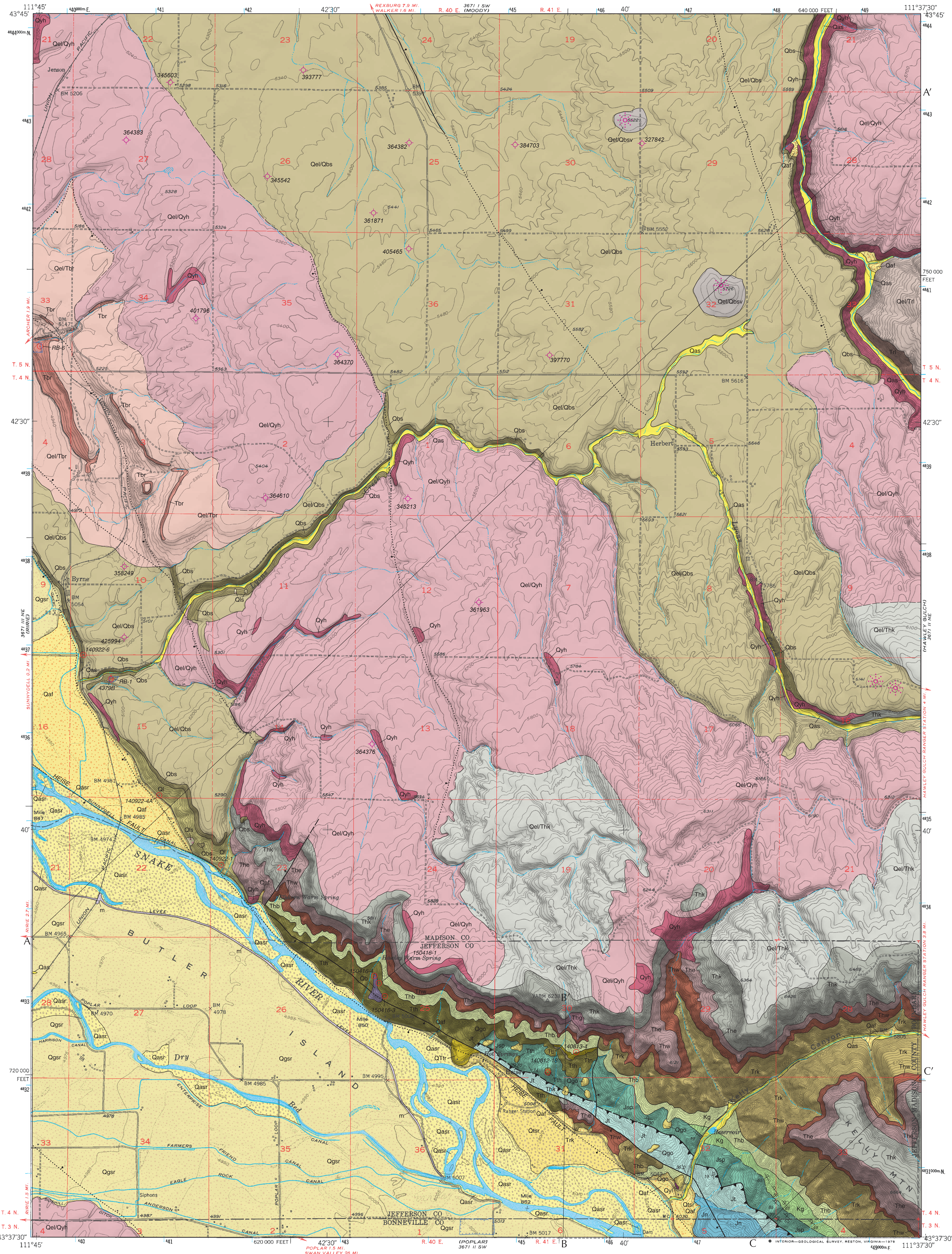
Geologic Map of the Heise Quadrangle, Bonneville, Jefferson, and Madison Counties, Idaho

Mapped and Compiled by William M. Phillips, Daniel K. Moore, Dennis M. Feeney, and Glenn F. Embree

2016



Base Map Credit

Base digitally scanned from 24,000-scale USGS film separates, 1951.

Shaded elevation from 10 m DEM.

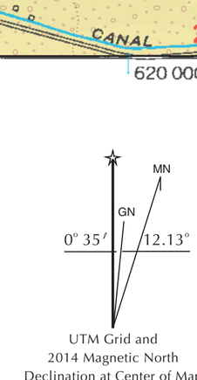
Topography by multiplex methods and plane-table surveys 1951. Aerial photographs taken 1946.

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

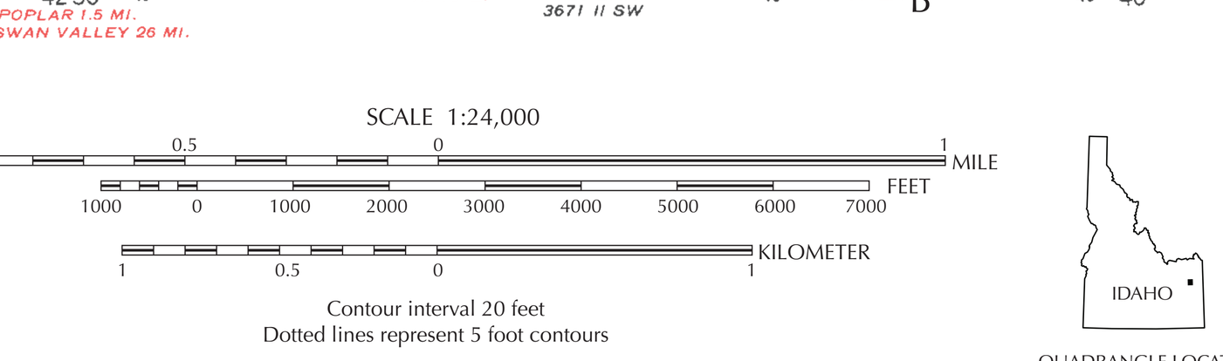
10,000-foot grid ticks based on Idaho coordinate system, east zone.

1000-meter Universal Transverse Mercator grid ticks, zone 11.

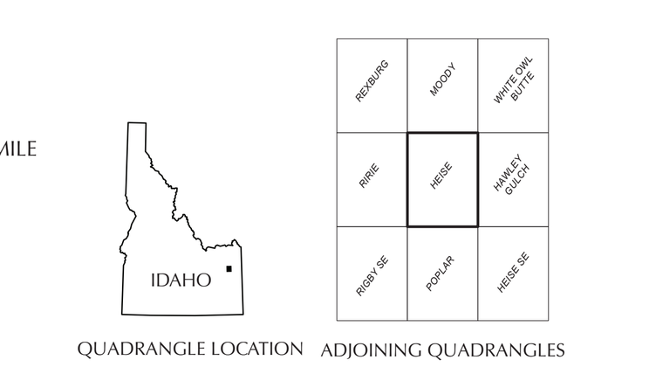
Declination from NOAA National Geophysical Data Center.



UTM Grid and 2014 Magnetic North Declination at Center of Map



Contour interval 20 feet
Dotted lines represent 5 foot contours



QUADRANGLE LOCATION   ADJOINING QUADRANGLES

Field work conducted 2014.

This geologic map was funded in part by the U.S. Geological Survey National Cooperative Geologic Mapping Program, USGS award no. G14AC00164.

Digital cartography by Loudon R. Stanford at the Idaho Geological Survey's Digital Mapping Lab.

Technical review status: Authors only.

Map version 4-7-2016.

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

CORRELATION OF MAP UNITS

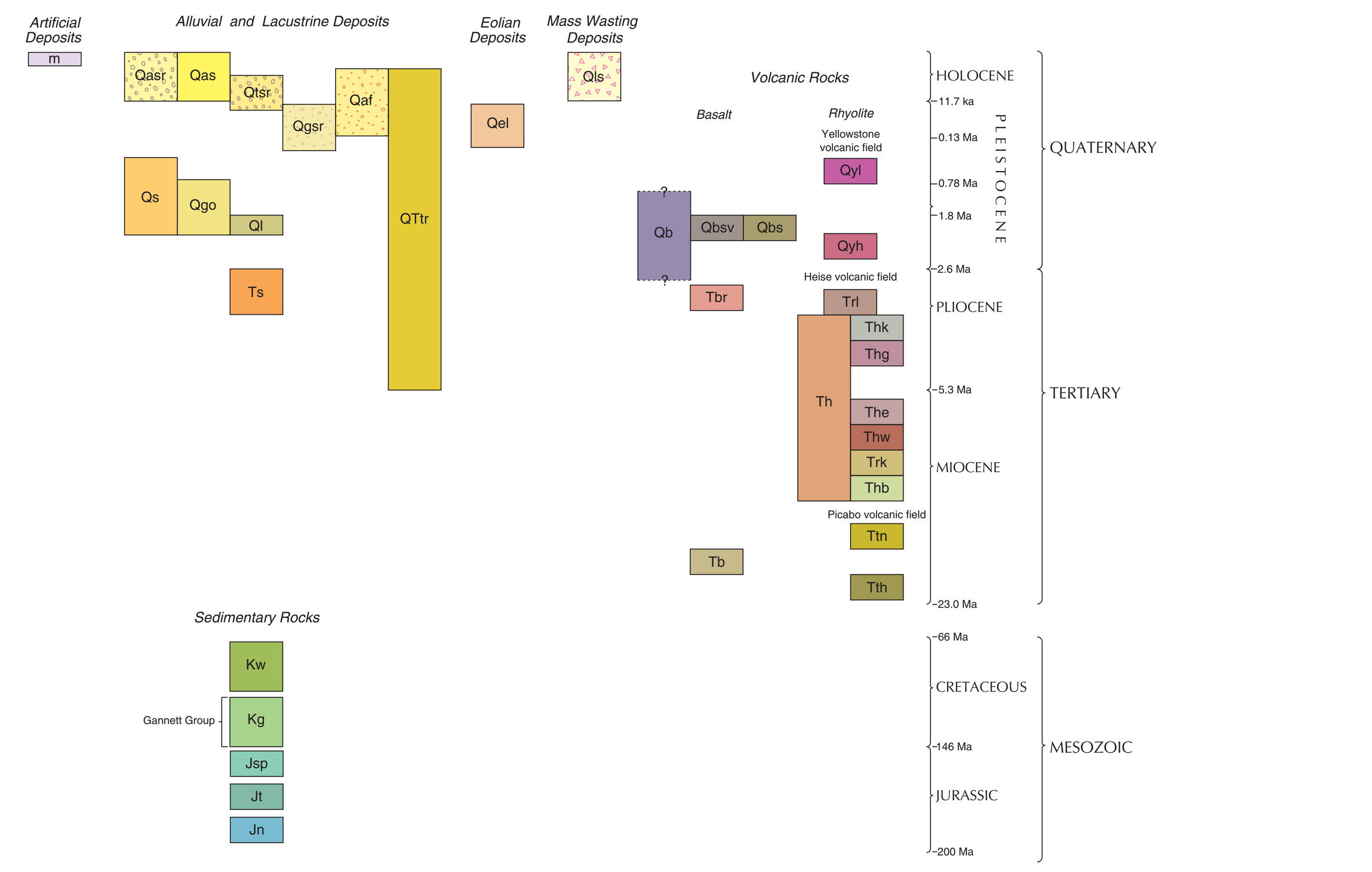


Table 1. Paleomagnetic data for the Heise quadrangle.

Sample number	Unit name	Latitude	Longitude	n	D°	I°	α_{95}	R	κ	Polarity	Treatment
4379B	Qbs	43.682	-111.739	8/8	130.3	-86.2	3.1	7.981	373	R	PCA

n = number of cores used / number of cores measured.
D° = site mean declination of characteristic remanent magnetization (ChRm).
I° = site mean inclination of ChRM.
α_{95} = confidence limit for the mean direction at the 95% level.
κ = precision parameter.
Polarity: N = normal; R = reverse.
Treatment used to isolate ChRM; PCA = principal component analysis of AF demagnetization steps.
Analysis performed in the USGS paleomagnetism laboratory, Meno Park, California by D. Champion.

Table 2. Major oxide and trace element chemistry of samples collected in the Heise quadrangle.

Sample number	Latitude	Longitude	Unit name	Map unit	SiO_2	TiO_2	Al_2O_3	Fe*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	SUM	LOI
					Major elements in weight percent											
RB-1†	43.68200	-111.73900	basalt of Sommers Butte volcanic rift	Qbs	49.39	3.52	14.35	15.02	0.27	4.40	8.31	1.90	1.70	1.12	99.98	-0.92
140922-6‡	43.68448	-111.74287	basalt of Sommers Butte volcanic rift	Qbs	47.40	3.32	13.87	16.72	0.26	4.75	7.82	3.04	1.55	1.35	100.08	-0.61
RB-6†	43.71600	-111.74900	basalt of Rexburg	Tbr	48.08	2.15	16.37	12.86	0.20	7.28	10.37	2.11	0.37	0.30	100.09	-0.73
140812-18‡	43.64184	-111.67754	tuff of Hawley Spring	Tth	76.26	0.13	12.69	1.24	0.03	0.09	0.71	3.58	4.91	0.02	99.66	1.18
140813-4‡	43.64392	-111.67353	basaltic andesite (unnamed)	Tb	54.70	0.92	16.48	9.82	0.36	4.35	9.62	2.74	0.82	0.24	100.05	3.43
150416-4‡	43.65170	-111.70192	basalt (unnamed)	Qb	47.76	2.61	14.86	14.21	0.19	6.96	9.74	2.59	0.57	0.46	99.95	0.17
150416-3‡	43.64962	-111.70045	basalt (unnamed)	Qb	48.21	2.65	14.48	13.86	0.19	6.69	10.11	2.51	0.59	0.48	99.77	0.77
150416-1‡	43.65096	-111.70129	basalt (unnamed)	Qb	48.21	2.56	14.84	13.90	0.19	6.84	9.84	2.57	0.59	0.45	99.99	0.2
140922-4A‡	43.67014	-111.73220	block in hyaloclastite deposit	Ql	46.80	2.27	15.30	13.88	0.19	7.55	10.43	2.59	0.36	0.44	99.81	0.56
140922-1‡	43.66303	-111.72344	block in hyaloclastite deposit	Ql	48.98	1.95	16.67	14.33	0.18	4.04	10.35	2.67	0.25	0.30	99.72	2.49

Sample number	Ni	Cr	Sc	V	Ba	Rb	Sr	Zr	Y	Nb	Ga	Cu	Zn	Pb	La	Ce	Th	Nd	U	Co
	Trace elements in parts per million																			
RB-1†	11	22	na	167	1220	32	348	488	68	45	27	na	na	na	55	104	na	54	na	na
140922-6‡	14	46	23	195	1045	27.3	364	438	54	44.3	21	43	163	3	28	53	1.3	na	0.8	44
RB-6†	90	80	na	275	287	4	259	166	32	16	23	na	na	na	18	36	na	23	na	na
140812-18‡	5	7	<1	8	1094	182.6	60	239	40	52.3	24	2	52	16	54	108	35.5	na	5.6	<1
140813-4‡	125	203	27	193	567	20.4	544	140	27	16.2	17	33	145	4	34	66	0.6	na	<0.5	35
150416-4‡	68	251	27	277	423	9.3	384	183	31	16.4	19	48	117	<1	15	22	0.5	na	<0.5	49
150416-3‡	63	252	27	280	380	9.1	375	188	32	16.4	19	40	114	<1	14	24	<0.5	na	1.1	47
150416-1‡	66	246	26	255	395	8.7	387	185	32	16.9	20	53	111	2	14	30	<0.5	na	0.9	48
140922-4A‡	80	200	23	284	301	5.2	319	177	34	16.5	19	56	114	31	12	26	0.7	na	1.2	56
140922-1‡	97	122	27	284	260	3.1	311	158	31	13.1	20	60	117	<1	14	23	0.9	na	<0.5	60

*Total Fe expressed as FeO for BYU analyses and as Fe_2O_3 for Franklin and Marshall College analyses.
LOI is loss on ignition.
SUM is unnormalized total of major elements for all analyses.
†XRF analyses performed at Brigham Young University, Provo, UT; major elements normalized to 100% on a volatile-free basis.
‡XRF analyses performed at Franklin and Marshall College, PA by S. Mertzman; major elements unnormalized.
na = not analyzed

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.

60 Strike and dip of bedding.

80 Strike and dip of bedding interpreted to be overturned on the basis of stratigraphic succession or position.

Basaltic volcanic vent, concealed.

RB-1 Geochemical sample (see Table 2).

4379B Paleomagnetic 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).

Gravel pit.

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.

Sources of map information compiled and consulted include Prostka and Hackman (1974) and Prostka and Embree (1978), plus references cited in the "Description of Map Units" below. Barney and others (in preparation) compiled unpublished mapping by David J. Doherty conducted in the 1970s and/or early 1980s with focus on units of the Heise volcanic field. They also collected new geological mapping information. Unpublished mapping by Roger Hoggan conducted in the 1970s and/or early 1980s with emphasis on Mesozoic sedimentary rocks was also consulted. Both Doherty's and Hoggan's maps are from files held by the Department of Geology, BYU-Idaho, Rexburg, Idaho, and released with permission from the authors. Soil information (Soil Survey Staff, 2015) and water well logs (Idaho Department of Water Resources, 2015) were also consulted.

STRATIGRAPHY

The Heise quadrangle contains the most complete and easily accessible exposures of rhyolitic ignimbrites of the Heise volcanic field (HVF). Numerous stratigraphic, petrological, and geochronological studies are based on samples from the Heise cliffs. The HVF is the second youngest of eruptive centers along the Snake River Plain-Yellowstone hotspot trend. The HVF tuffs consist of large-volume, generally densely welded ignimbrites erupted from overlapping, nested calderas. Major units consist of the Blacktail Creek Tuff (6.62 Ma), Walcott Tuff (6.27 Ma), tuff of Wolverine Creek (5.57 Ma), Conant Creek Tuff/tuff of Elkhorn Spring (~5.5 Ma), and Kilgore Tuff (4.45 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 (e.g. tuff of Elkhorn Spring, Anders and others, 2014); here, we use the nomenclature of Morgan and McIntosh (2005).

STRUCTURE

The map region contains three structural elements: 1) termination of a portion of the Idaho overthrust belt consisting of thrust faulted and folded Mesozoic sedimentary rocks as it enters the Eastern Snake River Plain; 2) normal faulting on the Heise and Snake River faults (splays of the Grand Valley fault zone; Piety and others, 1992) that have uplifted the Rexburg Bench, exposing Miocene-Pliocene volcanic rocks of the HVF; and 3) calderas for the Blacktail Creek Tuff and the Kilgore Tuff have been postulated as occurring in the Eastern Snake River Plain adjacent to the map area (Prostka and Embree, 1978; Morgan and McIntosh, 2005; Phillips and others, 2016). Extracaldera facies of the HVF ignimbrites rest unconformably on Mesozoic strata in the map.

GEOLOGIC HAZARDS

Spring floods along the Snake River, and Willow Creek where it enters the Eastern Snake River Plain, were significant hazards prior to construction of the Palisades Dam in 1957 and Ririe Dam in 1978. Levees now protect portions of the former Snake River floodplain but some flood damage continues to occur during years with heavy spring runoff.

The Heise fault has late Pleistocene offset in the Rexburg area (U.S. Geological Survey and Idaho Geological Survey, 2015). No Holocene ground rupture or historical earthquakes are known to have occurred on this structure.

MINERAL AND ENERGY RESOURCES

The following map units have potential as aggregate resources: sand and gravel, *Qgsr*, *Qtsr*; crushed rock, *Tbr* and *Qbs*. An existing gravel pit developed in *Qgsr* is in NE¼ NE¼ sec. 1, T. 3 N., R. 40 E.

Potential geothermal resources include: Heise Hot Springs (47.8°C; U.S. Geological Survey, 1970); Elkhorn Warm Spring (20°C, Spring 65-1, SE¼ SW¼ sec. 23, T. 4 N., R. 40 E.; Dansart and others, 1994) and Bill Webster well (22°C Well 65-6, NW¼ sec. 36, T. 5 N., R. 40 E.; Dansart and others, 1994).

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). Volcanic rocks are classified by total alkali versus silica chemical composition according to International Union of Geological Sciences 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 Cohen and Gibbard (2011). Radiometric ages are reported with 2σ errors unless otherwise noted.

ARTIFICIAL DEPOSITS

m **Man-made land (Holocene)**—Flood control levees about 2 m (7 ft) high adjacent to the Snake River.

ALLUVIAL AND LACUSTRINE DEPOSITS

Qasr **Alluvium of the Snake River (Holocene)**—Gravel, sand, and silt deposited in and adjacent to braided channels of the active floodplain; clast grain size and lithologies similar to *Qgsr*. Includes low terraces capped with about 25 cm (10 in) silty sand. Maximum thickness from water wells is about 24 m (80 ft). Areas underlain by this unit are subject to frequent seasonal flooding and standing water. Contains ecologically important stands of riparian cottonwood gallery forest.

Qas **Alluvium of side streams (Holocene)**—Gravel and sand deposits of small tributary channels; thickness generally is <3 m (<10 ft). May be subject to flooding during wet seasons or during intense thundershowers.

Qtsr **Terrace alluvium of the Snake River (Holocene)**—Stratified sand, silt, and gravel deposited and incised during large pre-Palisade Dam or prehistoric floods. Lithologies of gravels similar to unit *Qgsr*. Thickness from topographic profiles is about 3 m (10 ft).

Qaf **Alluvial fan deposits (Holocene-late Pleistocene)**—Gravel, sand, and silt deposited where Lyons Creek and Kelly Creek join the Snake River; also small fans deposited in canyons. Thickness from topographic profiles ≤3 m (≤10 ft). May be subject to local flooding during seasonally high runoff or during high intensity storms.

Qgsr **Gravel outwash of the Snake River (late Pleistocene)**—Gravel and sand deposited during the Pinedale glaciation of the Snake River headwaters; generally poorly exposed in the map. Gravel pits in surrounding areas show unit to consist of massive to thickly bedded, well-rounded cobble to pebble gravel, with an open framework filled by subangular sand. Rare beds of coarse to medium sand are cross bedded. Gravel clasts are dominated by quartzite with lesser sandstone, granitic rocks, porphyritic mafic igneous rocks, rhyolite, basalt, and limestone. Water wells indicate thickness of about 23 to 27 m (74 to 89 ft). Age of deposits based on deglaciation dates for Pinedale glaciation of Yellowstone-Grand Teton area are about 18.8 to 13.5 ka (Licciardi and Pierce, 2008). Dates for similar outwash deposits in the Idaho Falls area range from about 25 to 13 ka (Phillips and others, 2009). Well-drained Bannock, Bock, Heiseton, and Packham soils are developed on unit with as much as 115 to 150 cm (45 to 60 in) of sandy loam covering gravels. Contains aggregate (sand and gravel) resources.

Ql **Lake deposits (early Pleistocene)**—Light-gray, silty sands and silts, laminated to thinly-bedded; locally disrupted and reddened by interaction with basalt of Sommers Butte (*Qbs*). Minimum thickness is about 6 m (20 ft). Interbedded and/or underlain by crudely bedded alluvial fan deposits containing angular pebbles of Jurassic Nugget Sandstone (*Jn*) and cobbles of basalt in a light-gray to light reddish-brown silty sand matrix.

Qgo **Older gravels (Pleistocene)**—Boulders, cobbles, and gravels, well-rounded, locally split into angular fragments. Clasts are dominantly very hard, fine-grained Nugget Sandstone (*Jn*), with lesser limestone, dolomite, sandstone, and welded tuff. Consists of thin dissected remnants of alluvial fan, colluvium, and stream deposits that overlie Mesozoic sedimentary rocks. In SW¼ sec. 32, R. 41 E., T. 4 N., consists of about 24 m (80 ft) of crudely bedded gravels interbedded with thin, lenticular beds of sand and silt containing tephra of Lava Creek Tuff (*Qyl*).

Qs **Younger sedimentary deposits (Pleistocene)**—Clay, sand, and gravel recorded in water well logs beneath *Qgsr* and above *Qyh*. Possibly correlative, in part, with *Ql*. Shown in cross section only.

Ts **Older sedimentary deposits (Pliocene-late Miocene)**—Clay, sand, and gravel recorded in water well logs in adjacent Ririe quadrangle (Phillips and others, 2014) and in map area underlain by Snake River deposits where they consistently underlie basalt flows correlated with *Tbr*. Thickness increases away from Heise fault from about 60 m (200 ft) to about 150 m (500 ft). Also includes clay, sand, and gravel on the Rexburg Bench beneath *Qyh* and above undivided Heise rhyolites (*Th*). Most logs indicate that fine-grained sediments dominate, suggesting lacustrine environment with intermittent fluvial activity. Thickness ranges from 17 to 140 m (55 to 460 ft).

MASS WASTING DEPOSITS

Qls **Landslide deposits (Holocene-late Pleistocene)**—Small surficial debris slides along steep hillslopes in Lyons Creek, on Heise cliffs (unmapped) and Moody Creek (unmapped).

EOLIAN DEPOSITS

Qel **Loess (late Pleistocene)**—Unit shown in cross section only and as a component of other geologic units (e.g. *Qel/Qbs*). Massive, brown to light-gray, silt, very fine sand, and clay; 3 to 11 m (10 to 35 ft) thick in water wells in the Rexburg Bench portion of the map. 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 Snake River Plain, 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 for farming of wheat and other grains.

SPRING DEPOSITS

QTtr **Travertine (Holocene-Pliocene?)**—Sloping mound of light-gray to yellowish-gray, thin-bedded limestone deposited at Heise Hot Springs. Thickness from topographic profiles is about 10 m (33 ft). Hot springs location and activity may be influenced by proximity to Heise or other normal faults.

SEDIMENTARY ROCKS

Kw **Wayan Formation (Early Cretaceous)**—Shown in cross section only. Sandstone, shale, carbonaceous shale, conglomerate, and limestone. Thickness about 457 to 610 m (1500 to 2000 ft) south of the map area.

Kg **Gannett Group (Early Cretaceous)**—Consists of Draney Limestone, Bechler Formation, Peterson Limestone, and Ephraim Conglomerate. Poor exposure conditions precluded separation of the units on map. Mapped on occurrence of distinctive sublithographic, white-weathering limestones with a conchoidal fracture (Draney or Peterson) separated by red shale or mudstone beds (Bechler). Less frequently, diagnostic pebble conglomerates interbedded with heterogeneous red, gray-green or purple sandstones and siltstones of the Ephraim Conglomerate were identified. Thickness totals about 367 m (1205 ft) in the Caribou Range (Jobin and Schroeder, 1964); and about 442 m (1452 ft) in the Snake River Range (Staaz and Albee, 1966). In both areas, the Ephraim Conglomerate makes up >300 m (>1000 ft) of the Group.

Jsp **Stump and Preuss Formations, undivided (Middle to Late Jurassic)**—Stump Formation consists of gray-green, thick-bedded, fine-grained silty limestone; gray-green shale and calcareous siltstone; and gray-green to brown, calcareous glauconitic sandstone. Preuss Formation is swale-forming, red to reddish-gray, thin-bedded calcareous siltstone grading upward into thicker bedded hematitic-red calcareous sandstone. Generally poor exposure conditions precluded separation of the units on map. Thickness in the Caribou Mountains is about 49 m (160 ft) for Stump and about 114 m (375 ft) for Preuss (Jobin and Schroeder, 1964); in the Snake River Range, about 57 to 76 m (186 to 250 ft) for Stump and 6.4 to 20 m (21 to 68 ft) for Preuss (Staaz and Albee, 1966).

Jt **Twin Creek Limestone (Middle Jurassic)**—Dark-gray and gray-yellow, thin-bedded shaly limestone; characteristically weathers to light-gray and yellowish-gray splintery or pencil-shaped fragments 7 to 10 cm in length; interbedded with sandy oolitic medium-bedded limestone. Thickness is about 365 m (1200 ft) in the Caribou Range (Jobin and Schroeder, 1964) and about 265 m (870 ft) in the Snake River Range (Staaz and Albee, 1966).

Jn **Nugget Sandstone (Early Jurassic)**—Pale reddish-brown to moderate reddish-orange, medium-bedded and cross-bedded, fine- to medium-grained, quartz arenite. Typically forms low ridges covered with boulders of sub-rounded, very hard sandstone. Thickness is about 163 m (535 ft) in the Caribou Range (Jobin and Schroeder, 1964) and about 78 to 91 m (255 to 299 ft) in the Snake River Range (Staaz and Albee, 1966).

VOLCANIC ROCKS

Qb **Basalt, unnamed (Pleistocene)**—Medium-gray basalt, glomerophyric with moderately abundant clusters of plagioclase laths, 2 to 5 mm, and olivine, 0.2 to 0.5 mm. Groundmass is dense and fine grained, locally with vesicles, 5-10 mm, that are commonly filled with moderate orange pink mineral. Exposures consist of scattered boulders, 0.5-1.5 m, on dissected strath surface. The boulders may be remnants of an intercanyon lava flow. Geochemical analyses (Table 2) do not indicate correlations with any of the other basalts in the map area or surrounding region.

Qel/Qbs, Qbs **Basalt of Sommers Butte Volcanic Rift (early Pleistocene)**—Dark greenish-gray basalt, fine-grained, dense to vesicular with abundant reddish-brown olivine 0.25 to 0.5 mm. Erupted from vents along the 22 km (13 mi) Sommers Butte volcanic rift. On Rexburg Bench, mostly concealed by loess 3 to 10 m (10 to 33 ft) thick. Shown as *Qel/Qbs* where covered by loess. Extent mostly mapped with the water wells indicated on map and geomorphic criteria. Thickness of basalt within the rift graben is up to 77 m (254 ft); thins away from the rift graben to about 30 to 38 m (100 to 125 ft). In the map area, basalt flowed from at least 3 vents down Lyons Creek where it interacted with the Snake River to form phreatomagmatic deposits. These deposits consist of dense basalt pillows and dikes surrounded by sandy brown hyaloclastite breccias. Reverse magnetic polarity (Table 1). 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).

Qel/Qbsv, Qbsv **Vents of Sommers Butte Volcanic Rift (early Pleistocene)**—Vents along the Sommers Butte volcanic rift, concealed by loess. Shown as *Qel/Qbsv* where covered by loess. Water well logs in vicinity of the vents document cinder and scoria in association with lavas. Highest vent at ~6,300 ft in adjacent Hawley Gulch quadrangle (SE¼ sec. 15, T. 4 N., R. 41 E.) directed flows westward onto the map area where they coalesced with flows from three other vents (hill 5726, hill 5522, and unnamed hills in NE¼ sec. 16, T. 4 N., R. 41 E.) to the north before flowing down Lyons Creek to the Snake River.

Qel/Tbr, Tbr **Basalt of Rexburg (Pliocene)**—Dark-gray columnar-jointed flows of dense to vesicular diktytaxitic basalt containing phenocrysts of plagioclase and olivine. Shown as *Qel/Tbr* where covered by loess. Informally named for exposures in the adjacent Rexburg quadrangle. Maximum exposed thickness is about 50 m (165 ft). Consists of 8 to 10 lava flow units. Individual flows have thicknesses of 3 to 4 m (10 to 13 ft). Reversed magnetic polarity (Table 1). Dated by $^{40}Ar/^{39}Ar$ analyses of groundmass concentrate in the adjacent Ririe quadrangle at ~3.6 Ma (Phillips and others, 2014).

Tb **Basalt (late Miocene)**—Light olive gray, dense to vesicular basaltic andesite (Table 2); contains glomerocrysts of plagioclase and olivine 1 to 1.5 mm; groundmass consists of plagioclase microlites 100 to 200 μm with sub-parallel alignment, clinopyroxene 10 to 20 μm, and cubic to irregular black opaque oxides 30 to <10 μm. Vesicules are locally filled with earthy brown secondary mineral. There are two populations of olivine phenocrysts; larger grains are altered to orange-brown iddingsite and slightly smaller grains are unaltered. Generally poorly exposed; forms locally abundant float of boulders 0.2 to 2 m in diameter. Minimum thickness is 1 to 1.5 m. In sec. 30, T. 4 N., R. 41 E., overlies *Tth* and lies beneath *Ttn*, therefore not part of HVF.

Rhyolite

Yellowstone volcanic field

Qyl **Lava Creek Tuff (middle Pleistocene)**—White ash layer contained in mixed colluvial, fluvial, and lacustrine deposits of *QTs*. Consists of sandy to silty ash about 30 cm (76 in) thick. Correlated with the Lava Creek B eruption (639 ± 2 ka; Lanphere and others, 2002) from the Yellowstone volcanic field (Christiansen, 2001) by M.H. Anders (written communication to G.F. Embree, 2013).

Qel/Qyh, Qyh **Huckleberry Ridge Tuff (early Pleistocene)**—Rhyolitic ignimbrite, densely to moderately welded, with moderately abundant (~10 percent), small (1 to 4 mm) phenocrysts of sanidine and quartz with lesser plagioclase and pyroxene. Shown as *Qel/Qyh* where covered 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. 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 Member A (C. Wilson, written communication, 2015). Maximum thickness of Huckleberry Ridge Tuff is about 30 m (100 ft) near the Heise cliffs (Barney and others, in press); water wells on the Rexburg Bench show thickness ranges from about 6 to 25 m (21 to 83 ft). 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

Th **Heise volcanic field, undivided (Pliocene-Miocene)**—Shown in cross section only. Well logs suggest mixed welded rhyolites and devitrified pyroclastic rocks with possible fluvial and lacustrine intervals; minimum total thickness of about 210 to 300 m (700 to 1000 ft).

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. Locally consists of devitrified rhyolite with highly contorted white and dark-gray flow banding. Near top of flow, locally grades into pink tuff with black shards and vitrophyre clasts (Prostka and Embree, 1978). Maximum exposed thickness 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 $\delta^{18}O$ and other geochemical features that suggest a link with residual magma of the Kilgore Tuff (Watts and others, 2011).

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 covered by loess. Well-developed black vitrophyre up to 1 m (3.3 ft) thick present in most Heise cliff exposures. 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. Maroon and dark-gray, flattened pumice 3 to 3.5 cm in length are locally abundant. Top of unit capped with thin orange to reddish-brown vitric tuffs and locally with dark-brown vitrophyre. Reverse magnetic polarity that can be measured in field with fluxgate magnetometer. 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 (Anders and others, 2014, error 1σ). 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).

Thg **Tuff of Hawley Gulch (Pliocene)**—Light-gray, unwelded rhyolitic airfall and ash-flow tuffs, locally reworked; thickly bedded to massive; composed of poorly sorted, coarse-grained (1 to 3 mm) white glass shards, rounded crystal-poor pumice and light-colored lithics (1 to 3 cm), and sparse plagioclase and quartz crystals. Lower part contains orange and yellow mottled zones 10 to 25 cm thick and concretionary cementation suggestive of paleosol formation. Poorly exposed basal contact with *The* contains reddish-brown clay-rich soils also indicative of paleosol development. Minimum exposed thickness is about 5 m (16 ft); topographic profiles suggest maximum thickness of about 30 m (100 ft). Stratigraphic position and evidence of paleosol formation suggest correlation with upper portion of unit *Tht* in adjacent Poplar quadrangle (Phillips and others, 2016).

The **Tuff of Elkhorn Spring (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. Grades from basal, nearly aphyric black vitrophyre up to 2 m (6.5 ft) thick to eutaxitic devitrified zone overlain by lithophysal zone. Maximum thickness in map area is about 100 m (330 ft). Locally, top of unit has reddish surface staining from overlying paleosol at base of unit *Thg*. 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 questioned by Anders and others (2014) who suggested that the tuff of Elkhorn Springs is slightly younger than Conant Creek Tuff. Sanidine laser-fusion single-crystal $^{40}Ar/^{39}Ar$ ages for tuff of Elkhorn Springs are 5.52 ± 0.03 Ma (1σ error, Anders and others, 2014) and 5.51 ± 0.13 Ma (2σ error; Morgan and McIntosh, 2005) 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).

Thw **Wolverine Creek Tuff (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. Stratification ranges from massive and planar to cross-bedded, consistent with airfall and pyroclastic surge deposits (Doherty, 1976). Elutriation pipes produced by escaping gas present in most exposures. Poorly exposed but outcrops can be easily spotted by white soil colors. Thickness about 18 to 60 m (60 to 300 ft) in the Heise cliffs area. 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 Kelley Canyon (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 ~5.7 Ma (Morgan and McIntosh, 2005). Well exposed at "Elephant Rock" campground and climbing area (SW¼ NE¼ sec. 31, T. 4 N., R. 41 E.).

Thb **Blacktail Tuff (Miocene)**—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). Plagioclase and quartz are 1 to 2 mm; sanidine about 1 to 0.5 mm; and pyroxenes <0.5 mm. Most exposures in map are cliff forming, columnar jointed, medium gray, devitrified, intensely welded, and locally with lithophysal cavities 5 to 10 cm in diameter. Basal vitrophyre overlying reddish paleosol is exposed along Cress Nature Trail (SE¼ SW¼ sec. 23, T. 4 N., R. 40 E.). Strong normal magnetic polarity easily verified with flugate magnetometer. 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 (Anders and others, 2014, error 1σ). 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). Thicker exposures resemble *Tth* but lack biotite.

Picabo volcanic field?

Ttn **Tuff of Newby Ranch (Miocene)**—Light-gray and yellowish-gray, unwelded rhyolitic tuff; thinly laminated, fine-grained ash, reported to locally contain 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. Possibly associated with *Tth* or other Picabo volcanic field (PVF) units.

Tth **Tuff of Hawley Spring (Miocene)**—Yellow-brown to reddish, locally altered, welded rhyolitic tuff with abundant (>20 percent) phenocrysts 1-3 mm of plagioclase, quartz, and sanidine with sparse black biotite, 0.5 to 1 mm. Locally, quartz is milky gray and bipyramidal. Most exposures are cliff forming and devitrified with well-developed eutaxitic foliation. Visible alteration consists of coating of fractures with brown and orange Fe-oxides and reduction of rock strength; alteration may be related to position near normal faults. Along Cress Nature Trail (SW¼ SE¼ sec. 23, T. 4 N., R. 40 E.) the welded tuff is overlain by unwelded, light-gray, crystal-rich, biotite-bearing rhyolitic tuff that grades upward into a paleosol interval marked by reddish clayey soils. Unit named "rhyolite of Hawley Spring" by Prostka and Embree (1978) and apparently interpreted as a rhyolite lava flow. Some outcrops closely resemble unit *Thb* but presence of biotite and bipyramidal quartz are diagnostic. Mean single-crystal laser-fusion $^{40}Ar/^{39}Ar$ age from locality in sec. 25, T. 4 N., R. 40 E. (43.6469° -111.6975°) is 7.50 ± 0.04 Ma (Morgan and McIntosh, 2005, Table 1, Figure 5, and Appendix 4). Using a sample from the same locality, Drew and others (2013, sample PC-76, p. 66-67) correlated the tuff of Hawley Spring with Arbon Valley Tuff of the Picabo volcanic field on the basis of mineralogy, geochemistry, and stratigraphic position. However, $^{40}Ar/^{39}Ar$ sanidine ages and U-Pb zircon ages for the Arbon Valley Tuff range from about 10.2 to 10.4 Ma (Morgan and McIntosh, 2005; Anders and others, 2014; Drew and others, 2013). Further work is needed to establish the extent and correlation of tuff of Hawley Spring.

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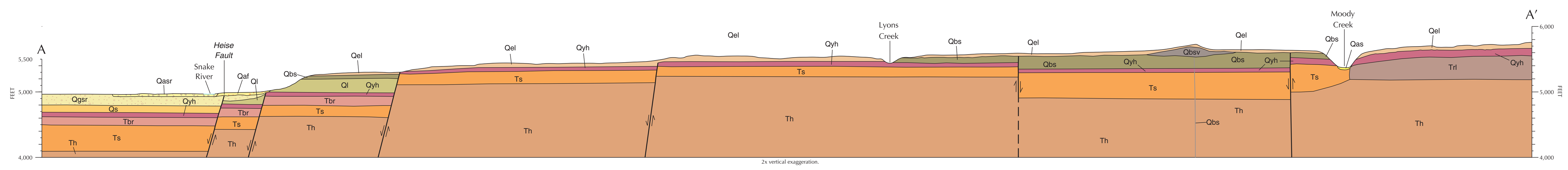

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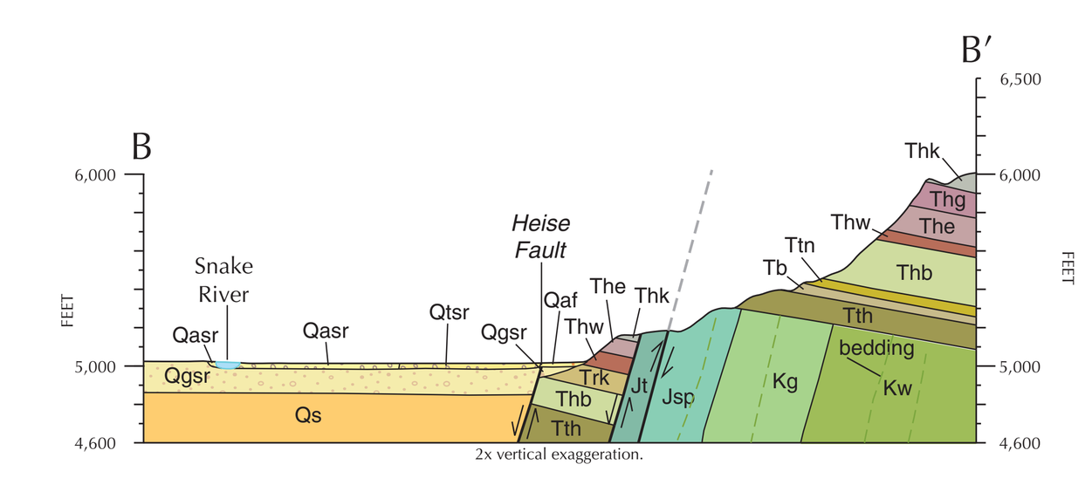

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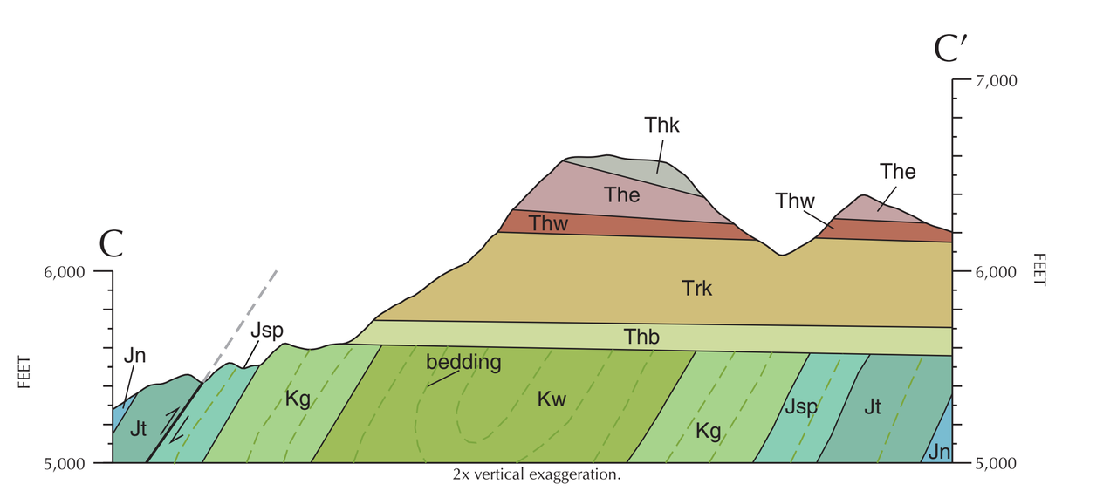

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