GEOLOGIC MAP OF THE HAWLEY GULCH QUADRANGLE, BONNEVILLE AND MADISON COUNTIES, IDAHO

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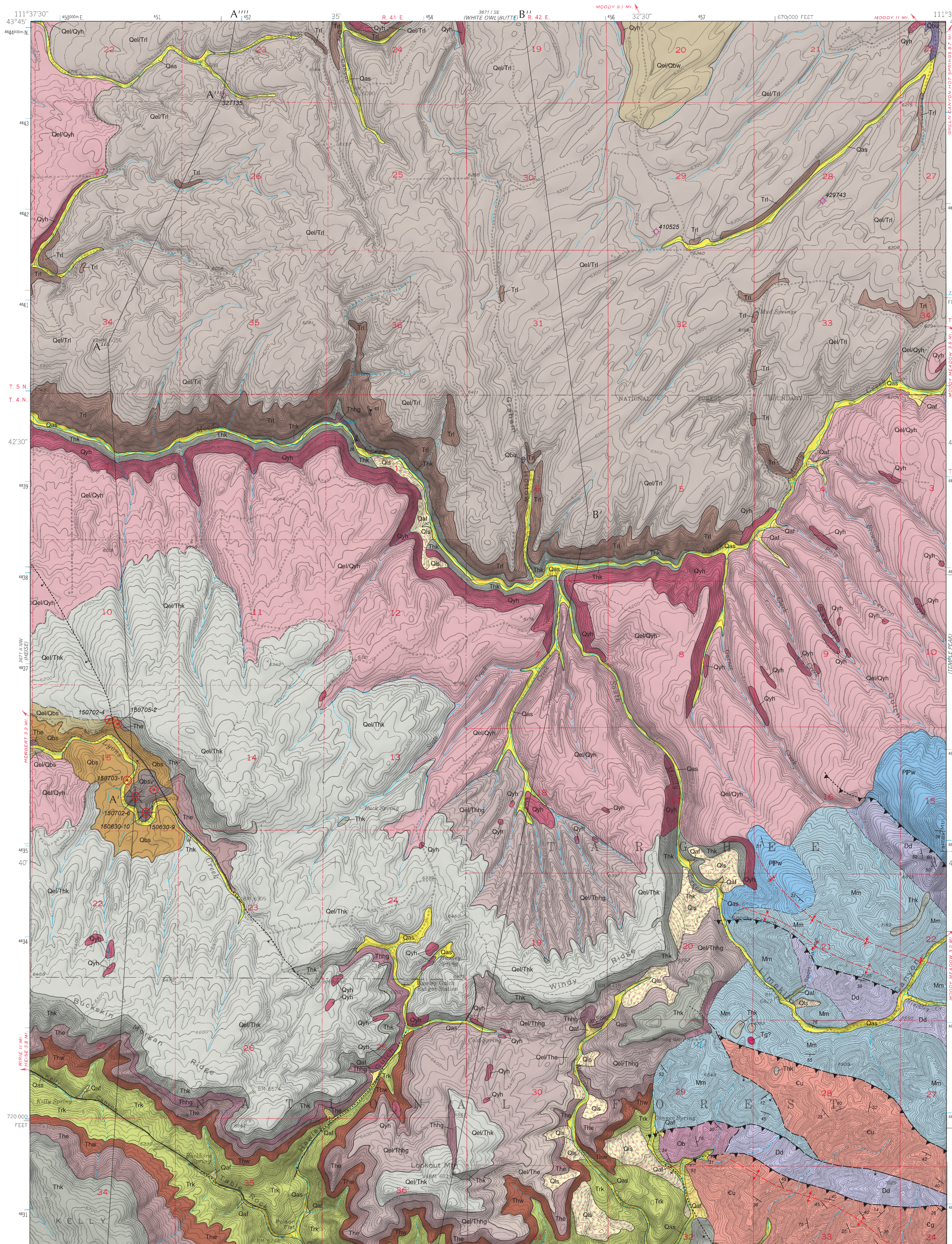
2019



Base Map Credit

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

Topography from aerial photographs taken 1946. Field checked 1951. Map photoinspected 1975; no major culture or drainage changes observed.

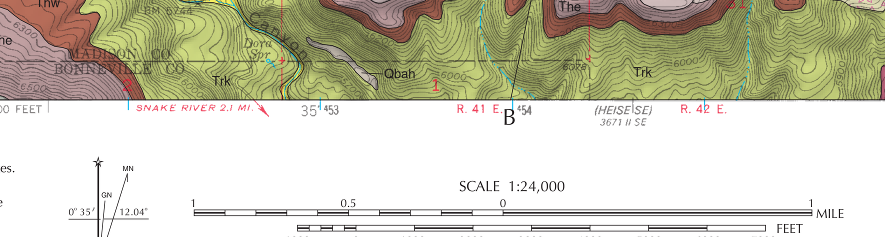
Shaded elevation from 10 m DEM.

Polyconic Projection. 1927 North American Datum.

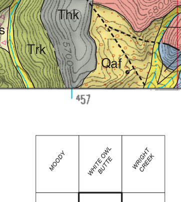
10,000-foot grid ticks based on Idaho coordinate system, east zone.

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

Declination from NOAA National Geophysical Data Center.



QUADRANGLE LOCATION



ADJOINING QUADRANGLES

Field work conducted 2015.

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

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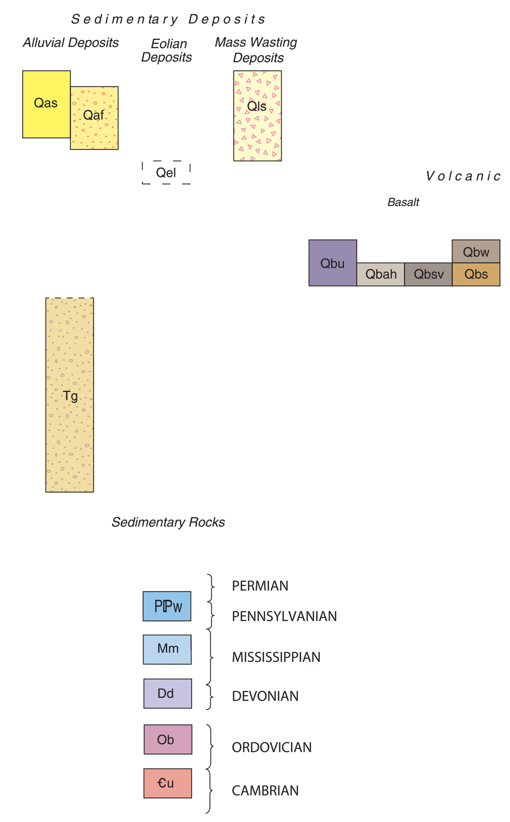

INTRODUCTION

This map depicts rock units exposed at the surface or underlying a thin cover of soil or colluvium. Surficial geological units are also depicted where mappable at a scale of 1:24,000. In areas covered by thick loess, bedrock units lying beneath the loess are also indicated.

Sources of map information compiled and consulted include Staatz and Albee (1966), Prostka and Hackman (1974), Prostka and Embree (1978), and the unpublished mapping of Barney and others. The latter reference contains a compilation of unpublished mapping by David J. Doherty conducted in the 1970s and/or early 1980s that focused on units of the Heise volcanic field (HVF). Soil information (Soil Survey Staff, 2016) and water well logs (Idaho Department of Water Resources, 2016) were also consulted. Additional sources of information are cited in the Description of Map Units.

Paleozoic geology and structures in the southeast corner of the map were reconnaissance mapped only and should be considered preliminary. Major structures were interpreted from mapping to the east by Staatz and Albee (1966). The Idaho-Wyoming fold and thrust belt along the entire Snake River Range needs updated 1:24,000-scale mapping.

SYMBOLS

Contact: dashed where approximately located.

Normal fault: ball and bar on downthrown side; dashed where approximately located; dotted where concealed.

Thrust fault: teeth on upper plate; dashed where approximately located; dotted where concealed.

Syncline axial trace.

Anticline axial trace.

28 Strike and dip of bedding.

43 Strike and dip of eutaxitic foliation.

Basaltic volcanic vent.

150702-6 Geochemical sample (see Table 1).

346573 Water well shown with Idaho Department of Water Resources WellID number. Water well logs can be found at http://www.idwr.idaho.gov/apps/appswell/RelatedDocs.asp?WellID=xxxxxx (where "xxxxxx" is the six-digit WellID).

STRUCTURE

The map area contains three major structural features: the Snake River Range; the Grand Valley fault (sec. 32, T. 4 N., R. 42 E.), and the Rexburg Bench. The Snake River Range consists of Cambrian through Cretaceous sedimentary rocks deformed by thrust faulting and folding. In the southeastern portion of the map, Cambrian carbonates are thrust over folded Devonian-Carboniferous limestones and sandstones (cross section C-C'). Bedding dips are dominantly to the southwest, with thrust faults trending northwest-southeast. Observed folds are meso-scale structures best exposed in the Gallatin Formation (Ꞓg) near the thrust contact with the Darby Formation (*Dd*) in sec. 33, T. 4 N., R. 42 E. The Grand Valley normal fault extends 140 km from western Wyoming into the Eastern Snake River Plain before terminating in the map area (Piety and others, 1992). Motion on the fault and associated splays uplifted the Snake River Range and tilted rocks in the map area towards the north (cross sections A and B) during the middle Miocene through early Pleistocene (Anders and others, 1989). Continuing extension and magmatism along the Grand Valley trend produced an array of small offset normal faults and basaltic lava flows and vents. They are best displayed on the Rexburg Bench, which consists of Miocene to Pleistocene rhyolitic rocks associated with Snake River Plain-Yellowstone hot spot magmatism capped by Pleistocene basaltic lavas. The Rexburg Bench is separated from the adjacent Eastern Snake River Plain by normal faults.

STRATIGRAPHY

Sedimentary rocks typical of the eastern Idaho fold and thrust belt are the oldest rocks exposed in the southeastern portion of the map area. These include the Cambrian-Ordovician succession of interbedded shale and limestone, limestone, and dolomite (Gros Ventre, Gallatin, and Big Horn formations, respectively); Devonian marine dolostone and limestone (Darby Formation); Mississippian carbonate units (Madison and Lodgepole formations); and Pennsylvanian-Permian fine-grained sandstone (Wells Formation).

Overlying the Paleozoic units and comprising most of the rest of the map area are Miocene-Pleistocene rhyolitic rocks. The Heise volcanic field (HVF) is the second-youngest eruptive center along the Snake River Plain-Yellowstone hotspot trend. The HVF tuffs consist of large-volume, generally densely welded ignimbrites erupted from overlapping, nested calderas. Together with the adjacent Poplar and Heise quadrangles (Phillips and others, 2016a,b), the map area contains among the most complete and easily accessible exposures of the HVF. Major units consist of the Blacktail Creek Tuff (6.62 Ma), Walcott Tuff (6.27 Ma; not present in map area), tuff of Wolverine Creek (5.57 Ma), tuff of Elkhorn Spring (5.5 Ma), and Kilgore Tuff (4.45 Ma). Two large rhyolite lava flows are also present and probably are related to HVF magmatism. These are rhyolite of Kelly Canyon (about 5.7 Ma) and rhyolite of Long Hollow (3.8-4.3 Ma). Several names have been applied to the HVF units over the years (Embree and others, 1982; McBroome and others, 1981), and nomenclature for some units continues to be debated. Here, we use the nomenclature of Morgan and McIntosh (2005) with the exception of distinguishing the tuff of Elkhorn Springs (*The*) from the Conant Creek Tuff, as suggested by Anders and others (2014). The youngest rhyolite in the map area is the Huckleberry Ridge Tuff (*Qyh*), erupted about 2.0 Ma from the Yellowstone volcanic field.

GEOLOGIC HAZARDS

Inactive landslides are present in the map area. They tend to occur on steep hillslopes that are underlain by weak pyroclastic and volcaniclastic sediments (*Thw* and *Thhg*), or on steep hillslopes with north aspects along Moody Creek that are underlain by unit *Qyh*.

MINERAL RESOURCES

Two abandoned limestone mines are reported in the map area (Idaho Geological Survey, 2016): Morning Glory Mine (lat 43.6486°N., long 111.5350°W.); and Limekiln Canyon (lat 43.6620° N., long 111.5335° W.).

DESCRIPTION OF MAP UNITS

The metric system is used for sizes of mineral or clast constituents of rocks, and for small-scale features of outcrops. Unit thickness and distance are given in both meters (m) and feet (ft). Rock colors are after Geological Society of America (2013). Grain size classification of sediments and sedimentary rocks is based on the Wentworth scale (Lane, 1947). Carbonate rock classification is after Dunham (1962). Volcanic rocks are classified by total alkali versus silica chemical composition according to IUGS recommendations (Le Bas and Streckeisen, 1991). Phenocryst abundances in rhyolites are reported as volume percent basis where known, or as relative to a well-characterized regional ignimbrite (Blacktail Creek Tuff of the Heise volcanic field; Bolte and others, 2015). The geologic timescale is after U.S. Geological Survey (2010) with Pleistocene subseries after Walker and others (2012) and Cohen and Gibbard (2011). Radiometric ages are reported with 2σ errors unless otherwise noted. Descriptions of Paleozoic and Mesozoic rocks are modified from Staatz and Albee (1966). Age assignments for these units are after National Geologic Map Database Geolex (U.S. Geological Survey, 2016).

SEDIMENTARY DEPOSITS

Alluvial Deposits

Qas **Alluvium of side streams (Holocene)**—In Limekiln Canyon and tributary streams, consists of boulders, cobbles, sand, and silt of rhyolite, quartzite, breccia, and limestone. Elsewhere, consists of boulders, cobbles, and coarse sand of rhyolite and basalt. Thickness is <3 m (<10 ft).

Qaf **Alluvial fans (Holocene-Late Pleistocene)**—Cobbles, pebbles, sand, and silt composed of locally derived, sub-angular to sub-rounded rhyolite, limestone, basalt, and/or quartzite. Poorly sorted and crudely stratified. Typically consist of steep deposits at the junction of small tributary streams with larger streams. Subject to flooding and debris flows during periods of heavy rainfall.

Tg **Gravel (Pliocene-Miocene)**—Gravel and pebbles of limestone and quartzite, sub-rounded to sub-angular; locally cemented into poorly sorted conglomerate that weathers into boulders up to 50 cm in length. Poorly exposed along the crest of ridge in secs. 28 and 29, T. 4 N., R. 42 E. Exposed thickness <1m (3 ft). Origin and age are uncertain. May represent erosional remnants of alluvial fans deposited in the Snake River graben that have been uplifted and isolated by motion on the Grand Valley fault.

Mass Wasting Deposits

Qls **Landslides (Holocene-Late Pleistocene)**—Hummocky complexes of flows and slumps composed of poorly exposed angular boulders of rhyolite. Active scars generally absent. Associated with unwelded pyroclastic deposits (*Thw* and *Thhg*) that underlie blocky rhyolite (units *Thk* or *Thr*). Also, consists of rotational slumps of rhyolite (unit *Qyh*) on steep slopes with northern aspects along Moody Creek.

Eolian Deposits

Qel **Loess (Late Pleistocene)**—Massive, brown to light-gray, silt, very fine sand, and clay; 4.5 to 11 m (15 to 35 ft) thick in water wells north of Moody Creek. Present in most areas of the map. Thins with elevation and is nearly absent on Farnes Mountain (sec. 15, T. 4 N., R. 42 E.). Shown as a component of other geologic units (e.g. *Qel/Qyh*). The Ririe and Potell soil series developed in the loess contains multiple pedigenic carbonate (Bk) horizons suggesting several periods of deposition. Loess is associated with glaciation in the headwaters of the Snake River. During glaciations, fine-grained sediments were transported onto the Eastern Snake River Plain, and then blown by northeast-directed winds onto uplands. In the Idaho Falls area, loess deposition occurred between 15 to 25 ka, and about 75 ka (Phillips and others, 2009). In the Jackson Hole, Wyoming area, episodic loess deposition occurred between about 16 ka and 154 ka (Pierce and others, 2011). Soils developed in loess are widely cultivated on the Rexburg Bench portion of map for farming of wheat and other grains.

VOLCANIC ROCKS

Basalts

Qel/Qbw, Qbw **Basalt of White Owl Butte (Early Pleistocene)**—Medium dark-gray, glomeroporphyritic, locally diktytaxitic basalt. Here shown as *Qel/Qbw* where *Qbw* is concealed by loess. Phenocrysts are plagioclase 0.2-1 mm and olivine 0.3-0.8 mm. Groundmass is dense and partly glassy with clinopyroxene and opaque minerals 0.1-0.3 mm. The thickness at the White Owl Butte vent area, north of this map (SW¼ sec. 18, T.5 N., R. 41 E.), from water well logs is about 25 m (82 ft). Reversed magnetic polarity (Embree and others, 2016).

Qel/Qbs, Qbs **Basalt of Sommers Butte volcanic rift (Early Pleistocene)**—Medium dark-gray, weathering brownish-gray, fine-grained basalt. Shown as *Qel/Qbs* where concealed by loess. Glomeroporphyritic with phenocrysts of olivine 0.6-0.8 mm, plagioclase 0.1-0.18 mm, and opaque minerals 0.1-0.2 mm. Groundmass is dense and holocrystalline, with very abundant aligned, elongate plagioclase 0.1-0.15 mm, clinopyroxene 0.01–0.03 mm, and opaque minerals 0.01–0.03 mm. Consists of at least one lava flow with pahoehoe surface that ponded in the vent area then flowed down Lyons Creek. Flow is cut by northwest-trending normal fault with as much as 30 m (100 ft) displacement. Some of the displacement may have been accomplished by deflation of the flow during or shortly after eruption. Thickness is about 3-9 m (10-30 ft). The Sommers Butte volcanic rift is 22 km (13 mi) long and extends northwest into the adjacent Heise and Moody quadrangles. Basalts of the Sommers Butte volcanic rift are dated by whole-rock step-heated $^{40}Ar/^{39}Ar$ analyses at about 2.0 Ma (Embree and others, 2016).

Qbsv **Vent of Sommers Butte volcanic rift (Early Pleistocene)**—Two lava cones 12 to 15 m (40 to 50 ft) high separated by ponded lava. Blocky basalt, pahoehoe, and pale reddish-brown spatter make up the cones. Basalt bombs 10-20 cm, cinders, and ash are present adjacent to vents. Normal magnetic polarity as measured by fluxgate in the vent area.

Qbah **Basalt of Antelope Flat, hyaloclastite facies (Early Pleistocene)**—Light-brown to moderate reddish-orange, coarse to granule sand, composed of palagonite, cinders, vesicular spatter, and angular clasts of basalt (cobbles to boulders). Generally massive with locally graded beds with trough cross-bedding. Erupted from a loess-concealed vent on Antelope Flat in the Wheaton Mountain quadrangle (sec. 2, T. 2 N., R. 42 E.). The basalt of Antelope Flat dammed the South Fork of the Snake River; *Qbah* formed in the temporary lake created by the dam (Dossett and others, 2012). Thickness 12–21 m (40-70 ft).

Qbu **Basalt, undivided (Early Pleistocene)**—Medium- to dark-gray, fine-grained basalt, dense to vesicular, with abundant plagioclase phenocrysts 0.5-1.5 mm and glomerocrysts of brown olivine 0.2-0.5 mm. Shown as *Qel/Qbu* where concealed by loess. Appears to be an intercanyon flow. Preliminary correlation made with the basalt of White Owl Butte (*Qbw*) on the basis of geochemistry (Table 1). Exposure consists of numerous large boulders. Thickness uncertain.

Rhyolites

Yellowstone Volcanic Field

Qel/Qyh, Qyh **Huckleberry Ridge Tuff (Early Pleistocene)**—Rhyolitic ignimbrite, densely to moderately welded, with moderately abundant (about 10 percent), small (1 to 4 mm) phenocrysts of sanidine and quartz with lesser plagioclase and pyroxene. Shown as *Qel/Qyh* where concealed by loess. Phenocrysts tend to be concentrated (20 to 30 percent) in lower portion of unit and sparse (<5 percent) higher up in the unit. Most exposures in map consist of light-gray to grayish-pink densely welded devitrified tuff with well-developed eutaxitic texture. In secs. 8 and 9, T. 4 N., R. 42 E., most exposures are altered to pale yellowish-brown, relatively crystal-rich rhyolite with white flattened pumice 2-5 mm and moderate brown specks 1-2 mm of altered fayalite(?) and/or earthy mineraloid. Three Huckleberry Ridge Tuff members (A, B, and C) were erupted from the Big Bend Ridge caldera in the Yellowstone volcanic field about 60 km (38 mi) north of the map (Christiansen, 2001). However, known exposures in map are probably restricted to Member A (C. Wilson, written communication, 2015). Thickness is about 10 to 30 m (30 to 100 ft) in the map area and widely varies because of deposition over irregular topography. Unmapped outcrops of *Qyh* overlying *Trl* may be present in areas of thick loess deposits in northern portion of the map. Magnetic polarity is excursional with subhorizontal inclination and southwesterly declination (Reynolds, 1977). Recently measured ages from single-crystal laser-fusion $^{40}Ar/^{39}Ar$ analyses of sanidine range from 2.123 ± 0.006 Ma (Ellis and others, 2012) to 2.0794 ± 0.0046 (Rivera and others, 2014).

Heise Volcanic Field

Qel/Trl, Trl **Rhyolite of Long Hollow (Pliocene)**—Red and black, perlitic rhyolite lava flow. Shown as *Qel/Trl* where covered by loess. Contains abundant (10 to 30 percent) phenocrysts of sanidine, quartz, plagioclase, and pyroxene. Lithophysae zones and flow banding are commonly near-vertical and convoluted. Locally consists of devitrified rhyolite with highly contorted white and dark-gray flow banding. Near top of flow, grades into pink tuff with black shards and vitrotrophyre clasts (Prostka and Embree, 1978). Maximum exposed thickness is 140 m (460 ft). K-Ar age is 3.5 ± 0.4 Ma (Morgan and McIntosh, 2005; p. 298); U-Pb concordia age from zircons is 4.28 ± 0.18 Ma (Bindeman and others, 2007, p. 1020). *Trl* has similar $^{18}δO$ and other geochemical features that suggest a link with residual magma of the Kilgore Tuff (Watts and others, 2011). Best exposures of the unit are along North Fork Moody Creek (secs. 5 and 6, T. 4 N., R. 42 E.).

Qel/Thk, Thk **Kilgore Tuff (Pliocene)**—Rhyolitic ignimbrite, densely welded, with sparse (2 to 7 percent), small (<2 mm) phenocrysts of plagioclase, quartz, and sanidine. Shown as *Qel/Thk* where concealed by loess. Well-developed basal black vitrophyre up to 1 m (3.3 ft) thick is present in many Lookout Mountain exposures (sec. 36, T. 4 N., R,. 41 E.). Abundant, small (1 to 4 cm diameter) lithophysae are concentrated in the middle to upper part of unit, forming highly resistant, blocky, devitrified rhyolite with a "swiss cheese" appearance. Dark reddish-brown ("maroon") and dark-gray, flattened pumice 3 to 3.5 cm in length are locally abundant. Top of unit capped with thin light-brown to pale reddish brown vitric tuffs and locally with grayish-brown vitrophyre. Reverse magnetic polarity. Mean ages from sanidine single-crystal laser-fusion $^{40}Ar/^{39}Ar$ analyses are 4.45 ± 0.05 Ma (Morgan and McIntosh, 2005) and 4.61 ± 0.01 Ma (1σ error, Anders and others, 2014.). Formerly called "tuff of Heise C" (Prostka and Embree, 1978) on southeastern margin of Eastern Snake River Plain; and "tuff of Spencer" on northern side (McBroome and others, 1981). Renamed and formally defined by Morgan and McIntosh (2005). Thickness on the map ranges from 10 to 100 m (33 to 328 ft). The Kilgore tuff has largest estimated volume (1800 km³) of the Heise ignimbrites (Morgan and McIntosh, 2005).

Qel/Thhg, Thhg **Tuff of Hawley Gulch (Pliocene)**—Light-gray, yellow, and pink, unwelded rhyolitic airfall and ash-flow tuffs, locally reworked. Shown as *Qel/Thhg* where concealed by loess. Thickly bedded to massive, composed of poorly sorted, coarse-grained (1 to 3 mm) white glass shards, long-tubed crystal-poor pumice and light-colored lithics (1 to 3 cm), and sparse plagioclase and quartz crystals (Prostka and Embree, 1978). Generally poorly exposed and subject to landsliding. Forms distinctive rilled or hummocky topography where not overlain by resistant caprock of *Thk* (e.g. secs. 18 and 19, T. 4 N., R. 42 E.). Thickness varies greatly from <15 to >140 m (<50 to >460 ft), probably because of deposition over irregular topography. Stratigraphic position suggests correlation with upper portion of unit *Tht* in the adjacent Poplar quadrangle (Phillips and others, 2016a).

Qel/The, The **Tuff of Elkhorn Spring (late Miocene)**—Grayish-brown, grayish-pink, and pale-purple, densely welded, rhyolitic ignimbrite; crystal-poor with <1 percent small (<2 mm) plagioclase, quartz, sanidine, and augite. Shown as *Qel/The* where concealed by loess. Grades from basal, nearly aphyric black vitrophyre up to 2 m (6.5 ft) thick to eutaxitic devitrified zone overlain by a lithophysal zone. Distinctive blocky talus forms below cliff exposures. Maximum thickness in map area is about 100 m (330 ft). Reverse magnetic polarity. Formerly called "tuff of Heise B" (Prostka and Hackman, 1974); renamed tuff of Elkhorn Spring by Prostka and Embree (1978). Correlated with the Conant Creek Tuff of the western Teton Range (Christiansen and Love, 1978) by Morgan and McIntosh (2005). This correlation was questioned by Anders and others (2014) who suggested that the tuff of Elkhorn Spring is slightly younger than Conant Creek Tuff. Sanidine laser-fusion single-crystal $^{40}Ar/^{39}Ar$ ages for tuff of Elkhorn Spring are 5.48 ± 0.13 Ma for a sample from the map area (Morgan and McIntosh, 2005; sample ESRP-95-2013, lat 43.64197° N., long 111.60072° W.), and 5.52 ± 0.03 Ma (1σ error, Anders and others, 2014, sample from Heise Cliffs), while the Conant Creek Tuff age is 6.01 ± 0.07 Ma (1σ error, Anders and others, 2014). Feldspar crystals and glass from tuff of Elkhorn Spring, Conant Creek Tuff, and Wolverine Creek Tuff are nearly identical in their major and trace element concentrations (Szymanowski and others, 2015), suggesting that they are closely spaced events from the same caldera (Anders and others, 2014). Unit thins to the north and east, and is entirely absent in the Big Hole Mountains (Price and Rodgers, 2010; Phillips and others, 2013).

Thw **Wolverine Creek Tuff (late Miocene)**—Unwelded to weakly welded near top, pumiceous rhyolitic tuff (Prostka and Embree, 1978; Morgan and McIntosh, 2005; Szymanowski and others, 2015). Angular to sub-rounded, black obsidian fragments 2 to 10 mm, and black and white bubble wall shards dominate; pale yellowish-brown pumice 0.5 to 3 cm with elongated bubble walls, and very sparse (<1 percent) crystals of plagioclase, augite, and sanidine also present. General color is light gray becoming medium dark-gray toward top because of increase in obsidian glass. The upper part of unit, informally known as "rainbow tuff", is partially welded and commonly bright shades of red, orange, and purple. Stratification ranges from massive, to planar, to cross-bedded, consistent with airfall and pyroclastic surge deposits (Doherty, 1976). Elutriation pipes produced by escaping gas present in many exposures. Outcrops can be easily spotted by white soil colors. Thickness about 18 to 60 m (60 to 300 ft). Laser-fusion single-crystal $^{40}Ar/^{39}Ar$ ages from sanidine yielded an age of 5.59 ± 0.05 Ma (Morgan and McIntosh, 2005). The Wolverine Creek Tuff and tuff of Elkhorn Spring have nearly identical major and trace element concentrations in feldspar crystals and glass, and $^{40}Ar/^{39}Ar$ ages, suggesting that they are closely spaced events from the same caldera (Szymanowski and others, 2015; Anders and others, 2014).

Trk **Rhyolite of Kelly Canyon (late Miocene)**—Rhyolite lava flows, crystal poor, with a range of textures and colors. Most exposures are cliff forming, brown, devitrified, and massive with closely spaced joints and flow banding, some of which conform to regional bedding and others which are highly eccentric. Autobrecciation common in some outcrops. Less commonly consists of gray perlite with black and orange obsidian remnants (Proskta and Embree, 1978). Diagnostic features are maroon, flow-deformed chips and blocks contained in aphyric groundmass. Maximum thickness in map is 300 m (984 ft). K-Ar age is about 5.7 Ma (Morgan and McIntosh, 2005).

Thu **Heise volcanic field, undivided (late Miocene)**—Cross section only. Consists of tuffaceous sediments and pyroclastic deposits in the time interval between *Thb* (about 6.6 Ma) and *Trk* (about 5.7 Ma). Shown as deposited adjacent to *Trk*. May correspond to aquitards encountered in deep irrigation wells on the adjacent Rexburg Bench (Embree and others, 2016; Phillips and others, 2016b).

Thb **Blacktail Creek Tuff (late Miocene)**—Cross section only. Exposed in adjacent Heise and Poplar quadrangles (Phillips and others, 2016a,b). Rhyolitic ignimbrite, densely welded, with most abundant (10 to 20 percent) phenocrysts of any Heise unit. Phenocrysts are plagioclase, quartz, sanidine, augite, opaque oxides (magnetite and ilmenite), and pigeonite (Bolte and others, 2015). Mean age from single-crystal laser-fusion $^{40}Ar/^{39}Ar$ analyses is 6.62 ± 0.03 Ma (Morgan and McIntosh, 2005) and 6.66 ± 0.01 Ma (1σ error, Anders and others, 2014). Formerly called "tuff of Spring Creek" or "Heise A" on southern margin of the Snake River Plain (Prostka and Embree, 1978), and "tuff of Edie School" on northern margin (Embree and others, 1982).

Ttn **Tuff of Newby Ranch (Miocene)**—Cross section only. Light-gray and yellowish-gray, thinly laminated, fine-grained rhyolitic ash; locally contains snail and reed impressions (Prostka and Embree, 1978). Maximum thickness 70 m (230 ft) but most outcrops are <3 m (10 ft). K-Ar age is 8.6 ± 0.5 Ma (Morgan and McIntosh, 2005, p. 298); therefore probably lies outside of age range of HVF. Likely includes older Miocene rocks in the central and northern map area.

SEDIMENTARY ROCKS

PPw **Wells Formation (early Permian to Pennsylvanian)**—Medium-grained, white to very pale-orange quartzite; locally stained light brown or pale pink. Grains are subangular and moderately poorly sorted, and composed of quartz, chert, and rare feldspar. Very resistant; forms major ridges such as Farnes Mountain. Weathers into angular boulders 0.25 - 1.5 m in length. While float from this unit is common, outcrops are rare. Thickness ranges from 335 to 792 m (1100 to 2600 ft).

Mm **Madison Group, undivided (Middle to Lower Mississippian)**—Mission Canyon Limestone and Lodgepole Limestone undivided; thinly bedded to massive, very fine- to lithographic, pale-blue limestone, mudstone, wackestone, and grainstone. Infrequent fossils to beds rich with crinoidea, cnidarian (rugosa and tabulata corals), fusulinida, brachiopoda, bryozoa, gastropoda, and cephalopoda. Platy weathering. Cliff forming and slope forming with large discontinuous blocks. Large algal mats and recrystallized calcite crystals are present at Morning Glory Mine (lat 43.6486° N., long 111.5350° W.) and south slope of Limekiln Canyon (lat 43.6478° N., long 111.5160° W.). Ranges in thickness from 207 to over 1158 m (680 to over 3800 ft).

Dd **Darby Formation (Lower Mississippian to Upper Devonian)**—Consists of two members. Lower member contains medium-bedded, brownish-gray to pale-brown, fine-grained limestone, dolomitic limestone, and limestone breccia. These were termed "chocolate-brown" carbonates by Staatz and Albee (1966) who noted that these rock colors are scarce in the mapped area except in the Darby. Networks of fine white calcite veins and whitish mottling are present on many weathered surfaces. The veins are resistant, creating a "honeycomb" effect. Upper member consists of fine-grained, light- to medium-gray, massive to brecciated dolostone that weathers pale yellowish-orange; locally calcareous. Grain size is fine to medium. Fossils are scarce. Thickness ranges from 213 to 274 m (700 to 900 ft).

Ob **Bighorn Dolomite (Upper to Middle Ordovician)**—White to medium-gray, thick-bedded to massive dolostone that is locally calcareous. Weathers to a characteristic very light gray; light-gray mottling is also commonly present. Grain size is fine to medium. Fossils are scarce. Commonly forms small cliffs. Thickness ranges from 24 to 99 m (80 to 325 ft). The unit thins from the Temple Peak quadrangle to the northwest toward the mapped area and appears to be absent in some exposures.

Ꞓu **Cambrian, undivided (upper to middle Cambrian)**—Gallatin Formation and Gros Ventre Formation undivided; grayish- purple to grayish- olive fissile, thin- bedded shale with interbedded gray silty limestone and occasional intraclastic conglomerate and medium light-gray to light olive-gray, generally thin-bedded limestone interbedded with light-olive shale and moderate-yellow siltstone. Desiccation structures, borings, burrows, and other bioturbation in limestone interbeds are common, creating a mottled appearance. Some beds contain brown ooids. Fossils are scarce. Thickness ranges from 43 to 363 m (140 to 1200 ft).

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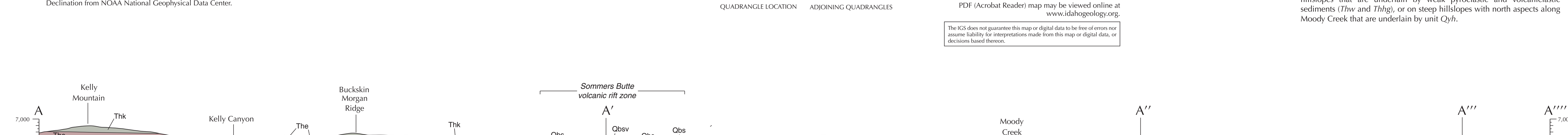
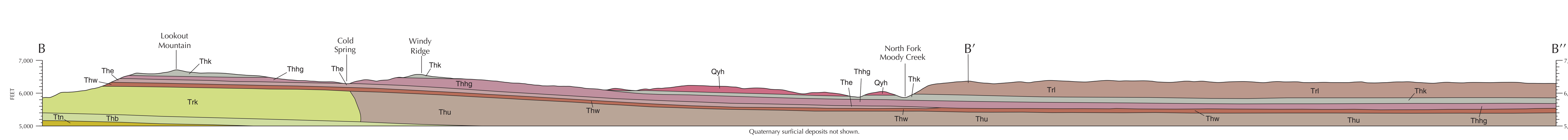


Water well shown with Idaho Department of Water Resources WellID number. Water well logs can be found at http://www.idwr.idaho.gov/apps/appswell/RelatedDocs.asp?WellID=xxxxxx (where "xxxxxx" is the six-digit WellID).

Quaternary surficial deposits not shown.



Quaternary surficial deposits not shown.

Table 1. Major-element oxide and trace element chemistry of samples collected in the Hawley Gulch quadrangle.

Sample number	Latitude	Longitude	Unit name	Map unit	Major-element oxides in weight percent: SiO_2	TiO_2	Al_2O_3	Fe_2O_3*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total	LOI
150630-9	43.67386	-111.608118	basalt of Sommers Butte volcanic rift	Qbs	46.36	3.33	14.28	16.78	0.26	5.11	8.19	3.04	1.46	1.35	100.16	-0.28
150630-10	43.67163	-111.609237	basalt of Sommers Butte volcanic rift	Qbsv	46.42	3.27	14.02	16.65	0.34	5.06	8.14	3.09	1.54	1.30	99.83	-0.29
150702-4	43.68080	-111.614272	basalt of Sommers Butte volcanic rift	Qbs	46.66	3.34	13.89	16.44	0.26	4.48	8.15	3.20	1.65	1.46	99.53	-0.01
150702-6	43.67321	-111.610638	basalt of Sommers Butte volcanic rift	Qbs	47.44	3.22	13.84	16.26	0.26	4.99	7.97	3.09	1.52	1.30	99.89	-0.20
150703-1	43.67479	-111.611775	basalt of Sommers Butte volcanic rift	Qbs	44.27	3.59	15.09	17.82	0.29	4.81	8.10	3.07	1.20	1.38	99.62	1.06
150705-2	43.68037	-111.61308	basalt, undivided	Qbu	47.96	2.23	16.43	13.36	0.19	6.68	9.80	2.69	0.42	0.36	100.12	1.11
150705-8	43.76108	-111.551531	basalt of White Owl Butte	Qbw	49.24	2.22	15.79	12.98	0.19	6.13	9.98	2.70	0.58	0.33	100.14	0.53

Sample number	Trace elements in parts per million: Rb	Sr	Y	Zr	V	Ni	Cr	Nb	Ga	Cu	Zn	Co	Ba	La	Ce	U	Th	Sc	Pb
150630-9	27.6	346	54.4	424	211	22	69	45.7	19.7	13	170	45	956	25	44	<0.5	7.9	24	12
150630-10	25.8	348	53.6	400	209	25	70	42.6	18.5	20	166	46	875	26	43	<0.5	9.4	24	11
150702-4	30.8	373	56.0	463	188	10	29	47.6	19.2	13	175	43	1041	29	51	<0.5	8.5	22	14
150702-6	26.4	331	54.3	412	206	25	72	43.1	18.7	16	172	49	822	23	43	<0.5	8.8	23	11
150703-1	11.7	360	54.3	441	221	23	66	46.7	20.0	18	171	50	1075	26	42	<0.5	8.2	27	2
150705-2	5.3	415	40.1	203	286	63	265	20.4	18.1	26	127	49	522	22	30	<0.5	4.7	29	<1
150705-8	11.1	429	38.5	200	251	43	194	20.1	19.5	16	110	43	606	26	45	1.0	2.1	24	1

* Total Fe expressed as Fe_2O_3.

All analyses by x-ray fluorescence and performed at Franklin and Marshall College, Lancaster, Pennsylvania.

Sample 150705-8 is located in the White Owl Butte quadrangle.

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