GEOLOGIC MAP OF THE NORTH FORK QUADRANGLE, LEMHI COUNTY, IDAHO

Jeffrey D. Lonn, Kurt L. Othberg, Reed S. Lewis, Russell F. Burmester, Loudon R. Stanford, and David E. Stewart

2013

Base Map Credit

Base digitally scanned from 24,000-scale USGS film separates, 1966.

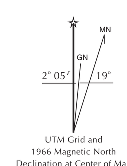
Shaded elevation from 10 m DEM.

Topography by photogrammetric methods from aerial photographs taken 1965. Field checked 1966.

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

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

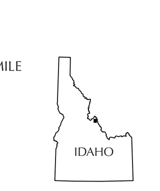
1000-meter Universal Transverse Mercator grid ticks, zone 12.

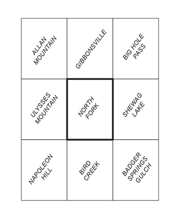


SCALE 1:24,000

MILE · FEET · KILOMETER

Contour interval 40 feet





Field work conducted 2012.

This geologic map was funded in part by the U.S. Geological Survey National Cooperative Geologic Mapping Program, USGS award number G12AC20113.

Digital cartography by Jane S. Freed at the Idaho Geological Survey's Digital Mapping Lab.

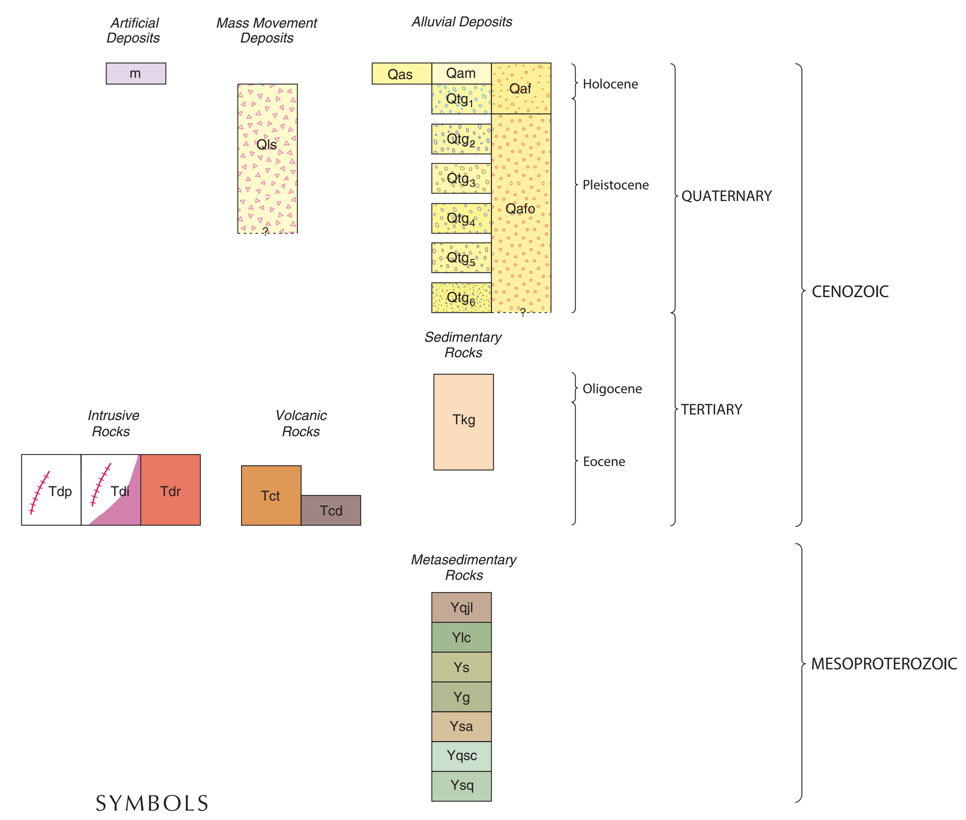
Map version 11-4-2013.

Technical review status: Authors only.

Editorial review by Alyson R. Kral.

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

CORRELATION OF MAP UNITS



SYMBOLS

- Contact: dashed where approximately located.
- Normal fault: ball and bar on downthrown side; dashed where approximately located; dotted where concealed.
- Detachment fault: hachures on upper plate; dotted where concealed.
- Thrust fault: teeth on upper plate; dashed where approximately located; dotted where concealed.
- Anticline axial trace; dashed where approximately located; dotted where concealed.
- Syncline axial trace; dashed where approximately located; dotted where concealed.
- Strike and dip of bedding.
- Strike of vertical bedding.
- Strike and dip of bedding where sedimentary structures show bedding to be upright.
- Approximate strike and dip of bedding.
- Strike and dip of flow or compaction foliation in volcanic rocks.
- Strike and dip of foliation.
- Strike and dip of cleavage.
- Strike and dip of vertical cleavage.
- Bearing and plunge of lineation, type unknown.
- Vein: arrow indicates dip.
- Location of Mesoproterozoic granite boulders.
- Tectonic breccia.
- Gravel pit or rock quarry.
- Landslide headwall.

INTRODUCTION

The map is the result of research and field work in 2011 and 2012, and previous work in the region by others. Many concepts for geologic units were developed in the Beaverhead Mountains to the southeast (e.g. Lonn and others, 2008; Lewis and others, 2009; Burmester and others, 2011a) during a 1:24,000-scale collaborative mapping project by the Idaho Geological Survey (IGS) and the Montana Bureau of Mines and Geology (MBMG) that started in 2007. Attitudes from previous mapping by Anderson (1959) were used to supplement the structural data collected by the authors. Soils information is from Hipple and others (2006).

The oldest rocks in the quadrangle are metasedimentary rocks of Mesoproterozoic age that form the mountains in the east but also underlie the Salmon River valley, and the Tertiary rocks in the central part of the map. Two major regional thrust faults and many normal faults displace the metasedimentary rocks. Remnants of Tertiary volcanic and sedimentary rocks of the Challis Volcanic Group extend along the central part of the map. The northern terminus of the Tertiary Salmon basin, here largely represented by conglomeratic sedimentary rocks, is within the quadrangle. Much of the basin sedimentary section has been eroded. The Quaternary deposits show evidence of terracing, incision, and landsliding.

DESCRIPTION OF MAP UNITS

The geologic map of the North Fork quadrangle shows rock units exposed at the surface or underlying a thin surficial cover of soil and colluvium. Surficial alluvial and landslide deposits are shown where they are thick and extensive enough to be mapped. Intrusive rocks are classified according to International Union of Geological Sciences (IUGS) nomenclature using normalized values of modal quartz (Q), alkali feldspar (A), and plagioclase (P), on a ternary diagram (Streckeisen, 1976). 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). Bed thicknesses are given in abbreviation of metric units (e.g. cm=centimeter). Formation thickness, distances, and elevation are listed in both metric and English units. Multiple lithologies within a rock unit description are listed in order of decreasing abundance.

ARTIFICIAL DEPOSITS

m **Made ground (Holocene)**—Artificial fills and gold placer tailings. Composed of excavated, transported, and emplaced earth materials typically derived locally. Includes dams and berms for small ponds.

ALLUVIAL DEPOSITS

Qam **Main-stream alluvium (Holocene)**—Well-rounded, moderately sorted and stratified pebble to boulder sandy gravel of the Salmon River. Gravel clasts include quartzite, siltite, granite, and volcanic rocks. Includes flood-plain areas of silt, clay, and sand. Deposits are 3-9 m (10-30 ft) thick. Soils undeveloped to weakly developed.

Qas **Side-stream alluvium (Holocene)**—Subrounded to well-rounded, moderately sorted and stratified pebble to boulder sandy gravel. Gravel clasts are primarily quartzite and siltite. Locally includes minor sheet wash, colluvium, and alluvial-fan deposits composed of angular, poorly sorted gravelly sandy silt. Deposits are 1-6 m (3-20 ft) thick. Soils undeveloped to weakly developed.

Qaf **Alluvial-fan and debris-flow deposits (Holocene to late Pleistocene)**—Angular to subrounded, poorly sorted, matrix-supported pebble to boulder gravel in a sand, silt, and clay matrix. Commonly grades into, interfingers with, and caps stream alluvium (*Qam, Qas, Qtg₁*). Thickness of deposits varies greatly, ranging from 1 to 24 m (3 to 80 ft). Soils weakly developed to moderately developed.

Qafo **Older alluvial-fan deposits (Pleistocene)**—Angular to subrounded, poorly sorted, matrix-supported pebble to boulder gravel in a matrix of sand, silt, and clay. Locally caps and interfingers with older terrace gravel (*Qtg_3, Qtg_4*). Thickness of deposits varies greatly, ranging from 1 to 15 m (3 to 50 ft). Soils moderately developed to well-developed.

GRAVEL TERRACE DEPOSITS

Gravel deposits of Pleistocene alluvial terraces are composed of moderately sorted, clast-supported sandy gravel. Clasts are subrounded to rounded pebbles and cobbles. Clasts are primarily quartzite and siltite from the adjacent mountains; granite and volcanic clasts are present in Salmon River terraces. Terrace deposits form relatively thin (3-9 m; 10-30 ft) caps over streamcut bedrock surfaces. Several levels of terraces and terrace remnants are preserved 9-210 m (30-700 ft) above the present-day streams. These record long-term episodic incision of the Salmon basin, which was probably driven by glacial climate during the Pleistocene. Terrace gravels commonly are capped by and interfinger with alluvial-fan deposits (*Qaf* and *Qafo*), which are included in the terrace unit locally.

Qtg_1 **Gravel of first terrace (Holocene to Late Pleistocene)**—Forms terrace approximately 9 m (30 ft) above Salmon River. Weakly developed soils.

Qtg_2 **Gravel of second terrace (Middle? Pleistocene)**—Forms terrace 12-18 m (40-60 ft) above the modern streams. Moderately developed soils.

Qtg_3 **Gravel of third terrace (Middle? Pleistocene)**—Forms terrace 30-46 m (100-150 ft) above Fourth of July Creek. Well developed soils.

Qtg_4 **Gravel of fourth terrace (Middle? Pleistocene)**—Forms terrace approximately 61 m (200 ft) above the Salmon River. Well developed soils.

Qtg_5 **Gravel of fifth terrace (Early? Pleistocene)**—Forms terrace 91-122 m (300-400 ft) above the Salmon River. Soils of original terrace surface eroded away.

Qtg_6 **Gravel of sixth terrace (Early? Pleistocene)**—Forms terrace remnants 150-210 m (500-700 ft) above Fourth of July and Little Fourth of July creeks. May include outwash deposited by meltwater from glaciated mountains in the adjacent Shewag Lake quadrangle.

MASS MOVEMENT DEPOSITS

Qls **Landslide deposits (Holocene to Pleistocene)**—Unstratified, poorly sorted silty clay and gravelly silty clay. Deposited by slumps, slides, and debris flows. For some, map shows the landslide scarp and the headwall (steep area adjacent to and below the landslide scarp) from which material broke away (see Symbols).

TERTIARY SEDIMENTARY DEPOSITS OF THE SALMON BASIN

Harrison (1985) demonstrated that the late Eocene and Oligocene Salmon basin sediments form conformable units, and the lithologic distribution within the sediments resulted from depositional environments that varied by proximity to an active, basin-bounding fault. The sediments were deposited in alluvial-fan, braided-stream, mixed-channel and flood plain, and lake environments in a downfaulted subsiding basin. Only the Kriley Gulch formation (*Tkg*), comprising proximal deposits of primarily coarse-grained debris flows, is present in the North Fork quadrangle.

Tkg **Kriley Gulch formation (Oligocene and Eocene)**—Matrix-supported conglomerate and minor sandstone and claystone. Clasts are commonly cobbles and boulders that cover surfaces as lag deposits from weathered and eroded beds. Two deposits opposite the mouth of Hughes Creek near the northern part of the map contain boulders and cobbles of Precambrian granite and amphibolite gneiss that were likely sourced from rocks west of the Brushy Gulch fault (Evans and Green, 2003), 8 km (5 mi) southwest of North Fork. These two exposures also contain interlayered(?) Challis Volcanic Group rocks, suggesting an Eocene age of sediment deposition. Other exposures of *Tkg* here and to the south are likely younger (Oligocene?).

CHALLIS VOLCANIC GROUP

Rocks of the Challis Volcanic Group formed from eruptions, intrusions, erosion and deposition in the Eocene (about 51-44 Ma). They are widespread southwest of the North Fork quadrangle where they were mapped in the Challis 1° x 2° quadrangle (Fisher and others, 1992). About 60 km (40 mi) to the southeast of the North Fork quadrangle, northwest of Lemhi Pass, Blankenau (1999) established a stratigraphic section that is more useful for Salmon area mapping. However, only a few remnants of these volcanic rocks are present in the North Fork quadrangle.

Tct **Challis tuff, undivided (Eocene)**—Mixed unit of predominantly rhyolitic composition. Most or all of unit is welded tuff, but wide compositional range is suggestive of several extrusive events. The largest mass of tuff immediately southeast of Wagonhammer Creek contains abundant lithic clasts of medium gray, fine-grained quartzite along with abundant crystals of dark gray and light gray quartz, lesser plagioclase, and sparse altered mafic minerals. Crystal-lithic tuff is also present north of Wagonhammer Creek, but there the lithic clasts are dark gray to black. Tuff with black quartzite lithics is also present near the mouth of Little Fourth of July Creek. This part of the section is likely correlative to the Tqt unit on the Baker quadrangle southeast of Salmon (Othberg and others, 2011), which characteristically contains black quartzite lithic fragments. Stratigraphically above the tuff with black quartzite lithics is a crystal tuff containing feldspar, biotite, quartz, and possibly hornblende.

Tcd **Challis dacite (Eocene)**—Porphyritic hornblende-biotite dacite. Phenocrysts consist of plagioclase, quartz, biotite, and hornblende. Exposures in Little Fourth of July Creek have a very fine-grained to glassy groundmass and weather easily to a brown soil. They are interpreted here as dacite lava flows. Alternatively, these exposures may be shallow intrusive rocks and thus equivalent to *Tdr* unit. Exposures of *Tcd* near the northern map boundary include some rhyolite (*Tct?*), but most are probably dacite or andesite. Quartz phenocrysts are lacking in these rocks, but they are otherwise similar to dacite in the southeast part of the quadrangle.

INTRUSIVE ROCKS

Tdp **Porphyritic dacite dikes (Eocene)**—Highly porphyritic dacite dikes with plagioclase, quartz, hornblende, and biotite phenocrysts. Proportions of phenocrysts vary.

Tdi **Diorite dikes (Eocene)**—Dark gray to dark green fine-grained mafic dikes. Similar dike rock in the Goldstone Pass quadrangle of the central Beaverhead range (Lonn and others, 2009b) was dated at 46 Ma by zircon U-Pb methods (Richard Gaschnig, written commun., 2009).

Tdr **Dacite or rhyolite intrusion (Eocene)**—Extensively altered porphyritic dacite or rhyolite interpreted as shallow intrusive bodies. Phenocryst mineralogy uncertain, but less-altered areas contain plagioclase, biotite, and hornblende phenocrysts. Includes rocks along Highway 93 that appear to be coalesced dike swarms, as well as rocks across the Salmon River in Dry Gulch that Anderson (1959) assigned to the Challis volcanics and which were not investigated during this study. Also includes two masses of dacite between Wagonhammer and Silverlead creeks that may be volcanic rather than intrusive and could alternatively be classified as *Tcd*.

MESOPROTEROZOIC STRATA

Metasedimentary rocks of Mesoproterozoic age are widely exposed in the quadrangle and are similar to rocks in the Beaverhead Range to the southeast. Before their order was rearranged by Cretaceous thrust faults and younger normal faults, they were a relatively complete section from low in the Lemhi Group up through the overlying Gunsight, Swauger, and Lawson Creek formations and into a thick section of fine-grained feldspathic quartzite above the Lawson Creek Formation. The upper strata resemble the Gunsight Formation, but are clearly higher in the section. We informally designate these upper strata as quartzite of Jahnke Lake after their occurrence in the Beaverhead Range north of Goldstone Pass (Burmester and others, 2013).

Yqjl **Quartzite of Jahnke Lake (Mesoproterozoic)**—Well-sorted, fine-to very fine-grained, medium- to thick-bedded, pale pink to medium gray, feldspathic quartzite. Red chert clasts and green "porcellanite" that is softer than chert, but not as soft as argillite, are rare but unique to this unit. Plagioclase feldspar in excess of potassium feldspar. Bedding and sedimentary structures are difficult to see, but flat laminations and ripple cross laminations are present locally. Top and base not exposed and thus thickness is uncertain; a minimum of 1,500 m (5,000 ft) is likely. Correlative strata in the Beaverhead Range (in the central sequence on the Goldstone Pass quadrangle; Lonn and others, 2009a; b) are as thick as 4,300 m (14,000 ft).

Ylc **Lawson Creek Formation (Mesoproterozoic)**—Shown only in cross section where suspected to underlie the quartzite of Jahnke Lake. Lithologies found in the Lawson Creek Formation at its type section (Hobbs, 1980) include red argillite and siltite, fine-grained feldspathic quartzite, and subordinate medium-grained quartzite.

Ys **Swauger Formation (Mesoproterozoic)**—White to light gray, poorly sorted, fine- to coarse-grained, trough and planar crossbedded, feldspathic quartzite in beds as thick as 2 m (6 ft). Characterized by well-rounded quartz grains and local granules. Potassium feldspar invariably in excess of plagioclase. Top not exposed. Thickness uncertain because of faulting and lack of an upper contact, but correlative rocks are more than 1,800 m (6,000 ft) thick on the Homer Youngs Peak quadrangle (Lonn and others, 2008). Correlated with the Swauger Formation based on similarity to the Swauger in the Lemhi Range and on previous assignment of this unit to the Swauger by Anderson (1959). Subdivisions of conglomeratic and multicolored quartzite mapped to the southeast (Lonn and others, 2008) are not recognized here due to poorer exposure or lack of lateral continuity.

Yg **Gunsight Formation (Mesoproterozoic)**—Well-sorted, fine-grained, medium-to thick-bedded, medium gray, light weathering feldspathic quartzite and minor darker siltite and argillite. Flat laminations more common than cross bedding. Plagioclase content subequal to or greater than potassium feldspar. Grades upward into coarser grained quartzite of the Swauger Formation; base not exposed due to faulting and less than 500 m (1,600 ft) of thickness is exposed. Correlated with the Gunsight Formation based on grain size, feldspar content, sedimentary structures, and stratigraphic position below the Swauger Formation.

Ysa **Siltite and argillite (Mesoproterozoic)**—Thin-bedded phyllitic siltite and argillite. Strong cleavage obscures most sedimentary structures, but unit appears to be dominated by centimeter- to millimeter-scale couplets of light gray to light green siltite that grades upward to dark gray argillite. Desiccation cracks, mud rip-up clasts, and load casts in some horizons; two locations contained ptygmatically folded "crinkle cracks." Other intervals contain light gray decimeter-scale beds of fine-grained flat laminated and ripple cross-laminated quartzite. Along the ridge between the North Fork of the Salmon River and Silverlead Creek, several intervals of brown weathering calcitic and dolomitic strata contain 1-4 mm garnets. Those garnets predate the latest fabric and support top to the northeast shearing. Top and base not exposed and thickness highly uncertain. Correlated with rocks below the Gunsight Formation in the Lemhi Range, specifically rocks described near Golden Trout Lake by Winston and others (1999) and referred to as the Yellow Lake unit of the Apple Creek Formation by Tysdal (2003), and not type Apple Creek Phyllite (Anderson, 1961), which is probably younger (Lonn and others, 2009a; 2013). Our correlation is based on fine grain size, sedimentary structures, and presence of carbonate.

Yqsc **Carbonate-bearing quartzite and siltite (Mesoproterozoic)**—Shown only in cross section where suspected to underlie the siltite and argillite unit (*Ysa*). Lithologies found in *Yqsc* on the Bohannon Spring quadrangle (Lewis and others, 2009) include very fine-grained to rarely medium-grained quartzite, calcareous quartzite, and siltite.

Ysq **Siltite, quartzite, and argillite (Mesoproterozoic)**—Laminated siltite, intervals of feldspathic quartzite, and minor argillite. Siltite very dark green in 1-3 dm thick tabular beds. Lamination typically planar, but difficult to see in siltite because of its dark color. Quartzite very fine grained and dark gray to fine grained and lighter gray, with color likely reflecting biotite content. Plagioclase content well in excess of potassium feldspar (75 percent or more of all feldspar). Some fine-grained quartzite may be recrystallized siltite. Coarser beds as thick as 1 m in sets 5 to 15 m thick may be at the bottoms of thinning and fining-upward sequences. They constitute about 5 percent of the section and show mostly flat laminations, but also soft-sediment deformation, convolute lamination, loads and truncation, and rare ripple drift and climbing ripple cross lamination. Most lack dark (hematite) mineral laminations typical of *Yg*. Thickness uncertain because of deformation, but a minimum of 1,800 m (6,000 ft) likely. Except for higher apparent metamorphic grade, unit is similar to rocks mapped as *Ysq* in the Goldstone Pass quadrangle to the southeast (Lonn and others, 2009) and in the Bird Creek quadrangle to the south (Burmester and others, 2012). Dominance of quartzite and siltite and paucity of argillite favors correlation with type Inyo Creek Formation of the Lemhi Group (Ruppel, 1975) and rocks below the Inyo Creek that have not been described.

STRUCTURE

The IGS/MBMG team has mapped a complex fault system that extends from near Lemhi Pass northwest through the Beaverhead Range and across the North Fork quadrangle (Lonn and others, 2013). This fault zone does not appear to be a terrane boundary (Burmester and others, 2011b), but instead is interpreted as cutting a folded, but essentially intact, Lemhi subbasin section (the Lemhi Group and the overlying Swauger and Lawson Creek formations). Most deformation probably occurred during Cretaceous Sevier contraction and Eocene-Oligocene extension. Oligocene and younger normal faults also occur.

SALMON BASIN DETACHMENT

The Salmon Basin detachment, mapped by Tucker (1975) and later interpreted as a low-angle detachment fault by Blankenau (1999), enters the southeast corner of the map where it drops volcanic deposits (*Tct*) down on the southwest against Mesoproterozoic rocks (*Ylcl*). The trace of the detachment in this quadrangle gives the appearance of a steep fault rather than a low angle detachment fault. The fault apparently steepens northward from the range front southeast of Salmon to the North Fork area. The northward extent of the fault is uncertain, but it may become the fault that continues northward out of the quadrangle just west of the North Fork of the Salmon River. This fault places Swauger Formation to the east in its footwall against the younger quartzite of Jahnke Lake in its hanging wall, just as does the Beaverhead Divide fault system at the crest of the Beaverhead Mountains. Possibly, the Salmon Basin fault reactivated the Beaverhead Divide fault in this area.

FREEMAN THRUST

The Freeman thrust crosses Highway 93 about 5 km (3 miles) north of North Fork, where it places thinly bedded garnet-bearing phyllite (*Ysa*) over lower metamorphic grade pink fine-grained feldspathic quartzite of the quartzite of Jahnke Lake (*Yqjl*). As near Freeman Peak, 21 km (13 mi) to the southeast (Lonn and others, 2008), it strikes northwest, dips moderately to gently southwest, and is mylonitic. Lineations are poorly developed (at one locality east of Highway 93 they plunge 22° west) and at one locality shear sense indicators suggested top-to-the-east displacement consistent with Cretaceous thrust motion. The presence of garnet in the hanging wall also suggests postmetamorphic thrust movement. The lineation direction and hanging wall rocks are similar to those near Freeman Peak. The Freeman thrust trace is parallel to the trace of the North Fork fault throughout the length of the Beaverhead Mountains, except for areas where they are complicated by normal faults that offset the thrusts, such as in the southern part of the quadrangle.

NORTH FORK FAULT

The herein-named North Fork fault crosses Highway 93 about 2.5 km (1.5 miles) north of North Fork, where it places thinly bedded siltite and very fine-grained quartzite (*Ysq*) over more thinly bedded garnet-bearing phyllite (*Ysa*). It strikes northwest, dips moderately to gently southwest, and exhibits mostly brittle deformation. It is best exposed on the ridge between Little Silverlead Creek and the North Fork River. There it strikes west-northwest and dips gently southwest, but in general its trace crosses the North Fork quadrangle in a northwesterly direction. Lineations or definitive shear sense indicators could not be found in outcrop. Similar footwall and hanging wall rocks are found on opposite sides of an unnamed thrust along the southwest side of the Beaverhead Range, 16 km (10 miles) northeast of Salmon in the Bohannon Spring quadrangle (Lewis and others, 2009). This is interpreted to be the same fault. It may also continue southeast into the Goldstone Mountain quadrangle (Lewis and others, 2011) where it is exposed as the gently dipping Pattee Creek thrust carrying *Ysq* in its hanging wall into the Lemhi Pass area. Alternately, the North Fork fault may be a normal fault. Most deformation is brittle, and the relative ages of footwall and hanging wall units are not well established.

FOLDS

Most of the Mesoproterozoic sections appear to be homoclinal within a given fault block, but an anticline-syncline pair folding *Ysq* is likely present immediately northeast of North Fork. Most of the Gunsight Formation dips to the west, whereas the Swauger Formation dips consistently east. These relationships indicate that the normal fault separating the two may have broken a large-scale anticline.

REFERENCES

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.

Anderson, A.L., 1961, Geology and mineral resources of the Lemhi quadrangle, Lemhi County, Idaho: Idaho Bureau of Mines and Geology Pamphlet 124, 111 p.

Blankenau, J.J., 1999, Cenozoic structural and stratigraphic evolution of the southeastern Salmon basin, east-central Idaho: Utah State University M.S. thesis, 143 p.

Burmester, R.F., J.D. Lonn, R.S. Lewis, and M.D. McFaddan, 2013, Stratigraphy of the Mesoproterozoic Lemhi subbasin, east-central Idaho and southwestern Montana, *in* R.S. Lewis, M.M. Garsjo, and R.I. Gibson, eds., Belt Symposium V and other Papers: Northwest Geology, v. 42, p. 1-20.

Burmester, R.F., J.D. Lonn, R.S. Lewis, M.D. McFaddan, and R.M. Gaschnig, 2011b, The Beaverhead Divide fault on the Idaho-Montana border— Cretaceous contraction, Eocene extension, but not a terrane boundary: Geological Society of America Abstracts with Programs, v. 43, no. 4, p. 50.

Burmester, R.F., R.S. Lewis, K.L. Othberg, J.D. Lonn, L.R. Stanford, and M.D. McFaddan, 2011a, Geologic map of the Badger Spring Gulch quadrangle, Lemhi County, Idaho: Idaho Geological Survey Digital Web Map 132, scale 1:24,000.

Burmester, R.F., R.S. Lewis, K.L. Othberg, L.R. Stanford, M.D. McFaddan, and J.D. Lonn, 2012, Geologic map of the Bird Creek quadrangle, Lemhi County, Idaho: Idaho Geological Survey Digital Web Map 153, scale 1:24,000.

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.

Fisher, F.S., D.H. McIntyre, and K.M. Johnson, 1992, Geologic map of the Challis quadrangle, Idaho: U.S. Geological Survey Miscellaneous Investigations Series Map I-1819, scale 1:250,000.

Harrison, S.L., 1985, Sedimentology of Tertiary sedimentary rocks near Salmon, Idaho: University of Montana Ph.D. dissertation, 175 p.

Hipple, K., K. Langersmith, R. Winward, D. Ames, and B. Duncan, 2006, Soil survey of Custer-Lemhi area, Idaho, parts of Blaine, Custer, and Lemhi counties: United States Department of Agriculture, Natural Resources Conservation Service, 1270 p., soil maps at: http://websoilsurvey.nrcs.usda. gov/app/ (Accessed 10 January 2013).

Hobbs, S.W., 1980, The Lawson Creek Formation of Middle Proterozoic age in east-central Idaho: U.S. Geological Survey Bulletin 1483-E, 12 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., K.L. Othberg, R.F. Burmester, 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 583, scale 1:24,000.

Lewis, R.S., K.L. Othberg, L.R. Stanford, R.F. Burmester, J.D. Lonn,and M.D. McFaddan, 2011, Geologic map of the Goldstone Mountain quadrangle, Lemhi County, Idaho and Beaverhead County, Montana: Idaho Geological Survey Digital Web Map 134 and Montana Bureau of Mines and Geology Open File 604, scale 1:24,000.

Lonn, J.D., R.S. Lewis, R.F. Burmester, and M.D. McFaddan, 2009a, Regional stratigraphic implications from new mapping of the northern Beaverhead Range, Montana and Idaho: Geological Society of America Abstracts with Programs, v. 41, no. 7, p. 285.

Lonn, J.D., R.S. Lewis, R.F. Burmester, and M.D. McFaddan, 2013, The complex structural geology of the northern Beaverhead Mountains, Montana and Idaho, *in* R.S. Lewis, M.M. Garsjo, and R.I. Gibson, eds., Belt Symposium V and other Papers: Northwest Geology, v. 42, p. 111-130.

Lonn, J.D., R.S. Lewis, R.F. Burmester, 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 575, scale 1:24,000.

Lonn, J.D., L.R. Stanford, R.F. Burmester, R.S. Lewis, and M.D. McFaddan, 2009b, Geologic map of the Goldstone Pass quadrangle, Lemhi County, Idaho and Beaverhead County, Montana: Idaho Geological Survey Digital Web Map 114, scale 1:24,000.

Othberg, K.L., R.S. Lewis, L.R. Stanford, R.F. Burmester, and M.D. McFaddan, 2011, Geologic map of the Baker quadrangle, Lemhi County, Idaho: Idaho Geological Survey Digital Web Map 141, scale 1:24,000.

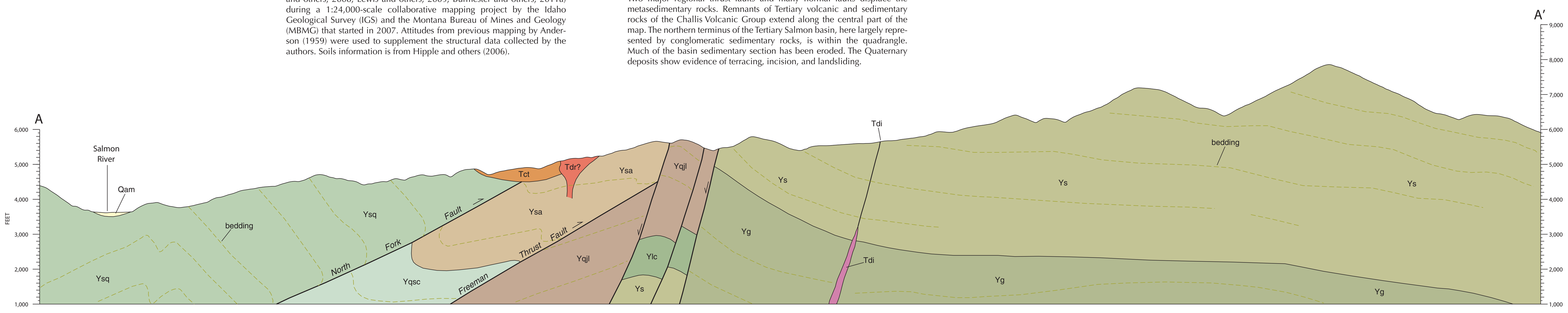
Ruppel, E.T., 1975, Precambrian Y sedimentary rocks in east-central Idaho: U.S. Geological Survey Bulletin 889-A, 23 p.

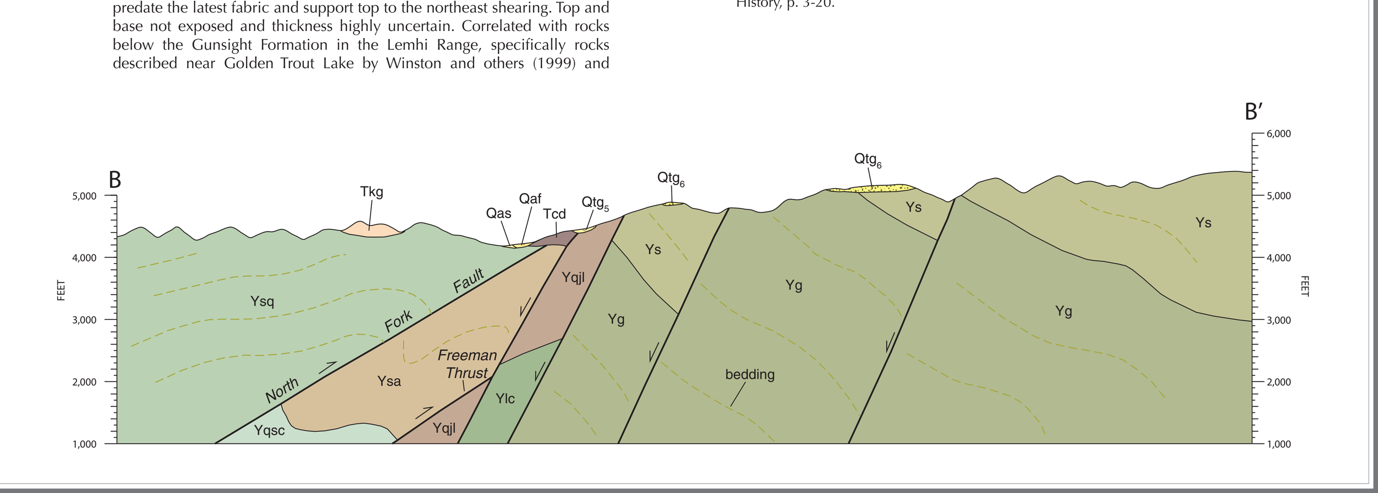
Streckeisen, A.L., 1976, To each plutonic rock its proper name: Earth-Science Reviews, v. 12, p. 1-33.

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: Miami University Ph.D. dissertation, 221 p., scale 1:48,000.

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.

Winston, Don, P.K. Link, and Nate 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 Museum of Natural History, p. 3-20.





Published and sold by the Idaho Geological Survey
University of Idaho, Moscow, Idaho 83844-3014