Russell F. Burmester[2], Reed S. Lewis[2], and Mark D. McFadden[2]

2009





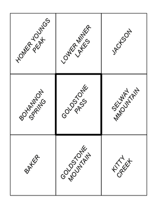
Base map scanned from USGS film positive, 1997.
Shaded elevation from 10 m DEM, vertically exaggerated 2x.
Topography compiled 1985. Planimetry derived from imagery taken 1995 and other sources.
Projection: Idaho coordinate system, central zone (Transverse Mercator). 1927 North American Datum.
10,000-foot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



SCALE 1:24,000

Contour interval 40 feet

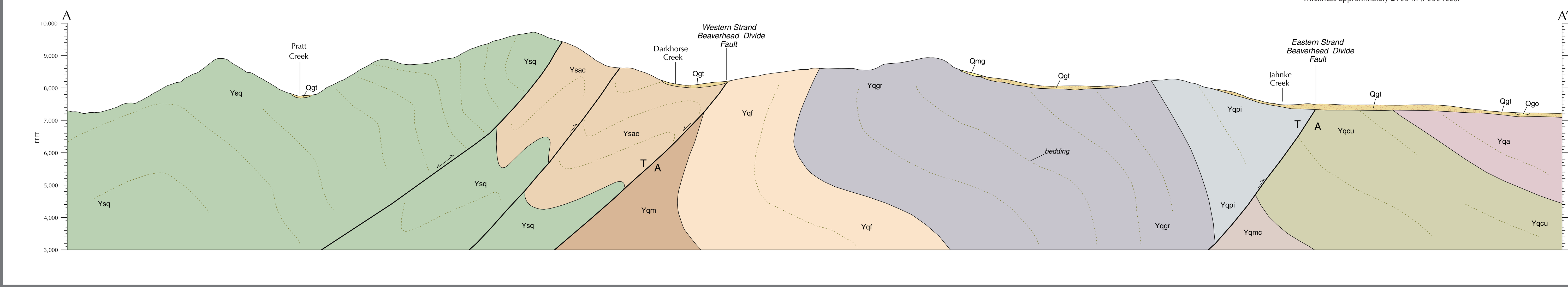
QUADRANGLE LOCATION



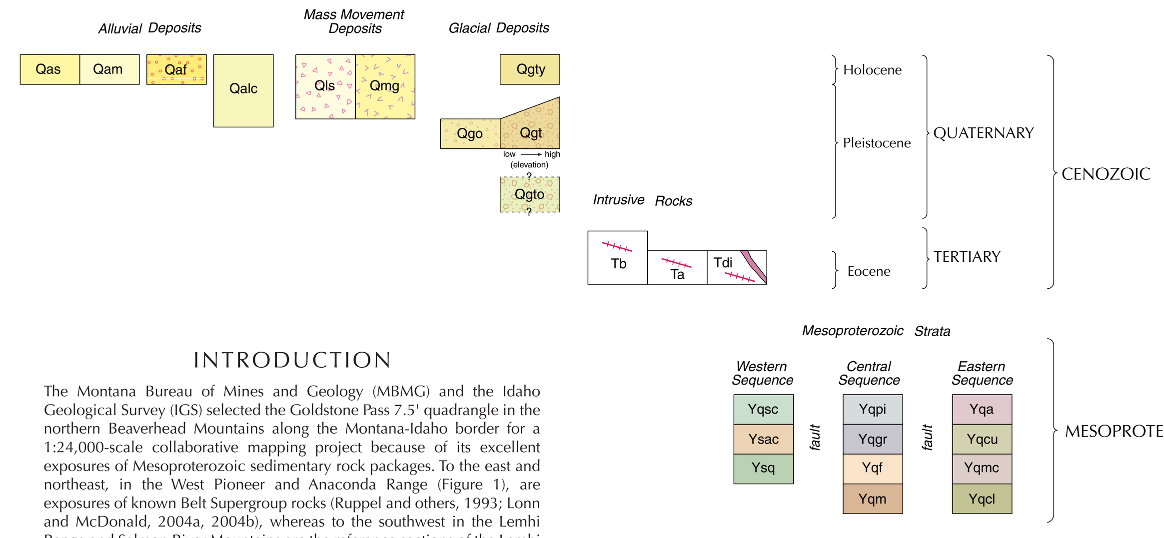
ADJOINING QUADRANGLES

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

Field work conducted 2008.
This geologic map was funded in part by the U.S. Geological Survey National Cooperative Geologic Mapping Program, USGS Award No. 08HQAG0054 (IGS).
Digital cartography by Loudon R. Stanford and Jane S. Freed at the Idaho Geological Survey's Digital Mapping Lab.
Map version 12-9-2009.
PDF (Acrobat Reader) map may be viewed online at www.idahogeology.org and www.mbmg.mtech.edu.



CORRELATION OF MAP UNITS



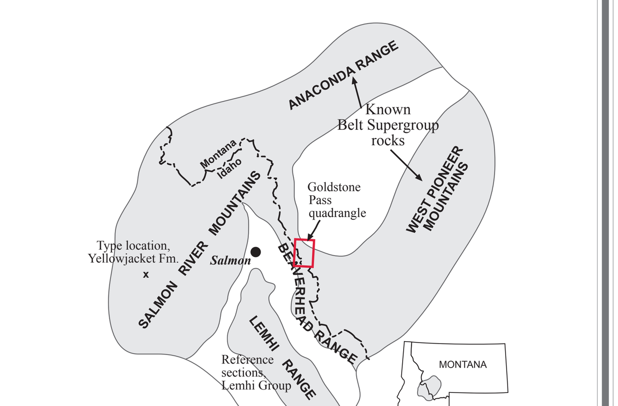


Figure 1. Location of Goldstone Pass 7.5' quadrangle with respect to known Belt Supergroup rocks and the reference and type sections of the Lemhi Group and Yellowjacket Formation. Shaded areas represent mountain ranges containing Mesoproterozoic sedimentary rocks.

INTRODUCTION

The Montana Bureau of Mines and Geology (MBMG) and the Idaho Geological Survey (IGS) selected the Goldstone Pass 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 Mesoproterozoic sedimentary rock packages. To the east and northeast, in the West Pioneer 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; Lopez and others, 2006). 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 and 2009 by Lonn, Burmester, Lewis, and McFadden was supplemented by earlier reconnaissance work by Lonn in 2004. Quaternary deposits were mapped in 2008 by Stanford. Attitudes from previous mapping by Anderson (1957 and unpublished mapping), Tucker (1975), and Lopez and others (2006) 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 is 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. Mostly 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 1-3 m (3-10 ft).

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

Qaf **Alluvial and debris-flow (fan gravels (Holocene)**—Angular to subangular poorly sorted boulder gravels and sand. Found on steep valley walls. Thickness 1-10 m (3-30 ft).

MASS MOVEMENT DEPOSITS

Qls **Landslide deposits (Holocene)**—Angular unsorted sandy boulder gravel. Thickness less than 12 m (40 ft).

Qmg **Mass movement and glacial deposits undifferentiated (Holocene)**—Angular unsorted to poorly sorted boulder to large boulder gravels. Mostly ramparts and slumps derived from moraine remnants and frost-wedged debris. Found high on glaciated valley walls. Includes some alluvial-fan gravel and young glacial and periglacial deposits. Thickness less than 18 m (60 ft).

GLACIAL DEPOSITS

Qgty **Young glacial and periglacial deposits (Holocene?)**—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 of the Little Ice Age and older(?) deposits in cirques and northeast-facing protected areas 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. Larger 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). Thickness up to 25 m (80 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 2600 m (8600 ft). Includes end moraine, recessional moraine, and some outwash. Thickness up to 120 m (400 ft).

Qgto **Older till deposits of the last glacial maximum (Pinedale) (Pleistocene)**—Poorly sorted bouldery till. Mostly subangular to subrounded clasts. Remnant till present on interfluve surfaces 80-180 m (260-600 ft) above more recently glaciated valley floors in the Berry Creek and Pioneer Creek drainages. Also found down stream from terminal moraine deposits of Qgt in the Bloody Dick Creek and Big Hole River drainages. Thickness highly varied, up to 50 m (160 ft).

Qgo **Glacial outwash gravels of last local glacial maximum (Pinedale) (Pleistocene)**—Subrounded to rounded, sorted sandy cobble to boulder gravel. Deposit on terrace 1.5 m (5 ft) above Qam. Thickness at least 2 m (6 ft).

INTRUSIVE ROCKS

Tb **Basalt dike (Tertiary)**—Single fine-grained mafic dike that appears to be less altered and thus younger than the Tdi unit. Exposed on the ridge southeast of Cowbone Lake where it both cuts bedding and locally branches parallel to it.

Ta **Andesite dikes (Eocene)**—Four north-northwest striking mafic dikes near the western map boundary. Euhedral plagioclase and hornblende 1 mm and less in length and similarly small stubby pyroxene(?) crystals compose the bulk of the rock.

Tdi **Diorite dikes and sills (Eocene)**—Medium- to fine-grained hornblende diorite. Similar rocks to the northwest 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 western strand of the Beaverhead Divide fault, where it is typically foliated or has sheared margins and chloritized fractures, and within the country rock near that fault, where it is less deformed. Sample 08RB057 has U-Pb age of 46 ± 2 Ma (Richard Gaschnig, written commun., 2009).

MESOPROTEROZOIC STRATA

Low metamorphic grade metasedimentary rocks of Mesoproterozoic age underlie most of the Goldstone Pass 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 and siltite 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. In the Homer Youngs Peak quadrangle, northwest of the Goldstone Pass quadrangle, we divided this thick (6000 m; 19,000 ft) sequence into four informal units based on grain size and sedimentary structures (Lonn and others, 2008). All four of those units are exposed in the Goldstone Pass quadrangle.

Yqa **Quartzite and argillite (Mesoproterozoic)**—Pink to white, medium- to coarsee-grained, trough- and planar-crossbedded quartzite in beds 15 cm to 1 m-thick, interbedded with 15 cm to 1 m-thick intervals of purple to green siltite and argillite in planar beds 0.6 to 5 cm-thick. Top of unit not exposed, but thickness at least 450 m (1500 ft). Very fine- to fine-grained feldspathic quartzite with rare red mud chips exposed in three small road cuts west of the Big Hole River tentatively included in this unit.

Yqcu **Upper coarse-grained quartzite (Mesoproterozoic)**—White to light gray, poorly sorted, coarse-grained, trough and planar crossbedded feldspathic quartzite. Beds are 30-180 cm thick, separated by black argillite interbeds as much as 8 cm thick. Contains abundant granule-sized grains and sparse floating pebbles. Large black mud rip-up clasts are common. Thickness approximately 1500 m (5000 ft).

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 feet).

Yqcl **Conglomeratic quartzite (Mesoproterozoic)**—White to light gray, poorly sorted, medium- to coarse-grained, trough and planar crossbedded, feldspathic quartzite. Exposed only at the western edge of the map. Base of unit not exposed. Similar quartzite along strike to the northwest in the Homer Youngs Peak quadrangle contains more potassium feldspar than plagioclase (Lonn and others, 2008). Minimum thickness in that quadrangle is 1800 m (6000 ft).

Central Sequence

Between the eastern and western strands of the Beaverhead Divide fault is a near-vertical, east-facing, 5300 m (17,000 ft) thick stratigraphic sequence of feldspathic, very fine- to medium-grained quartzite and subordinate siltite. Correlation of this sequence to units either west or east is uncertain. Most of this sequence is similar to the western sequence described below, but the lowest unit (Yqm, medium-grained quartzite) resembles rocks of the eastern sequence. We divided the central sequence into four informal units based on grain size, color, and sedimentary structures.

Yqpi **Pink quartzite (Mesoproterozoic)**—Medium- to fine-grained, well-sorted feldspathic quartzite that has a pinkish cast on fresh surfaces. Typically flat-laminated m to dm beds with little siltite or argillite. Includes more mud chips and muscovitic parting surfaces than underlying unit. One quartzite sample contains about 40 percent plagioclase and no potassium feldspar. The plagioclase in that sample is highly recrystallized. Top of unit not exposed, but thickness at least 900 m (3000 ft).

Yqgr **Green quartzite (Mesoproterozoic)**—Pale green, fine-grained feldspathic quartzite. Typically m- to dm-thick beds of flat-laminated to non-laminated quartzite and varied dark green siltite, most as graded tops to thick quartzite beds. Rare red argillite skins in upper part. Commonly weathers white but has surface stain of rusty red. Includes rare mud chips and muscovitic parting surfaces. Ten quartzite samples contain about 30-50 percent plagioclase and 0-10 percent potassium feldspar. Some of the potassium feldspar is patchy and probably secondary. One quartzite sample from the uppermost part of the unit contains about 16 percent plagioclase and 15 percent potassium feldspar. Appears to grade upward into *Yqpi* with increase in grain size through a zone of alternating colors. Grades downward into *Yqf* with a decrease in siltite and an increase in dark laminations that define trough cross beds and decrease in ripple cross lamination. Thickness approximately 2200 m (7000 ft).

Yqf **Fine-grained quartzite (Mesoproterozoic)**—Pale green to gray, fine- to very fine-grained, medium- to thick-bedded light-weathering feldspathic quartzite and minor darker siltite and argillite. Many beds appear to have about 30 percent feldspar; one quartzite sample contains about 18 percent plagioclase and 7 percent potassium feldspar. Bedding defined by dark laminations of specular hematite in discontinuous, non uniform laminations up to 2 mm thick. Despite well-developed cleavage or foliation, the dark laminations define large, low-angle trough cross bedding. High-angle planar, ripple, and climbing ripple cross lamination as well as flat laminations are less common. Some steep laminations (30-60 degree) truncate underlying laminations, defining loads that apparently grew during deposition. Argillite is present as thin layers or skins (some discontinuous) on quartzite parting surfaces, rarely as light-colored mud chips, and as graded tops of darker siltite and argillite couples within the unit. The lower contact with Yqm is obscured by strong northwest-striking, southwest-dipping cleavage developed at an acute angle to bedding, but Yqf appears to grade down section into Yqm. An alternate explanation is that the contact is a fault. Yqf is lithologically similar to the *Yqff* unit of the western sequence exposed to the northwest in the Homer Youngs Peak and Bohannon Spring quadrangles that is tentatively correlated with the Gunsight Formation of the Lemhi Group (Lonn and others, 2008; Lewis and others, 2009). Some folding in this unit makes thickness estimates problematic, but it is roughly 900 m (3000 ft) thick.

Yqm **Medium-grained quartzite (Mesoproterozoic)**—White, medium-grained quartzite in upward-fining sequence. Upper part is 15-30 cm thick flat-laminated quartzite beds interbedded with 7- to 10-cm-thick green argillite and siltite. Fewer and more diffuse heavy mineral laminations, more argillite, and thinner beds than the overlying Yqf unit. Lower part is more thickly bedded white quartzite. Two quartzite samples contain about 14 percent plagioclase and 10-11 percent potassium feldspar. Base of unit not exposed, but thickness at least 600 m (2000 ft). Approximately 1200 m (4000 ft) is present on the Bohannon Spring quadrangle to the west.

Western Sequence

West of the western strand of the Beaverhead Divide fault is a folded sequence consisting of siltite, fine- to very fine-grained feldspathic quartzite, and argillite. Carbonate cement is present locally. We correlate this sequence with the Lemhi Group of the Lemhi Range because of similarities to known Lemhi Group rocks 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 west in the Bohannon Spring quadrangle we divided this sequence into six informal units based on grain size, presence of carbonate, and sedimentary structures (Lewis and others, 2009). Only the three lowest of those units are exposed in the Goldstone Pass quadrangle.

Ysqc **Carbonate-bearing quartzite and siltite (Mesoproterozoic)**—Light 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 formerly occupied by carbonate, particularly near the upper part of the unit and, in places, appreciable magnetite. Two quartzite samples contained about 40-56 percent plagioclase and no potassium feldspar. A third contained patchy (late?) potassium feldspar (about 4 percent) and about 38 percent plagioclase. Thickness uncertain due to folding and erosion, but approximately 700 m (2300 ft) immediately west of map. Tentatively correlated with the Big Creek Formation of the Lemhi Group (Ruppel, 1975) based on similarity with rocks described in its type section.

Ysac **Carbonate-bearing siltite, argillite, and quartzite (Mesoproterozoic)**—Laminated to thinly bedded light green, darker argillite, and white, carbonate-bearing fine-grained feldspathic quartzite. More gray and less green in upper part of unit. Siltite and argillite as distinct, laterally discontinuous laminae and graded couplets but deformation obscures these characteristics where unit becomes a light colored phyllite. Local ptygmatically folded silt in non-polygonal "crinkle cracks". Includes 5-10 percent dm-scale or thinner siltite and quartzite that display hummocky and thin ripple cross lamination, load, and convolute bedding. Fine-grained quartzite layers similar to *Ysq*, but color and grain size variation typically more diffuse. Locally, some of these layers contain $MnCO_3$, judging by solubility in weak acid and chocolate-brown weathering, but some of this may be remobilized instead of original. Carbonate is most abundant in the Cowbone Lake area and may be more common low in the unit. Thicker skins of dark argillite have fluid escape structures to 3 cm wide. Highly folded, but a minimum thickness of 800 m (2600 ft) likely. Tentative correlation with the West Fork Formation of the Lemhi Group (Ruppel, 1975) because it appears below Ysqc.

Ysq **Siltite, quartzite, and argillite (Mesoproterozoic)**—Laminated to thin bedded dark green siltite and dark argillite. Coarser intervals have quartzite as thin (cm) bases of beds grading to dark siltite and darker argillite, and as thick layers commonly in groups of several beds. Siltite layers cm scale 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 mud chips and coarse quartz lag deposits a few cm thick. These alternate on a scale of 10-100 m with zones characterized by red-tan weathering slaty, very dark gray argillite that locally displays pinch and swell sediment type characteristics including clastic dikelets. Quartzite commonly has bedding defined by dark 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 any other. Nine quartzite samples contain 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 and commonly cleaved to foliated, with cleavage in graded beds curving from more normal in coarser bases to more bedding-parallel in argillitic tops. Cleavage in finer beds is axial planar to similar folds of the siltite and argillite couplets. Similar to, but overall coarser than, *Ysac* unit. Thickness highly uncertain, but minimum thickness 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.

STRUCTURE

The most prominent structure in the map, the Beaverhead Divide fault, was first described by MacKenzie (1949), who referred to the structure as the Miner Lakes fault. Anderson (1959) mapped its extension northwest and Tucker (1975) extended it southeast. 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. 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 it 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 suggests that the Beaverhead Divide fault is a southwest-dipping zone of both ductile and brittle deformation whose activity may span a long time (Proterozoic? to Eocene). On the Homer Youngs Peak quadrangle (Lonn and others, 2008), two closely spaced strands of the Beaverhead Divide fault were mapped. The eastern and western strands trace southeastward into the Goldstone Pass quadrangle, where they diverge and separate the map area into three major structural domains, each containing a distinct stratigraphic package, here termed the eastern, central, and western sequences. The eastern domain is a thick east-facing panel of overturned to moderately east-dipping strata (*Yqa*, *Yqcu*, *Yqmc*, *Yqcl*), tentatively assigned to the Missoula Group. Lonn and others (2008) interpreted this panel as the west limb of a huge east-verging syncline similar to the gigantic folds mapped by Tysdal (2002) in the Lemhi Range southwest of the map area. Cleavage in this domain is weakly developed, but roughly parallels the strong northwest-striking, steeply southwest-dipping cleavage of the central domain. The eastern strand of the Beaverhead Divide fault separates weakly foliated, east-facing vertical strata on the northeast (*Yqmc and Yqcu*) from strongly foliated east facing rocks on the southwest (*Yqm* and *Yqf*). The fault zone strikes northwest to west, dips southwest to south, and is characterized by chloritic breccia containing a mixture of strongly foliated and non-foliated clasts. The portions of the fault that are more northwesterly are interpreted as having moved as thrust faults during Cretaceous compressional deformation, while the more easterly trending portions are likely to have had a large component of left-lateral motion during that time. Brittle deformation probably post-dates thrusting, and may represent reactivation of the thrust as a normal fault.

The central domain consists of near vertical, east-facing strata of uncertain correlation (*Yqpi*, *Yqgr*, *Yqf*, and *Yqm*). This panel of central sequence strata roughly parallels that of the eastern domain, and it is possible that the central and eastern stratigraphic sequences are part of the same giant fold and that they were originally in stratigraphic contact. Strong northwest-striking, southwest-dipping cleavage is developed in the central domain; this cleavage is approximately parallel to the northwest-striking parts of both strands of the Beaverhead Divide fault, and is also parallel to the mylonitic foliation associated with the western strand. The western strand of the Beaverhead Divide fault is a zone of 25° to 60° southwest-dipping mylonitic foliation that approximately parallels the northwest to west strike of the zone. Because the western strand Beaverhead Divide fault and the Freeman thrust of the Homer Youngs Peak quadrangle (Lonn and others, 2008) merge just northwest of the Goldstone Pass quadrangle, the western strand here represents the combined displacement on both faults. It separates units *Yqm* and *Yqf* of the central sequence from *Ysac* of the western sequence. This ductile shear zone contains mafic sills (*Tdi*) that exhibit foliation parallel to that of the shear zone. Lineation within these sills plunges to the southwest with s-c fabric indicating top to the west normal motion. Like the sub-parallel eastern strand, this northwest-striking fault jogs eastward in the Goldstone Pass quadrangle. The portions that strike northwest are interpreted as having moved as thrust faults during Cretaceous compressional deformation, while the east-west striking portions are thought to have had a large component of left-lateral motion. Both strands of the Beaverhead Divide fault appear to turn southward just east of the quadrangle and become the Bloody Dick Creek fault zone of the Kitty Creek quadrangle (Lewis and others, 2009).

The western domain is complexly folded and faulted. Two ill-defined thrust faults were mapped. The northeastern of the two that passes through Cowbone Lake is characterized by strong foliation. Rocks in its hanging wall are tightly folded and locally overturned. The other fault southwest of Cowbone Lake is characterized by both ductile and brittle deformation. Mylonite and chloritic shears are present in the saddle south of Cowbone Lake and mylonite is present on the ridge near the west map boundary. Northeast-facing strata in its hanging wall are overturned or steeply northeast dipping. An asymmetric fold in it indicates some top to the west motion so it is probable that it, like the western strand of the Beaverhead Divide fault, was reactivated during Eocene extension.

SYMBOLS

Contact: dashed where approximately located.

Oblique thrust fault: teeth on upper plate; arrows indicate direction of motion; dashed where approximate; dotted where concealed.

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, dashed where 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 mylonitic foliation.

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

50 Strike and dip of cleavage.

Strike of vertical joint.

30 Bearing and plunge of mylonitic 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.

80 Vein.

Dike.

Fault breccia.

08RB057 Date sample location and number.

REFERENCES

Anderson, A.L., 1957, Geology and mineral resources of the Baker quadrangle, Lemhi County, Idaho: Idaho Bureau of Mines and Geology Pamphlet 112, 71 p.

Anderson, A.L., 1959, Geology and mineral resources of the North Fork quadrangle, Lemhi County, Idaho: Idaho Bureau of Mines and Geology Pamphlet 118, 92 p.

Evans, K.V., and G.N. Green, 2003, Geologic map of the Salmon National Forest and vicinity, east-central Idaho: U.S. Geological Survey Geologic Investigations Series Map I-2765, 19 p., scale 1:100,000.

Kilroy, K.C., 1981, $^{40}Ar/^{39}Ar$ geochronology and geochemistry of the Carmen Creek stock, and related intrusions of the northern Beaverhead Mountains, Idaho-Montana: Columbus, Ohio, Ohio State University, M.S. thesis, 100 p.

Lane, E.W., 1947, Report of the subcommittee on sediment terminology: Transactions of the American Geophysical Union, v. 28, no. 6, p. 936-938.

Lewis, R.S., R.F. Burmester, K.L. Othberg, J.D. Lonn, L.R. Stanford, and M.D. McFaddan, 2009, Geologic map of the Bohannon Spring quadrangle, Lemhi County, Idaho and Beaverhead County, Montana: Idaho Geological Survey Digital Web Map 113 and Montana Bureau of Mines and Geology Open File Report 583, scale 1:24,000.

Lewis, R.S., R.F. Burmester, L.R. Stanford, J.D. Lonn, M.D. McFaddan, and K.L. Othberg, 2009, Geologic map of the Kitty Creek quadrangle, Lemhi County, Idaho and Beaverhead County, Montana: Idaho Geological Survey Digital Web Map 112 and Montana Bureau of Mines and Geology Open File Report 582, scale 1:24,000.

Lonn, J.D., R.F. Burmester, R.S. Lewis, and L.R. Stanford, 2008, Geologic map of the Homer Youngs Peak quadrangle, Lemhi County, Idaho, and Beaverhead County, Montana: Idaho Geological Survey Digital Web Map 95 and Montana Bureau of Mines and Geology Open File Report MBMG 575, scale 1:24,000.

Lonn, J.D., and Catherine McDonald, 2004a, Geologic map of the Kelly Lake 7.5' quadrangle, western Montana: Montana Bureau of Mines and Geology Open File Report MBMG 500, 15 p., scale 1:24,000.

Lonn, J.D., and Catherine McDonald, 2004b, Geologic map of the Dickie Hills 7.5' quadrangle, southwestern Montana: Montana Bureau of Mines and Geology Open File Report MBMG 501, 14 p., scale 1:24,000.

MacKenzie, W.O., 1949, Geology and ore deposits of a section of the Beaverhead Range east of Salmon, Idaho: Moscow, Idaho, University of Idaho, M.S. thesis, 65 p., scale 1:31,000.

McKee, E.D., and G.W. Weir, 1953, Terminology for stratification and crosss-stratification in sedimentary rocks: Geological Society of America Bulletin, v. 64, p. 381-390.

Lopez, D.A., J.M. O'Neill, and E.T. Ruppel, 2006, Preliminary geologic map of the Montana parts of the Goldstone Pass and Goldstone Mountain quadrangles, southwestern Montana: Montana Bureau of Mines and Geology Open File Report MBMG 536, scale 1:24,000.

O'Neill, J.M., 2005, Newly recognized Chief Joseph metamorphic core complex and younger structures in the north-central Beaverhead Mountains-expanding the temporal and spatial limits of post contractional extension in the northern Rocky Mountains: Geological Society of America Abstracts with Programs, v. 37, no. 6, p. 4.

Ross, C.P., 1934, Geology and ore deposits of the Casto quadrangle, Idaho: U.S. Geological Survey Bulletin 854, 135 p.

Ruppel, E.T., 1975, Precambrian Y sedimentary rocks in east-central Idaho: U.S. Geological Survey Bulletin 889-A, 23 p.

Ruppel, E.T., J.M. O'Neill, and D.A. Lopez, 1993, Geologic map of the Dillon 1° x 2° quadrangle, Idaho and Montana: U.S. Geological Survey Miscellaneous Investigations Series Map I-1803-H, scale 1:250,000.

Tucker, D.R., 1975, Stratigraphy and structure of Precambrian Y (Belt?) metasedimentary and associated rocks, Goldstone Mountain quadrangle, Lemhi County, Idaho, and Beaverhead County, Montana: Oxford, Ohio, Miami University, Ph.D. dissertation, 221 p., scale 1:48,000.

Tysdal, R.G., 2000, Stratigraphy and depositional environments of Middle Proterozoic rocks, northern part of the Lemhi Range, Lemhi County, Idaho: U.S. Geological Survey Professional Paper 1600, 40 p.

Tysdal, R.G., 2002, Structural geology of the western part of the Lemhi Range, east-central Idaho: U.S. Geological Survey Professional Paper 1659, 33 p.

Tysdal, R.G., 2003, Correlation, sedimentology, and structural setting, upper strata of Mesoproterozoic Apple Creek Formation and lower strata of Gunsight Formation, Lemhi Range to Salmon River Mountains, east-central Idaho, *in* R.G. Tysdal, D.A. Lindsey, and J.E. Taggart, Jr., eds., Correlation, sedimentology, structural setting, chemical composition, and provenance of selected formations in Mesoproterozoic Lemhi Group, central Idaho: U.S. Geological Survey Professional Paper 1668-A, p. 1-22.

Tysdal, R.G., D.A. Lindsey, K.I. Lund, and G.R. Winkler, 2005, Alluvial facies, paleocurrents, and source of the Mesoproterozoic Gunsight Formation, east-central Idaho and southwestern Montana, Chapter B, *in* J.M. O'Neill, and R.G. Tysdal, eds., Stratigraphic studies in southwestern Montana and adjacent Idaho–Lower Tertiary Anaconda Conglomerate and Mesoproterozoic Gunsight Formation: U.S. Geological Survey Professional Paper 1700-B, p. 21-39.

Winston, Don, 1986, Sedimentology of the Ravalli Group, middle Belt carbonate, and Missoula Group, Middle Proterozoic Belt Supergroup, Montana, Idaho and Washington, *in* S.M. Roberts, ed., Belt Supergroup: A Guide to Proterozoic Rocks of Western Montana and Adjacent Areas: Montana Bureau of Mines and Geology Special Publication 94, p. 85-124.

Winston, Don, P.K. Link, and Nathan Hathaway, 1999, The Yellowjacket is not the Prichard and other heresies–Belt Supergroup correlations, structure, and paleogeography, east-central Idaho, *in* S.S. Hughes, and G.D. Thackray, eds., Guidebook to the Geology of Eastern Idaho: Pocatello, Idaho, Idaho Museum of Natural History, p. 3-20.

Published and sold by the Idaho Geological Survey and the Montana Bureau of Mines and Geology