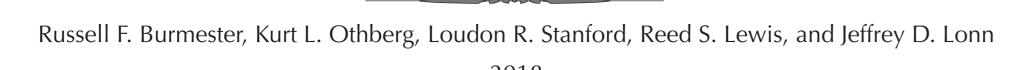
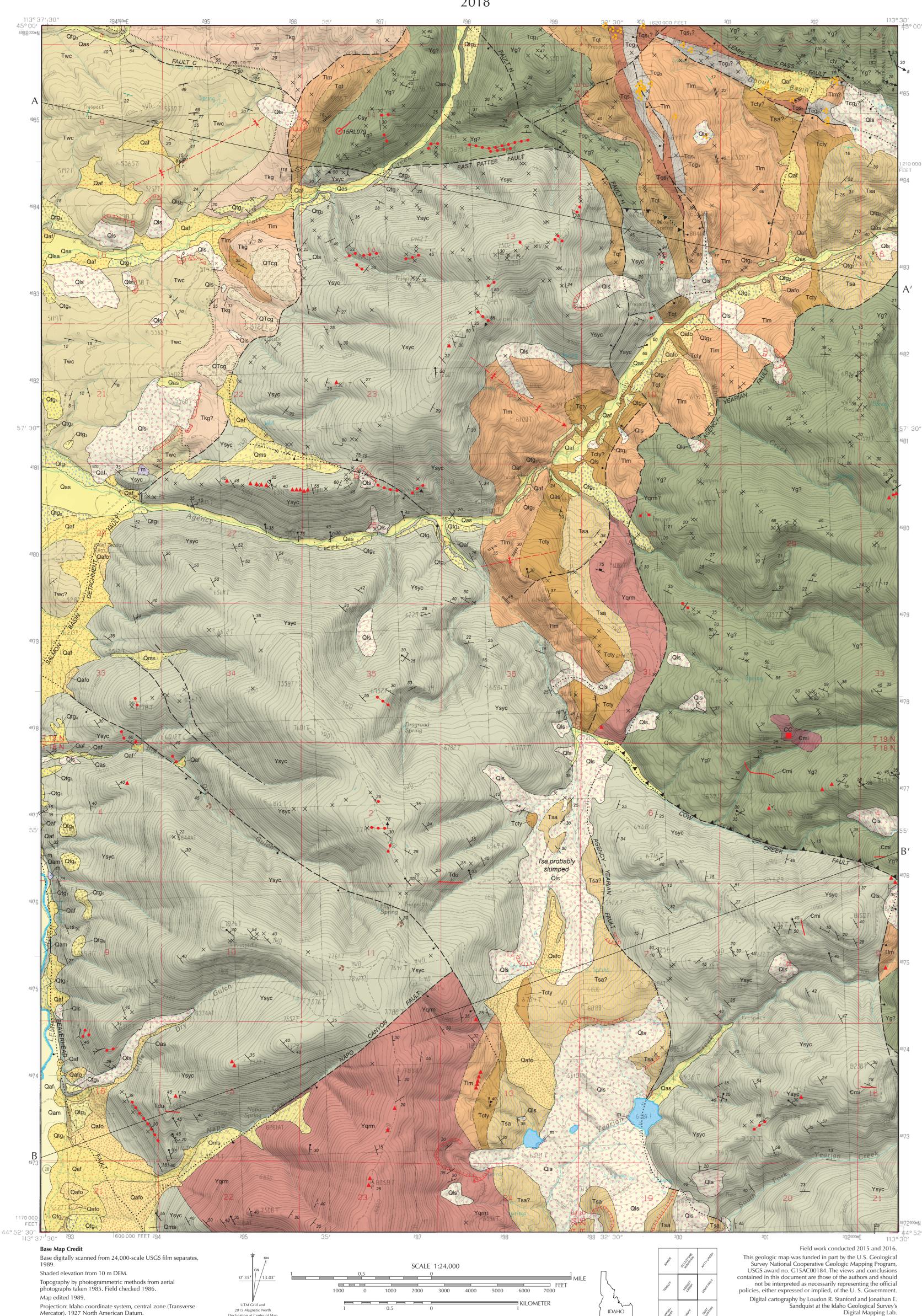
IDAHO GEOLOGICAL SURVEY DIGITAL WEB MAP 182 IDAHOGEOLOGY.ORG MOSCOW AND BOISE BURMESTER AND OTHERS

Geologic Map of the Agency Creek Quadrangle, Lemhi County, Idaho





OUATERNARY MESOPROTEROZOIC

CORRELATION OF MAP UNITS

INTRODUCTION

Bedrock mapping in 2015 and 2016 by Burmester and Lewis and field checking by Burmester, Lewis, and Stanford in 2017 followed reconnaissance work by Lonn, Burmester, and Lewis in 2006, 2007, and 2008. Mapping of Quaternary deposits was by Othberg and Stanford in 2015 and 2016. Attitudes from previous mapping by Anderson (1961), Staatz (1979), and Blankenau (1999) supplement the structural data collected by the authors. Mapping and unit descriptions by Blankenau (1999) facilitated our work in the Tertiary units through the central and northern parts of the map. Soils information is from Hipple and others (2006).

SYMBOLS

______ Contact: dashed where approximately located.

dotted where concealed.

Gradational contact between interfingering units. ·····- Fault: dashed where approximately located; dotted where concealed Detachment fault: hachures on downthrown side; dashed where approximately located; dotted where concealed.

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

Left-lateral strike-slip fault: arrows indicate direction of motion; dashed where approximately located; dotted where concealed. ...- Normal fault: ball and bar on downthrown side; dashed where approximately located; dotted where concealed. Syncline axial trace: arrow indicates plunge direction; dashed where

approximately located; dotted where concealed. ¹² Strike and dip of bedding.

 $begin{pmatrix}
begin{pmatrix}
begin{pmatr$

³³ Trike and dip of bedding, strike approximate. Strike and dip of bedding, strike variable.

Strike and dip of bedding determined from 3-point analysis.

Strike and direction of bedding dip: approximated from air-photo 15 Strike and dip of foliation.

Strike and dip of flow or compaction foliation in volcanic rocks.

// 30 Strike and dip of volcanic flows. Approximate strike and dip of volcanic flows

Strike and dip of mylonitic foliation. Strike and dip of cleavage.

Strike and dip of joints.

Bearing and plunge of slickenlines.

Bearing and plunge of lineation, type unknown.

Bearing and plunge of mylonitic lineation. 15RL079 Geochemical sample location.

U-Pb date sample location

Location of Mesoproterozoic granite boulder.

Location of large quartzite boulders.

Tectonic breccia.

Vein; arrow indicates dip.

Adit; mostly from Staatz (1979). × Prospect pit or short trench; mostly from Staatz (1979).

Headwall scarp of landslide; ticks at top of scarp.

DESCRIPTION OF MAP UNITS

Intrusive rocks classified according to International Union of Geological Sciences nomenclature uses normalized values of modal quartz (Q), alkali feldspar (A) and plagioclase (P) on a ternary diagram (Le Bas and Streckeisen, 1991). Mineral modifiers for igneous rocks appear in order of increasing abundance. Grain size classification of unconsolidated and consolidated sediment employs the Wentworth scale (Lane, 1947). Bedding thicknesses and lamination type are after McKee and Weir (1953), and Winston (1986). Grain sizes and bedding thicknesses are given in abbreviation of metric units (e.g., dm=decimeter). Unit thicknesses, distances, and elevations are in both metric and English units. Multiple lithologies within a rock unit description appear in order of decreasing abundance, and descriptions of stratigraphic units are from bottom to top where possible.

ARTIFICIAL DEPOSITS

m Man-made ground (Holocene)—Artificial fills composed of excavated, ALLUVIAL DEPOSITS Streams originate in high mountains and flow into the Lemhi River valley

and then north to the Salmon River. Prior to the Pleistocene, the continental divide, now just east at Lemhi Pass, was farther west. Evidence in this guadrangle indicates Eocene and possibly Oligocene southeast drainage of the area across the Beaverhead Range into the ancestral Missouri River system (see Tcg₃ and Tkg below). Later, Lemhi River valley drainage was captured by the ancestral Salmon River and the valley was deeply incised. No evidence was seen for thick Quaternary alluvial valley fills. In fact, available exposures and water-well logs show terrace gravel deposits and mainstream alluvium are thin coverings on stream-cut surfaces.

Qas Side-stream alluvium (Holocene)—Subangular to rounded, moderately sorted and stratified pebble to boulder sandy gravel. Gravel clasts primarily quartzite, siltite, and volcanic rocks. Includes minor colluvium, fan deposits, and pebbly to cobbly sandy silt in local lower energy drainages. Thickness 1 to 6 m (3 to 20 ft). Soils not developed to weakly developed.

Qam Main-stream alluvium (Holocene)—Well-rounded, moderately sorted and stratified pebble to boulder sandy gravel of the Lemhi River. Gravel clasts mostly quartzite, siltite, granite, and volcanic rocks. Includes flood-plain areas of sand, silt, and clay. Thickness variable: 1 to 12 m (3 to 40 ft). Soils not developed to weakly developed.

Technical review status: Dennis Feeney

PDF (Acrobat Reader) map may be viewed online at

The IGS does not guarantee this map or digital data to be free of errors nor

ume liability for interpretations made from this map or digital data, or

QUADRANGLE LOCATION ADJOINING QUADRANGLES

Map version 4-23-2018.

www.idahogeology.org.

to boulder gravel in a sand, silt, and clay matrix. Commonly grades into side-stream alluvium (Qas). Thickness variable: 1 to 15 m (3 to 50 ft). Soils undeveloped to weakly developed. Qato Older alluvial-fan deposits (Pleistocene)—Angular to subrounded, poorly and clay. Locally caps and interfingers with terrace gravel. Thickness of

Qaf Alluvial-fan and debris-flow fan deposits (Holocene to late Pleistocene)—

Angular to subrounded, poorly sorted, primarily matrix-supported pebble

sorted, matrix-supported pebble to boulder gravel in a matrix of sand, silt, deposits varies greatly, ranging from 1 to 15 m (3 to 50 ft). Soils moderately to well developed.

Gravel terrace deposits

Gravel deposits of Pleistocene alluvial terraces are composed of moderately sorted and clast-supported sandy gravel. Clasts are subrounded to rounded pebbles, cobbles, and boulders. Clast lithologies are quartzite, siltite, and volcanic rocks from the adjacent mountains. Terrace deposits form a relatively thin (9 m; 30 ft) cap over a stream-cut bedrock surface. Five levels of terraces and terrace remnants that are preserved range from 1.5 m (5 ft) to more than 91 m (300 ft) above present-day streams. The terrace sequence records long-term episodic incision of the Salmon basin and the Lemhi Valley, which was probably driven by glacial climate fluctuations during the Pleistocene. Terrace gravels commonly are capped by, and interfinger with, alluvial-fan deposits (Qaf and Qafo), which are included in the

Otg Gravel of first terrace (Holocene and Late Pleistocene)—Forms terrace 1.5 to 8 m (5 to 25 ft) above modern streams. Soils weakly developed.

terrace unit locally.

Ofg. Gravel of second terrace (Late Pleistocene)—Forms terrace 11 to 21 m (36 to Oft) above modern streams. Soils moderately developed. Gravel of third terrace (Middle? Pleistocene)—Forms terrace 24 to 40 m (80 to 130 ft) above modern streams. Soils well developed.

to 220 ft) above modern streams. Soils well developed. Gravel of fifth terrace (Early? Pleistocene)—Forms terrace 91 to 104 m (300 to ▼ ▼ Thrust fault: teeth on upper plate; dashed where approximately located; 340 ft) above modern streams. Soils of original terrace surface eroded away.

MASS MOVEMENT DEPOSITS

Mass-movement deposits in the quadrangle include deep-seated rotational landslides (slumps), thinner translational landslides (slides), debris flows of widely varying volume and extent, and periglacial colluvium that moved more actively by solifluction during times of Pleistocene glacial climates. Other colluvium, including talus, was not separately mapped but included in the rock units on which it lies. Mass-movement deposits are common in the quadrangle, but most are relict from the Pleistocene and provide evidence of a climate in which moisture more effectively saturated soil and rocks. Active landslides, i.e., ones that show historic activity, characteristically are associated with artificially altered local stream drainage and

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

Landslide deposits (Holocene to Pleistocene)—Unstratified, poorly sorted silty clay, gravelly silty clay, and boulders. Deposited by slumps, slides, slide blocks, earth flows, debris flows, debris avalanches, and rockfalls. Map may also show the landslide scarp and the headwall (steep area adjacent to and below the landslide scarp) from which material broke away (see Symbols). Qms Mass-movement deposits (Holocene to Pleistocene)—Angular to subangular

vium, and some alluvial-fan gravel. QTcg. Colluvial and alluvial-fan gravel (Early(?) Pleistocene to Pliocene?)—Pebble, cobble, and boulder gravel on foothill ridges that caps probable erosion surface on Tertiary sediments and Challis volcanics. Primarily colluvium with large, lag surface boulders. Deposits are 3 to 12 m (10 to 40 ft) thick.

Soils of original surface eroded away.

dated at 31 Ma (Axelrod, 1998).

poorly sorted silty and clayey gravel. Includes solifluction deposits, collu-

TERTIARY SEDIMENTARY DEPOSITS OF THE SALMON BASIN

Janecke and Blankenau (2003) interpreted the Salmon basin as one of several supradetachment basins that formed in east-central Idaho and western Montana between 46 and 31 Ma (late middle Eocene to early Oligocene). Blankenau (1999) studied the structure and stratigraphy in the southern portion of the Salmon basin. Previously, sedimentary rocks of the Salmon basin were described, subdivided, and mapped by Anderson (1957) and Tucker (1975). Harrison (1985), in studying sedimentology of the Tertiary sediments that fill the Salmon basin, identified a series of gradational facies and informal lithostratigraphic units that are conformable and were deposited in alluvial-fan, braided-stream, mixed-channel and floodplain, and lake environments in a downfaulted basin. Geomorphic expression of lithology was used to map the gradational contacts. Contacts with the underlying Challis Volcanic Group are unconformable but lack major angular unconformities. Age is constrained by the older Challis Volcanic Group and overlying Quaternary units. Well-preserved plant remains studied by Axelrod (1998) are representative of the Oligocene Haynes Creek Flora. This locality is near the mouth of Haynes Creek, 5.3 km (3.3 mi) northwest of the map. A thin tuff interbedded with lake sediments was

Tkg Conglomerate of Kriley Gulch (Oligocene to Eocene)—Matrix-supported conglomerate, clast-supported pebble to boulder conglomerate, and matrix-poor breccia. Includes interbeds of ash, vitric siltstone, and lithic sandstone. Colors are gray, white, and red. Silica and hematite cement are common. Lag cobbles and boulders as large as 3 meters in diameter cover surfaces of weathered and eroded beds. Boulders and cobbles of Mesoproterozoic quartzite and siltite predominate, but clasts of Challis volcanics are common near Challis Volcanic Group rocks. Unit predominantly composed of debris-flow deposits. Depositional environments vary from proximal fan and fan head to mid fan and proximal braided stream. ercentage of fine-grained beds increases basinward and the unit interfingers with the fine-grained unit *Twc*. Includes portions of Blankenau's (1999) middle conglomerate of the sedimentary rocks of Tendoy. Forms steep slopes with coarse gravelly soils and resistant ridges capped with common lag pebbles and cobbles, and scattered lag boulders. Rare boulders of Mesoproterozoic granite are found in this unit in the adjoining Goldstone Mountain quadrangle to the north (Lewis and others, 2011), but not here.

Twc Siltstone of Wimpey Creek (Oligocene to Eocene(?))—Vitric siltstone, bentonite, mudstone, and carbonaceous shale with minor interbeds of conglomerate and sandstone. Colors range from white to greenish gray and pinkish brown. Locally stained and cemented with iron and manganese. Bed thicknesses varies from a few millimeters to a few meters. Measured thickness of steeply dipping beds in sec. 3 and 4, T. 19 N., R. 24 E. is 850 to 890 m (2,800 to 2,930 ft). The following plant fossils were identified by William C. Rember:

> Macginitiea sp. Lithocarpus sp. Fagopsis sp. Taxodium sp.

Depositional environments include proximal mixed-load streams, sandy mixed-load streams, flood-basin swamps and ponds, and lake bottoms. Includes portions of Blankenau's (1999) shale facies of the sedimentary rocks of Tendoy. Where fine-grained facies predominate, forms gently sloping, low-relief, 'badland' topography. Prone to erosion and landsliding.

TERTIARY SEDIMENTARY DEPOSITS OF AGENCY CREEK

Tsa Sedimentary rocks and sediment of Agency Creek (Oligocene to Eocene)— Mixed unit consisting of conglomerates to siltstones and claystones that formed in small fault-controlled basins east of the Salmon basin detachment fault. Exposures in upper Cow Creek and upper Yearian Creek show light yellowish brown siltstone to claystone, sandstone, cobbles, and ooulders. Exposures are basin fill in the hanging wall of the Agency-Yearian fault and the coarser deposits are closest to the fault. The fine-grained deposits are interpreted as lacustrine. Highly susceptible to mass wasting. Staatz (1979) reported fossils from two nearby localities in the Cow Creek area. One locality is in a roadcut 1 km (0.6 mi) south of the junction of Cow Creek with a tributary that parallels the road in the NE 1/4 SE 1/4 sec. 1, T. 18 N., R. 24 E. The other locality is about 240 m (800 ft) north of the first locality and is on a barren hillside above the road and below a small Jack A. Wolfe:

Ginkgo sp.

Metasequoia sp Taxodium sp. Sassafras hesperia Berry

Alnus jarbidgana Axelrod

Mahonia cuprovallis Axel. "Zelkova" drymeja (Lesq.) R. W. Br. Quercus sp.

Crataegus copena (Lesq.) MacG. Rhus cf. R. obscura (Lesq.) MacG. Acer mysticum Kirch

Symphoricarpos salmonensis R. W. Br. Wolfe (written commun., 1974 in Staatz, 1979) notes that the alder, Alnus jarbidgana, is the most abundant plant in the collections, and that several species, including this one, are present in collections made in tuffaceous sedimentary rocks near Salmon, Idaho. He states that the oldest possible age of these collections is late Eocene, as this is the age of oldest known occurrences of "Zelkova" drymeja, Alnus jarbidgana, Mahonia cuprovallis, and Acer mysticum. The upper limit of this assemblage of plants is not as well known, but it does not extend into the Miocene according to Wolfe. William C. Rember (personal commun., 2016) thought that the plants in this listing could be Oligocene or Miocene in age. The fish tail was examined by David H. Dunkle (written commun., 1973 in Staatz, 1979), who stated that the scale characteristics, extended dorsal fin, and caudal fin structure are similar to that of the aberrant sucker, Amyzon. This genus was previously found in

sedimentary rocks that range in age from Eocene to middle Miocene. CHALLIS VOLCANIC GROUP

Rocks of the Challis Volcanic Group in the quadrangle are northeast of the main Challis volcanic field that erupted in the Eocene (about 51-44 Ma). Remnants of the lava flows, tuffs, and subordinate sediments, which are widespread in east-central Idaho, were mapped and described by D.H. McIntyre, E.B. Ekren, and R.F. Hardyman in the Challis 1° x 2° quadrangle to the southwest (Fisher and others, 1992). A stratigraphic section has also been established in the Agency Creek and Lemhi Pass areas (Blankenau,

Younger Challis tuff, undivided (Eocene)—Volcanic and sedimentary rocks erlying the mafic lava flows (Tlm). Includes tuff of Curtis Ranch and

overlying quartz-sanidine welded tuff. Younger quartz-sanidine welded tuff—White to pale-green or gray-green welded tuff. Contains euhedral chatoyant sanidine and smoky quartz in a fine ash groundmass. Degree of welding varies. Equivalent to Tqs2 unit of

 46.13 ± 0.19 Ma and 45.95 ± 0.12 Ma. Tuff of Curtis Ranch—White to greenish-white tuff. Contains abundant nic and quartzite lithics. 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. Equivalent to Tcr unit of Blankenau (1999) who obtained a 40Ar/39Ar age on single sanidine crystals

Blankenau (1999) who cited 40Ar/39Ar ages on single sanidine crystals of

TIm Mafic lava flows (Eocene)—Black to dark green-gray or dark brown-black aphanitic to porphyritic lava flows; locally contains round to irregular vesicles or amygdules and flow breccias. Thin biotitic tuffs and volcaniclastic sandstones are interbedded with the flows. Secondary chalcedony and calcite are common. Chemical analysis of similar rocks to the northwest shows both shoshonite and latite composition (map unit Tlm on Othberg and others, 2011). Equivalent to Tl unit of Blankenau (1999). Also correlative with TI unit of potassium-rich andesite, latite, and basalt lava in the

Challis 1° x 2° quadrangle to the southwest (Fisher and others, 1992).

of 47.58 ± 0.14 Ma.

Upper conglomerate (Eocene)—Poorly sorted, well-rounded, cobble and boulder gravel. Clasts predominantly quartzite but include distinctive boulders of Proterozoic porphyritic rapakivi granite. Equivalent to the granite clast conglomerate (Tcg2) of Blankenau (1999) but placed slightly higher in the stratigraphic section here. Blankenau (1999), Janecke and others (2000), and Chetel and others (2011) postulated that an Eocene paleoriver flowed from northwest of Salmon before the Salmon basin formed and transported the granite clasts across the Beaverhead Range at Lemhi Pass. These distinctive granitic boulders also locally appear stratigraphically higher in the section in the conglomerate of Kriley Gulch, which indicates that the through-flowing drainage also may have operated in the Oligocene. Many of these boulders also form lag deposits on various older units. A middle conglomerate unit (Tcg₂) present to the east in the Lemhi Pass quadrangle (below Tqs₁; Burmester and others, 2018) is absent

Older quartz-sanidine welded tuff (Eocene)—Tan-orange to light-pink welded tuff in northeast part of map. Contains pumice fragments, euhedral to subhedral crystals of sanidine and smoky quartz, and sparse quartzite lithics in a fine crystalline groundmass (Tqs1 of Blankenau, 1999).

Quartzite-bearing ash-flow tuff (Eocene)—White, white-gray, pinkish red, or pink-gray tuff in northern part of map. Contains sparse to abundant angular dark-gray to black quartzite lithic fragments and less abundant smoky quartz and plagioclase. Poorly to densely welded. Equivalent to Tqt unit of Blankenau (1999) who obtained a 40Ar/39Ar age on single sanidine crystals of 49.51 \pm 0.14 Ma on a sample collected in the Sal Mountain quadrangle to the west-northwest.

Basal conglomerate (Eocene)—Subrounded to well-rounded cobble to boulder, clast-supported conglomerate in northern part of map. Clasts are entirely quartzite, typically 1 to 2 dm diameter. Equivalent to Tcg1 unit of

INTRUSIVE ROCKS

Tdu / Dikes, undivided (Eocene?)—Includes very thin fine-grained diorite dike with east-west strike and presumed steep dip in southwest corner of map and dike with similar attitude northeast of High Spring. Less altered than typical *€mi* dikes so presumably younger.

Mafic intrusions (Cambrian)—Diorite, lamprophyre, and related bodies, mostly dikes. One small body in Yg near the east edge of the map north of Cow Creek was mapped as diorite with different areal extent by Anderson (1961) and Staatz (1979). It was reinterpreted as pyroxene lamprophyre and dated with TIMS U-Pb geochronology on zircons as early Cambrian $(534.37 \pm 0.22$ Ma; Gillerman and others, 2010, 2013).

Ssy / Syenite (Cambrian)—Poorly exposed medium-grained biotite syenite dike in northwest part of map north of Pattee Creek. Has aligned potassium feldspar, plagioclase, and minor interstitial quartz; high magnetite content. May be the same age as a syenite dike south of Lemhi Pass that has a SHRIMP zircon ²⁰⁷Pb/²⁰⁶Pb age of 529.1 ± 4.5 Ma (Gillerman, 2008; Gillerman and others, 2008, 2010).

MESOPROTEROZOIC STRATA

Low metamorphic grade metasedimentary rocks of Mesoproterozoic age

underlie most of the Agency Creek quadrangle. These rocks were assigned

to the Swauger and Lemhi quartzites of Ross (1947) by Anderson (1961), Gunsight Formation and unassigned quartzite and siltite units by Staatz (1979), and Gunsight and Apple Creek formations of Ruppel's (1975) Lemhi Group by Lund and others (2003). These rocks are mostly very fine- to fine-grained quartzite, with some medium-grained quartzite, and minor siltite and argillite, but they vary in details of bedding character and sedimentary structures. To the north we applied formal names to units (Burmester and others, 2016a) following revised stratigraphic nomenclature (Burmester and others, 2013; Burmester and others, 2016b) that uses the coarsest unit, the Swauger Formation, to distinguish otherwise similar rocks that are stratigraphically above and below it. Unit assignments north of the Lemhi Pass fault included the Gunsight Formation based on apparent continuity with strata below the Swauger Formation west of Salmon, Idaho. This continuity is now in question because diamictite, similar to that found above the Swauger in the Lemhi Range, is in strata west of what we had assigned to the stratigraphically much lower Yellow Lake Formation north of North Fork, Idaho (Burmester and others, 2017). Our recent unpublished mapping in the Lemhi and Goat Mountain quadrangles south and southeast of this map found Swauger Formation but not in direct contact with units on this map. Spherical, medium quartz grains are rare in Lemhi Group units below the Swauger but common in, if not characteristic of, the Swauger and Lawson Creek formations, reported in the Lake Mountain member of the Apple Creek Formation in the Salmon River Mountains (Gunsight Formation of Tysdal, 2003), and discovered in the diamictite member in the Lemhi Range. Thus, the most likely correlatives of the medium-grained strata in this quadrangle are above the Swauger, but which ones is unclear. Because

of this uncertainty we use local informal names for the units.

here. According to Staatz (1979) the following plants were identified by Yqrm Quartzite of Ramsey Mountain (Mesoproterozoic)—Feldspathic quartzite with minor siltite and argillite. Quartzite beds as thick as one meter but more commonly dm scale; mostly flat laminated, rarely cross laminated. These are repeated in cosets or interbedded with siltite. Platy parting with fine muscovite on surfaces common; mudchip bases less so. Seven samples of quartzite averaged 83 percent quartz, 16 percent plagioclase and no potassium feldspar. One sample on the east flank of Ramsey Mountain contained 10 percent potassium feldspar and 30 percent plagioclase. Interpreted to

uncertain because of deformation and lack of upper contact.

grade up from unit with mudcracks and chips assigned to Ysyc. Thickness

Ysyc Siltite of Yearian Creek (Mesoproterozoic)—Thinly bedded siltite and argillite, and white-weathering, gray and green quartzite. Characterized by undulating, uncracked graded couplets and rarer couples of medium-green siltite and light-green to light-buff or gray argillite. Mud cracked bedding surfaces less common than angular light-colored mud chips. Those commonly in bases of beds along with dark-green channels a few cm wide and as thick as 1 cm of well-rounded fine to rare but diagnostic spherical medium quartz grains. Similar grains also comprise quartzite beds a few cm to a few dm thick concentrated in widely scattered intervals but best exposed south of Yearian Creek. More common are 1-3 dm beds of white-weathering, very fine- to fine-grained feldspathic quartzite that look like Ygrm strata. Some of those beds have ripple tops and ripple cross lamination. Rare chips and thin layers are chert. Common in some intervals east of the Agency-Yearian fault are cm-scale intricately interbedded white and green quartzite with wide variation of grain sizes and feldspar content. Composition of quartzite west of the Agency-Yearian fault is similar to that of *Yqrm*. Eight of nine samples average are 84 percent for quartz and 16 percent for plagioclase. A lone sample from the northwest edge of the unit has 75 percent quartz, 15 percent potassium feldspar, and 10 percent plagioclase. Upper contact presumed to be the sharp transition from thin-bedded siltite and argillite with mud cracks and chips at the western foot of Ramsey Mountain to the quartzite of Ramsey Mountain. Thickness uncertain for lack of mapped

Gunsight Formation? (Mesoproterozoic)—Quartzite, siltite, and argillite. Characteristically, quartzite beds as thick as one meter are flat laminated; some grade to siltite and argillite tops. This gradation is emphasized by cleavage curving to be more parallel to bedding in the finer grained tops. Widespread are hummocky and trough cross stratification, climbing ripple or ripple drift cross laminations, and soft-sediment deformation. Some intervals contain sets of several to tens of white-weathering, very fine- to fine-grained feldspathic quartzite beds dm to m thick with bases loaded into underlying quartzite or dark argillite tops of underlying beds. Some thick beds have bedding defined by dark mm-scale laminations. One sample had 72 percent quartz, 5 percent potassium feldspar, and 25 percent plagioclase. Thickness uncertain because of deformation and lack

lower contact, folding, and faulting.

STRUCTURE

of contacts exposed in this area, but a minimum of 2,400 m (8,000 ft) was

estimated in the Kitty Creek quadrangle to the northeast (Lewis and

Several faults traverse the quadrangle. Young regional extension faults are discussed in detail by Blankenau (1999) and are shown in a simplified map controlled their distribution. Some are interpreted to be reactivated older faults. The main one is the Agency-Yearian fault, which continues to the south into the Lemhi quadrangle (unpublished mapping by authors, 2017) where it juxtaposes Swauger Formation on the west against *Ysyc*. This fault might be very old, and predate Cambrian(?) mineralization that is found on both sides now. Named faults within the quadrangle are described below.

SALMON BASIN DETACHMENT AND FAULT "C"

To the north, the range-front fault was mapped by Tucker (1975) and later interpreted as a low-angle detachment fault by Blankenau (1999). The "C" fault of Blankenau (1999) has a complex junction with the Salmon basin detachment, which Blankenau called the Muleshoe fault, in the northern part of the map. That fault merges with the Beaverhead fault that runs along the west side of the quadrangle. Blankenau (1999) showed the latter as a normal fault, but the others as detachments.

LEMHI PASS FAULT

The Lemhi Pass fault can be traced west-northwestward from Lemhi Pass at the head of Agency Creek across the northeast part of the map to the northern edge of the map. VanDenburg (1997) and Blankenau (1999) interpreted the structure as a 22°-24° south-dipping detachment fault, but its straight trace suggests that its dip is considerably steeper. Blankenau speculated that the Lemhi Pass fault is offset to the north by the Salmon basin detachment on the Goldstone Mountain quadrangle (Lewis and others, 2011) to the north. Also to the north is the Pattee Creek thrust, which has Gunsight Formation mapped in the hanging wall and Jahnke Lake member of the Apple Creek Formation interpreted to be in the footwall (Burmester and others, 2016a). This Pattee Creek thrust may continue southward, be the cause of horizontal shearing near the Lucky Horseshoe mine just east of the northeast corner of the map, and emerge from the Lemhi Pass fault hanging wall as the Cow Creek fault.

AGENCY-YEARIAN FAULT

Blankenau (1999) showed this fault having two splays through the central part of the map. We found no evidence or need for the eastern one that is within the Gunsight Formation and reinterpret the western one as the main sub-Challis detachment. Listric rotation on this fault explains tilting to the east of most overlying Challis rocks but the extent of the rotated block is uncertain. "Bookshelf" faulting could affect the Challis rocks similarly but tilt the metasedimentary rocks of hanging wall rocks less, as observed. Given the stratigraphy of the metasedimentary rocks, at least part of it had an earlier eastward thrust history that elevated the Ysyc block to the west relative to the footwall Yg? more than was recovered during Tertiary exten-

COW CREEK FAULT

East of the post-Challis detachment, the Cow Creek fault juxtaposes Yg? on the north against Ysyc on the south. It was interpreted to be a thrust by Lund and others (2003). If Yg? is Gunsight Formation, this fault must omit at least the Swauger Formation and have significant throw. If Yg? is a member of the Apple Creek Formation, this fault must have experienced significant translation to juxtapose such dissimilar strata from similar stratigraphic levels. However, nowhere along it is there mylonite, breccia, or fault gouge marking its trace or kinematics. Furthermore, REE-Th mineralization pervades both Yg? and Ysyc, consistent with them being in close proximity during the Cambrian and not juxtaposed during Cretaceous contraction. Apparent truncation or offset by the pre-Agency-Yearian thrust, and the lack of fault rock (mylonite, breccia, gouge) along it, are consistent with motion being very early, with evidence obliterated during later deformation.

EAST PATTEE FAULT

This east-west fault in the northwest part of the map is based on a lithology change across it and the presence of foliated quartzite. Slickenlines and brittle deformation are consistent with left-lateral strike slip displacement on a set of south dipping shears. It is interpreted as a left slip lateral ramp at the northern end of the ancestral Agency-Yearian thrust, but might have been reactivated as a splay of the Lemhi Pass fault, which has similarly shallow lineations near Lemhi Pass.

NAPO CANYON FAULT

Shown by Anderson (1961) to separate Gunsight and Swauger formations, here it offsets the contact between *Ygrm* and *Ysyc* and separates blocks with slightly different attitudes. It is nowhere exposed but is interpreted to be which rare boulders of medium-grained, feldspar-poor quartzite remain. If it dipped south and were younger than the ancestral Agency-Yearian thrust, its trace would have been offset in a right-lateral sense by the Agency-Yearian detachment. We picture it as being cut off by the fault along Big Dry Gulch, which we interpret to repeat *Ysyc*. Evidence for a fault along Big Dry Gulch includes a zone of intense alteration and brecciation in the west near the mouth and at High Spring where it crosses the ridge.

MINERALIZATION

The Agency Creek quadrangle includes the western part of the Lemhi Pass REE-Th district. Locations and details of many of the mines and prospects can be found in Anderson (1958) and Staatz (1979). Proterozoic metasediments and altered mafic rocks locally host quartz-chalcopyrite-bornite veins. REE-Th mineralization is present as quartz veins and biotite-rich replacements of country rock with abundant specular hematite, thorite and

monazite. Magnetite and magnetite-rich breccias are common. Recent work by Gillerman and others (2008, 2010, and 2013) (summarized below) indicates that mineralization ages are complex, but clearly old (Neoproterozoic to Paleozoic). The Cambrian syenite-lamprophyre magmatic suite was dated by U-Pb SHRIMP analysis on zircons at 529.1 ± 4.5 Ma (syenite east of map near Lemhi Pass) and 534.37 \pm 0.22 Ma (Cow Creek stock, a pyroxene porphyry lamprophyre on this map). The syenite is cut by specular hematite veins, and locally magnetite-rich veins. Wholerock geochemical analysis of the one syenite dike on this map (Table 1) indicates enrichment in Y (70 ppm), Nb (286 ppm), La (184 ppm) and Ce (379 ppm) relative to other intrusive rocks in the region. Dating of Nd-enriched monazite and thorite from the Lucky Horseshoe mine (located immediately east of the quadrangle) by electron microprobe analysis returned Carboniferous ages (300 to 350 Ma) for mineralization, much younger than the syenite-lamprophyre suite and not matching known intrusive events. Zircons from the Lucky Horseshoe ultramafic to mafic sill yielded ages from Neoproterozoic to Late Carboniferous. Neoproterozoic and Carboniferous cores appear to have younger Carboniferous overgrowths, but four zircon grains yielded concordant results with dates

between 317.9 and 315.1 Ma.

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., 1958, Uranium, thorium, columbium, and rare earth deposits in the Salmon region, Lemhi County, Idaho: Idaho Bureau of Mines and Geology 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. Axelrod, D.I., 1998, The Oligocene Haynes Creek flora of eastern Idaho: University of California Publications in Geological Sciences, v. 143, 99 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., 3 plates.

Burmester, R.F., Lonn, J.D., Lewis, R.S., and McFaddan, M.D., 2013, Toward a grand unified theory for stratigraphy of the Lemhi subbasin of the Belt Supergroup: Northwest Geology, v. 42, p. 1-19. Burmester, R.F., Lewis, R.S., Othberg, K.L., Stanford, L.R., Lonn, J.D., and McFaddan, M.D., 2016a, Geologic map of the western part of the Salmon 30 x 60 minute quadrangle, Idaho and Montana, scale 1:75,000. Burmester, R.F., Lonn, J.D., Lewis, R.S., and McFaddan, M.D., 2016b, Stratigraphy of the Lemhi subbasin of the Belt Supergroup, in J.S. MacLean, and J.W. Sears,

eds., Belt Basin: Window to Mesoproterozoic Earth: Geological Society of America Special Paper 522, doi:10.1130/2016.2522(01). Burmester, R.F., Lewis, R.S., and Lonn, J.D., 2017, Were we wrong? Second thoughts on geology of the Lemhi subbasin: Northwest Geology, v. 46, p. 7-14. Burmester, R.F., Mosolf, J., Stanford, L.R., Lewis, R.S., Othberg K.L, and Lonn, J.D., 2018, Geologic map of the Lemhi Pass quadrangle, Lemhi County, Idaho, and Beaverhead County, Montana: Idaho Geological Survey Digital Web Map 183, scale 1:24,000. Chetel, L.M., Janecke, S.U., Carroll, A.R., Beard, B.L., Johnson, C.M., and Singer,

B.S., 2011, Paleogeographic reconstruction of the Eocene Idaho River: Geologi-

cal Society of America Bulletin, v. 123, no 1/2, p. 71-88. Fisher, F.S., McIntyre, D.H., and Johnson, K.M., 1992, Geologic map of the Challis quadrangle, Idaho: U.S. Geological Survey Miscellaneous Investigations Series Map I-1819, scale 1:250,000. Gillerman, V.S., 2008, Geochronology of iron oxide-copper-thorium-REE mineralization in Proterozoic rocks at Lemhi Pass, Idaho, and a comparison to coppercobalt ores, Blackbird Mining District, Idaho: Final Technical Report to U.S. Geological Survey for Grant 06HQGR0170, 148 p Gillerman, V.S., Fanning, C.M., Link, P.K., Layer, P., and Burmester, R.F., 2008,

Newly discovered intrusives at the Lemhi Pass thorium-REE iron oxide district, Idaho: Cambrian syenite and mystery ultramafics - signatures of a buried alkaline complex or two systems?: Geological Society of America Abstracts with Programs, v. 40, no. 1, p. 51. Gillerman, V.S., Schmitz, M.D., Jercinovic, M.J., and Reed, R., 2010, Cambrian and Mississippian magmatism associated with neodymium-enriched rare earth and thorium mineralization, Lemhi Pass district, Idaho: Geological Society of America Abstracts with Programs, v. 42, no. 5, p. 334.

Gillerman, V.S., Schmitz, M.D., and Jercinovic, M.J., 2013, REE-Th deposits of the Lemhi Pass region, northern Rocky Mountains - Paleozoic magmas and hydrothermal activity along a continental margin: Geological Society of America Abstracts with Programs. v. 45, no. 5, p. 41. Harrison, S.L., 1985, Sedimentology of Tertiary sedimentary rocks near Salmon, Idaho: University of Montana Ph.D. dissertation, 175 p. Hipple, Karl., Langersmith, Karen., Winward, Rulon., Ames, Dal., and Duncan, Bradley., 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 pages, soil maps at http://websoilsurvey.nrcs.usda.gov/app/ Janecke, S.U., VanDenburg, C.J., Blankenau, J.J., and M'Gonigle, J.W., 2000, Long-distance longitudinal transport of gravel across the Cordilleran thrust belt of Montana and Idaho: Geology, v. 28, no. 5, p. 439-442. Janecke, S.U., Blankenau, J.J., VanDenburg, C.J., and Van Gosen, B.S., 2001, Map of normal faults and extensional folds in the Tendoy Mountains and Beaverhead Range, southwest Montana and eastern Idaho: U.S. Geological Survey Miscellaneous Field Studies Map MF-2362, scale 1:100,000.

Janecke, S.U., and Blankenau, J.J., 2003, Extension folds associated with Paleogene detachment faults in SE part of the Salmon basin, in D.R. Lageson, and R.B. Christner, eds., 2003, Tobacco Root Geological Society Field Conference at the Belt Symposium IV: Northwest Geology, v. 32, p. 51-73. Lane, E.W., 1947, Report of the subcommittee on sediment terminology: Transactions of the American Geophysical Union, v. 28, no. 6, p. 936-938. Le Bas, M.J., and Streckeisen, A.L., 1991, The IUGS systematics of igneous rocks: Journal of the Geological Society, London, v. 148, p. 825-833. Lewis, R.S., Burmester, R.F., Stanford, L.R., Lonn, J.D., McFaddan, M.D., and

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 Lewis, R.S., Othberg, K.L., Stanford, L.R., Burmester, R.F., Lonn J.D., and McFaddan, M.D., 2011, Geologic map of the Goldstone Mountain quadrangle, Lemhi County, Idaho: Idaho Geological Survey Digital Web Map 134, scale 1:24,000. Lund, K.I, Evans, K.V., Tysdal, R.G., and Winkler, G.R., Geologic map of the east half of the Salmon National Forest, in Evans, K.V., and Green, G.N., 2003, Geologic map of the Salmon National Forest and vicinity, east-central Idaho: U.S.

Othberg, K.L., 2009, Geologic map of the Kitty Creek quadrangle, Lemhi

Geological Survey Geologic Investigations Series Map I-2765, 19 p., scale McKee, E.D., and Weir, G.W., 1953, Terminology for stratification and crossstratification in sedimentary rocks: Geological Society of America Bulletin, v. 64, p. 381-390. Othberg, K.L., Lewis, R.S., Stanford, L.R, Burmester, R.F., and McFaddan, M.D., 2011, Geologic map of the Baker quadrangle, Lemhi County, Idaho: Idaho Geological Survey Digital Web Map 141, scale 1:24,000. Ross, C.P., 1947, Geology of the Borah Peak quadrangle, Idaho: Geological Society

of America Bulletin, v. 58, p. 1085-1160. Ruppel, E.T., 1975, Precambrian Y sedimentary rocks in east-central Idaho: U.S. Geological Survey Bulletin 889-A, 23 p. Staatz, M.H., 1979, Geology and mineral resources of the Lemhi Pass thorium district, Idaho and Montana: U.S. Geological Survey Professional Paper 1049-A, Tucker, D.R., 1975, Stratigraphy and structure of Precambrian Y (Belt?) metasedi-

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 Tysdal, R.G., Lindsey, D.A., and Taggart, J.E., 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.

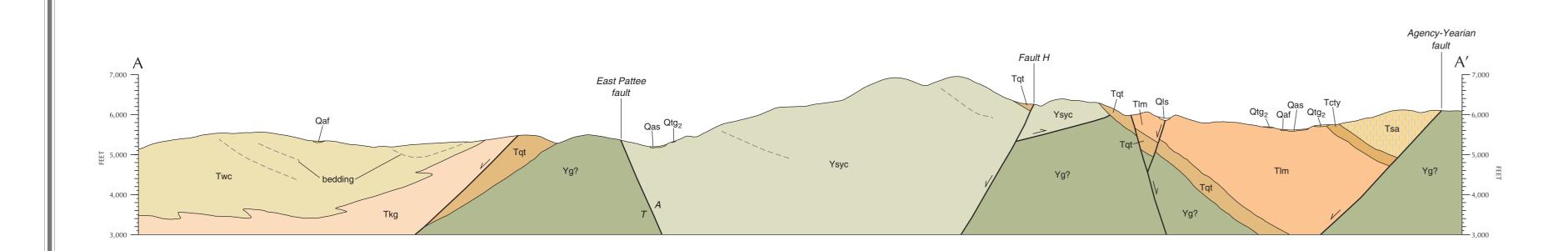
Horse Prairie half graben, southwest Montana: Utah State University M.S. Winston, Don., 1986, Sedimentology of the Ravalli Group, middle Belt carbonate, and Missoula Group, Middle Proterozoic Belt Supergroup, Montana, Idaho and Washington, in S.M. Roberts, ed., Belt Supergroup: A Guide to Proterozoic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

VanDenburg, C.J., 1997, Tectonic and paleogeographic evolution of the

Table 1. Major-oxide and trace-element analyses of samples collected in the Agency Creek quadrangle. Major-element oxides in weight percent Trace elements in parts per million number Latitude Longitude Unit name unit SiO₂ TiO₂ Al₂O₃ FeO* MnO MgO CaO Na₂O K₂O P₂O₅ Total LOI Ni Cr Sc V Ba Rb Sr Zr Y Nb Ga Cu Zn Pb La Ce Th U Co 5RL079A 44.9891 -113.5816 syenite dike 🕏 5x 62.35 0.26 16.64 8.71 0.15 0.22 0.30 6.39 4.73 0.09 99.84 0.89 5 14 <1 9 528 215.4 48 915 70.1 286.2 33.2 13 142 11 184 379 39.1 6.0 4

* Total Fe expressed as FeO. LOI = Loss on ignition.

Latitudes and longitudes are in the 1927 North American Datum (NAD27). All analyses performed at Washington State University GeoAnalytical Laboratory, Pullman, Washington.



Contour interval 40 feet

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

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

Declination from NOAA National Geophysical Data Center.

prospect pit. Abundant plant remains and the tail of a fish were collected