

CORRELATION OF MAP UNITS

Deposits

Man-made

Deposits

m

lluvial Deposits

Mass-movement

Deposits

### 116°22'30″ 5/19 1548 1330 000 FEFT INTRODUCTION The geologic map of the Cherry Gulch 7.5' quadrangle depicts the rocks exposed at the surface or underlying a thin cover of soil or colluvium; alluvial and man-made surficial deposits are also shown where they form significant mappable units. This map is a result of fieldwork conducted in 2016 by the authors, and by work done in the early 2000s by Spencer Wood. Field work was augmented with whole-rock geochemistry (Tables 1 and 2) and U-Pb zircon TIMS geochronology (Figure 1 and Table 3). Volcanic rocks were classified based on the IUGS total alkali versus silica volcanic rock classification (Le Bas and Streckeisen, 1991). Grain size classification of unconsolidated sediment and consolidated sedimentary rocks employs the Wentworth scale (Lane, 1947). Previous work in the area includes reconnaissance mapping by Kirkham (1931) and Savage (1961), and the field maps, field notes, fluxgate magnetometer data, whole-rock XRF analyses (which were reanalyzed in 2015), and posthumous Ph.D. of James Fitzgerald (1981). Previous work was consulted and incorporated where appropriate. Time scale is the Geological Society of America version 6.0 (Walker and Geissman, 2022) integrated with the 2019 version of the Global chronostratigraphical correlation table for the last 2.7 million years (Cohen and Gibbard, 2019). Informal time divisions (e.g., middle Miocene) are also utilized. Water wells are identified by Well ID (IDWR, 2017). All location data given in North American Datum 1927 (NAD27). The oldest rocks of the Cherry Gulch 7.5' quadrangle are the middle Miocene lower Columbia River basalt (Tcrl) flows of the Columbia River Basalt Group (CRBG). The lower Columbia River basalt unit mostly comprises Steens Basalt (basalt to basaltic andesite) with a few Imnaha Basalt flows near the top. The tuff of Willow Ridge (*Ttwr*), the Grande Ronde Formation (*Tcgn*,), the iron-rich andesite of Four Mile road (*Tiaf*), and the intercalated sedimentary beds of Payette Formation (*Tp*) are conformable with the lower Columbia River basalt. Volcanic units are subdivided using stratigraphic relationships, petrography, paleomagnetic data, and whole-rock XRF analyses (Table 1) and Table 2). Deposition of the sedimentary units subsequent to volcanism included the rocks of the upper Payette Formation (*Tp*) and Poison Creek Formation (*Tpc*). Quaternary alluvial deposits include active stream deposits, dissected older alluvium, and alluvial-fan deposits. Quaternary mass-movement deposits are rotational and translational landslides, resulting from the failure of competent basalt over unconsolidated Payette Formation sediments. On the west slope of Sehewoki'l Newenee'an Katete Butte is a boulder field (Qbd) dipping approximately 6 to 8 degrees to the west unconformably deposited on moderate-dipping CRBG and Payette Formation. LOCATION OF FIELD OBSERVATIONS Cherry Gulch Quadrangle Extent of LiDAR coverage as of 12/2022 SYMBOLS Contact: dashed where approximately located. Normal fault: ball and bar on downthrown side; hachures where scarp present; dashed where approximately located; dotted where concealed. Outcrop-scale fault; arrow indicates dip. $\chi_{74}$ Strike and dip of bedding. ×17 Approximate strike and dip of bedding 15 Strike and dip of volcanic rocks. Approximate strike and dip of basalt flows. Geochemical sample location (Table 1 and Table 2). Geochronology sample location (Table 3). Landslide headwall scarp; hachures point downslope. Open pit or quarry boundary. Tectonic breccia. Water well showing Well ID number. Selected water wells shown with Idaho Department of Water Resources Well ID number (IDWR, 2022). Patterned ground: Circular to elongate mima mounds composed of light-brown silt and fine sand. Mounds are separated by hard pan, bedrock, or gravel, forming a pattern of contrasting characteristics that are readily mappable from aerial images and LiDAR. The mounds average 9 to 21 m (30 to 70 ft) in diameter and 0.3 to 2 m (1 to 6 ft) in height. Patterned ground occurs on surfaces of Tertiary sediments and volcanics. Malde (1964) and Kessler and Werner (2003) attribute mima mounds and regional patterned ground to freeze-thaw cycles that sorts heavy material from soil. Overlay is meant to portray approximate distribution of distinct patterned ground; not all mima mounds were included. DESCRIPTION OF MAP UNITS MAN-MADE DEPOSITS 116°22′30′ 549000m.F m Made ground (late Holocene)—Sand, clay, gravel, and boulders built into an earthen dam at the west edge of the map; unit thickness is 5 m (16 ft) high. Field work conducted in 2016. This geologic map was funded in part by U.S. Geological Survey National Cooperative Geologic Mapping Program, ALLUVIAL DEPOSITS USGS award no. G16AC00163. The views and conclusions ontained in this document are those of the authors and should Qal Stream alluvium deposits (Holocene and Late Pleistocene)—Unconsolidated, not be interpreted as necessarily representing the official well- to moderately sorted, sand, silt, and gravel in channels, levees, and policies, either expressed or implied, of the U.S. Government. floodplains. Thickness ranges from <1 to 4 m (<3 to 13 ft). Digital cartography by David Vohra and Jonathan Sandquist at the Idaho Geological Survey's Digital Mapping Lab. Qat Alluvial-fan deposits (Holocene and Late Pleistocene)—Crudely stratified fan Technical review by Russel V. Di Fiori and Claudio Berti deposits of sand, silt, and gravel. Subangular gravel clasts are composed of Map version 12-28-2023. locally sourced basalt and basaltic andesite. Thickness less than 3 m (10 ft). This map can be downloaded in PDF format from www.idahogeology.org. Qao Older alluvium (Pleistocene)—Weakly consolidated, variably sorted, crudely QUADRANGLE LOCATION ADJOINING QUADRANGLES tratified deposits of sand, silt, and gravel in stream, floodplain, and minor alluvial-fan deposits above modern floodplains. Thickness ranges from 1 to 9.5 m (2 to 31 ft) as determined from water wells (Well IDs 812133, 291902; IDWR, 2017) and from well data in the neighboring Northeast The IGS does not guarantee this map or digital data to be Emmett and Hog Cove Butte quadrangles, to the south and west, respecfree of errors nor assume liability for interpretations made from this map or digital data, or decisions based thereon. tively. Kabt Kgbt No vertical exaggeration. Indicators of fault motion in cross section: arrow depicts relative motion.



#### **Qato** Older alluvial fan deposits (Middle? Pleistocene)—Crudely stratified, crudely sorted, highly dissected sand, silt, pebbles, and cobbles in a subdued fan shape. Cobble and pebble clasts are composed primarily of basalt. Thickness is less than 3 m (10 ft).

Boulder deposits (Pleistocene to Pliocene)—Boulders and cobbles of lower

Columbia River basalt composition that mantle the western upland hillslopes of Sehewoki'l Newenee'an Katete Butte. An angular unconformity separates this boulder field from the underlying volcanic bedrock and Payette Formation sediments. Boulders are subrounded, primarily composed of phyric to mega-phyric lower Columbia River Basalt (*Tcrl*), and up to 1.5 m (5 ft) in diameter. Appears as a single layer of boulders less than 2 m (6.5 ft) thick. MASS-MOVEMENT DEPOSITS **Landslide deposits (Holocene and Late Pleistocene)**—Silt- to boulder-sized debris from rotational and translational slides involving stiff dense basalt blocks over less competent, poorly consolidated sediments. Hummocky surface is evident in LiDAR-derived hillshade and aerial photography.

## SEDIMENTARY DEPOSITS Beds common to one or more sedimentary units:

in composition, but some beds contain subordinate sand grains. Only

ash deposits. Coarse sands are brown to gray and exhibit large-scale foreset

Thickness ranges from 2 to 30 m (6 to 100 ft).

exposed.

Sandstone beds (Miocene)—Moderately to well-cemented gray, yellow, and brown arkosic to arenitic sandstone in a silica-rich matrix. Typically, coarse to very coarse grained. Grains are largely quartz and feldspar. Beds form resistant ribs, and some exposures may locally be related to fluid flow along faults. Only shown on map where beds are well exposed. Tmt Mafic lapilli tuff beds (Miocene)—Beds of moderately consolidated green and yellow and brown mafic tuff. Scoriaceous clasts are glassy, highly vesiculated, and brown, and typically 1 - 5 cm in diameter. Predominantly volcanic

shown on map where beds are well exposed. Silicic ash tuff deposits (Miocene)—Very thick- to thin-bedded, light-blue, gray, to white ash with local small (< 1 cm) pumice lapilli and fine laminae. Massive beds appvear to have been reworked. Dewatering structures, local soft-sediment deformation, and crossbedding is common. While likely more common than indicated, only shown on map where beds are well Poison Creek Formation (Miocene)—Coarse- to fine-grained, well-bedded, arkosic sandstone, and weakly to non-consolidated fine bedded to massive medium- to fine-grained arkosic sandstone and siltstone, with subordinate

beds suggesting deposition by a system of nearshore lacustrine Gilbert deltas. Coase sands well cemented with silica are mapped as Tss (see description above). With exception to the coarse silicified sandstone the unit is poorly exposed. Thickness approximately 50 m (160 ft). **Payette Formation (Miocene)**—Unconsolidated to weakly indurated tan, very pale orange, grayish-yellow-green, pale greenish-yellow, and off-white coarse siltstone and claystone and subordinate sandstone. Sandstone is fine grained to coarse grained, arkosic, well bedded with mm to 2 cm scale bedding, as well as cross-bedded. Well-cemented, coarse-grained sandstones are mapped as Tss (see description above). Generally dipping 5 to 36 degrees with local variations. Beds of blue-gray to white silicic volcanic ash fall found throughout the formation are mapped as *Tst* (see descrip-

tions above). Also present are subordinate beds of moderately consolidated grayish-brown to yellowish-gray basaltic tuff, mapped as *Tmt* (see description above). The Payette Formation overlies the uppermost volcanic flows and is found intercalated throughout the middle Miocene volcanic flows but is most prevalent within Grande Ronde (*Tcgn*,) and the andesite of Four Mile Road (*Tiaf*). Maximum age of the formation is approximately 17 Ma (Smiley and others, 1975; Jarboe and others, 2010). The minimum age is not well constrained but is estimated at 14 Ma based on the end of the Miocene climactic optimum and ages of regional ash deposits (Böhme, 2003; Nash and Perkins, 2012). Immature paleosols are common throughout the deposit. Unit thickness is approximately 610 m (2,000 ft), not including layers interbedded in volcanic strata.

VOLCANIC ROCKS Iron-rich andesite of Four Mile Road (Miocene)—Dark-gray to gray-black

aphyric to sugary textured iron-rich andesite. Locally fractured into platey slabs. Iron-rich andesites, called Icelandites by Carmichael (1964), are geochemically distinct by having SiO<sub>2</sub> content between 56 to 65 percent and FeO/MgO ratios greater than three. Unit is difficult to distinguish in field samples from Grande Ronde Basalt (*Tcgn*<sub>1</sub>). However, if flow tops are present, stretched vesicles are more prominent in the andesite. Geochemistry indicates many flows of *Tiaf* occurred during *Tcgn*, time, however no attempt was made to map individual andesite flows in the main body of *Tcgn*<sub>1</sub>. Lambert and others (1995) describe the presence of ferro-andesite in Grande Ronde units and interpret this rock be a result of crystal fractionation. It is possible that *Tiaf* is a chemical variation of Grande Ronde, however we deem its presence is significant and should be mapped where possible. The most notable appearance of *Tiaf* is above *Tcgn*<sub>1</sub> and within Payette Formation (*Tp*) sediments, making it the youngest volcanic flow in the map. In published mapping to the north and northwest (Indian Valley quadrangle, Garwood and others, 2010; Crane Creek Reservoir quadrangle, Feeney and Schmidt, 2019; Paddock Valley Reservoir quadrangle, Feeney and others, 2023; Hog Cove Butte quadrangle, Love and others, 2023). Tiaf is associated with a rhyolite flow. In the Northeast Emmett quadrangle *Tiaf* is mapped as a part of Grande Ronde (*Tgn*,*a*, Feeney and others,

thickness is difficult to determine because of intercalated relationship and visual similarity to *Tcgn*, but some of the later flows are up to 60 m (200 ft) **Tuff of Willow Ridge (Miocene)**—Red, gray, and white massively bedded lithic crystal dacite tuff with a gray, tan, and pink flow-banded welded lapilli rhyolite tuff and dark-gray and yellow to tan basaltic tuff. Occurs as a mappable unit between the Lower Columbia River Basalt (Tcrl) and younger Grande Ronde Basalt *Tcgn*, A U-Pb zircon TIMS date on sample 17RL250 collected in the northeast part of the map revealed an age of  $16.448 \pm$ 0.014 Ma (Figure 1, Table 3). Red-colored tuff consists of 30 percent crystals, 10 percent lithics, and 60 percent devitrified glass; crystals are 60 percent plagioclase ranging from 0.2 to 0.6 mm in size and 40 percent unrecognizable mafic minerals ranging from 0.2 to 0.5 mm in diameter; lithics range from 0.2 to 1.0 mm in diameter. Groundmass is completely devitrified and contains rare microlites. Welded lapilli tuff shows alternating lapilli-rich and ash-rich wavy bands 0.2 mm to 2 cm thick. Lapilli consists of 60 percent lithics of devitrified angular glass fragments with rare

2018). There are at least five flows in the Cherry Gulch quadrangle;

above the other previous two lithologies and consists of palagonite-rich tuff containing scoria clasts and glass fragments up to several cm in diameter in massive and thinly bedded deposits. The basaltic tuff consists of 30 percent crystals and 60 percent glass that occurs as elongate globules and undulating seams between layers of crystals, and 10 percent yellowish clay that surrounds and fills in cracks within crystals and glass globules. Clay is likely to be altered glass. Crystals consist of 75 percent zoned euhedral plagioclase ranging in length from 0.3 to 4.0 mm. The remaining crystal fraction includes 15 percent olivine that is almost completely altered to iddingsite, and ranges from 0.5 to 1.5 mm in diameter, and 10 percent euhedral orthopyroxene and clinopyroxene ranging in size from 0.5 to 0.8 mm. Glass is partially devitrified and occurs in globules of two distinct colors, dark brown and light brown. Uncommon lithics are rounded to angular and consist of intricately banded glass and completely devitrified

plagioclase microlites. The remaining 40 percent is devitrified glass, with

abundant spherulites. Basaltic tuff occurs below, intercalated within, and

## varies from 3 to 15 m (10 to 50 ft). Columbia River Basalt Group

glass. Yellowish clay alteration forms an anastomosing system of seams in

the rock and fills fractures in crystals and glass globules. Unit thickness

The stratigraphic nomenclature for the Columbia River Basalt Group (CRBG) follows that of Reidel and others (2013). In Idaho, the group is divided into five formations. From oldest to youngest, these are the Steens Basalt, Imnaha Basalt, Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt (Barry and others, 2013). Work by Kasbohm and Schoene, (2018) indicate that the majority of the Columbia River Basalt (Steens, Imnaha, Grande Ronde, and Wanapum) erupted from 16.7 Ma to 15.9 Ma. Grande Ronde Basalt, from oldest to youngest, has been subdivided into the informal R<sub>1</sub>, N<sub>1</sub>, R<sub>2</sub>, and N<sub>2</sub> magnetostratigraphic units (Swanson and others, 1979). No Wanapum or Saddle Mountains flows are exposed in the quadrangle. An interpretation of all CRBG units in Cherry Gulch quadrangle is shown in Figure 2. Grande Ronde Basalt N<sub>1</sub>, flows and dikes (Miocene)—Dark-gray and mottled

fracturing common. Contains less than one percent microphenocrysts of plagioclase 1 mm or less in length; the remaining ~99 percent is microlitic groundmass of plagioclase, pyroxene, opaque minerals, and glass. Dikes are dark-gray to mottled light-orange, fine-grained aphyric basaltic andesite. Defined as Grande Ronde basalt by geochemical analyses. The larger of the two dikes is broken into segments but spans the length of 3,050 m (10,000 ft) and is 2 to 4 m (6 to 12 ft) wide, and is found in the central part of the map in *Tcrl* (Table 2). The smaller of the two is 210 m (690 ft) long and 2 to 4 m (6 to 12 ft) wide and located in the northwest and cross cuts *Tcrl* and *Ttrw*. The U-Pb zircon TIMS date (Table 3) from this study puts a lower limit on the appearance of Grande Ronde N<sub>1</sub> in the area to after 16.448  $\pm$ 0.014 Ma. A second U-Pb zircon date from a rhyolite in the neighboring Paddock Valley Reservoir quadrangle, to the northwest, yielded 16.4 Ma (Feeney and others, 2023) restricting the Grande Ronde basalts in the Cherry Gulch quadrangle to ~50,000 years beginning about 16.4 Ma. Unit is approximately 335 m (1,100 ft) thick. No attempt was made to map all Payette Formation (*Tp*) interbeds; locally present and only shown where mappable, most prominent exposure is on ridge tops. In secs. 3, 4, 9, and 10 of T. 8 N, R. 1 W. Grande Ronde flows are interfingered with fine-grained beds of the Payette Formation. The basalts are glassy, less than 2 m (6 ft) thick, light-gray, and a friable with spherulitic texture developing an apron of 0.5 to 2 cm diameter spherules in detritus at the base. Rare hyaloclastite is present in some of the zones between spherules in outcrop. All of these are suggestive of a flow front of fast-moving basalt flowing into a shallow lake (Godchaux and Bonnichsen, 2002). These flows were not thick enough to be mapped separately in this area.

Lower Columbia River Basalt flows and dike (Miocene)-Light-purple to

ayish-red-purple or light- to dark-gray, interlayered aphyric and coarse plagioclase-phyric basalt and basaltic andesite. Weathers to a coarse-grained grus; talus is rare. Aphyric flows contain microphenocrysts of plagioclase, olivine, iddingsite altered from olivine, and altered pyroxenes; remaining 50 percent groundmass composed of microlitic plagioclase, pyroxene, glass, and opaques. In coarse plagioclase flows, plagioclase crystals range from 1 to 5 cm in length and make up about 40 percent of the rock, with additional 5 percent in pyroxene and olivine; the remaining 55 percent is groundmass composed of plagioclase, olivine, pyroxene, glass, and opaque oxides. A single dike is approximately 180 m (590 ft) long and located on north central Sehewoki'l Newenee'an Katete Butte (44.04137°, -116.41061°). Dike is a dark-gray, fine-grained basalt. Located within and geochemically similar to *Tcrl*. Fitzgerald (1982) mapped Tcrl as Imnaha Basalt and noted a paleomagnetic transition (Fitzgerald, field notes) from reverse to normal on Sehewoki'l Newenee'an Katete Butte; Martin (1984) confirmed this transition. Hooper and others (2002) suggested this paleomagnetic transition is the change from R0-C5Cr to N0-C5Cn.3n and represents the boundary between older Steens Basalt and younger Imnaha Formation. Jarboe and others (2010) used <sup>40</sup>Ar/<sup>39</sup>Ar dates on transitional flows in the Steens Mountain area of Oregon to constrain the reversal to 16.73 +0.13/-0.08 Ma; in the same paper they report a 16.85  $\pm$  0.21 Ma date from a plagioclase-phyric flow at the top of Sehewoki'l Newenee'an Katete Butte (44.00571°, -116.40825°, datum unknown). The boundary between Steens Basalt and Imnaha Basalt is not well defined (Barry and others, 2013); the bottom of the Imnaha is 16.7 Ma (Hooper and others, 2002) and the top of the Steens is 16.6 Ma (Barry and others, 2013). Camp and others (2013) identified a series of flows south of Sehewoki'l Newenee'an Katete Butte that they considered as low in the stratigraphy as Steens Basalt. However, whole-rock XRF data from the butte indicates there is not enough geochemical delineation (Figure 3; Table 2) to draw a well-defined contact. Additionally, petrography shows little to no differentiation through the section. It is likely that all of Sehewoki'l Newenee'an Katete Butte is composed of Steens Basalt and that no Imnaha exists in this quadrangle. The U-Pb zircon date from the tuff of Willow Creek (*Ttwr*) reported here provides a youngest age of  $16.448 \pm 0.014$  Ma for *Tcrl*. INTRUSIVE ROCKS

Kgbt Garnet-biotite tonalite (Cretaceous)-Shown in cross section only. Unit projected from mapping in the Northeast Emmett quadrangle to the south (Feeney and others, 2018).

# STRUCTURE

The Cherry Gulch quadrangle is in the southwestern part of the western Idaho fault system (WIFS; Gilbert and others, 1983). The WIFS is characterized by north-striking, valley- and ridge- forming, high-angle normal faults. The WIFS extends from this quadrangle 50 km (32 mi) to the east and 100 km (62 mi) to the north. Activity along the WIFS is from the middle Miocene to the late Holocene (Gilbert and others, 1983). The quadrangle contains two significant faults zones, the Big Flat fault zone and the west Ola Valley fault zone (formerly the derogatory Squaw Butte/Creek fault zones; Capps, 1941; Hamilton 1962; Witkind, 1975; Fitzgerald, 1982; Gilbert and others, 1983). The Big Flat fault zone is a 10 km (6 mi) wide by 35 km (20 mi) long region of north-striking east- and west-dipping normal faults with offsets of up to 400 m (1,300 ft) which extend north of the quadrangle. The Indian Jakes valley in the northeast corner of the map, which becomes the Big Flat valley to the north, is a graben bounded by the Big Flat fault on the west and the Jakes Creek fault on the east. Trenching in 1982 across the Jakes Creek fault showed an estimated displacement of 0.3 to 0.4 m (1 to 1.5 ft) of latest Pleistocene to early Holocene soils (Gilbert and others, 1983). LiDAR elevation models confirm fault scarps in Quaternary sedimentary deposits along segments of the Jakes Creek fault, Big Flat fault, and an unnamed fault on the northwest side of the Sehewoki'l Newenee'an Katete Butte. These segments are identified on the map as fault scarps. A segment of the west Ola Valley fault, 6.5 km (4 mi) long, located in the southeast corner of the map, is part of a 50 to 55 km (31 to 34 mi) long system of down-to-the-east normal faults with a maximum displacement of 800 m (2,620 ft). A trench dug in poorly dated surficial deposits along the west Ola Valley fault near Ola, Idaho, northeast of the quadrangle, indicated about 2.4 m (8 ft) of Quaternary displacement, of which about 0.6 to 0.8 m (2 to 2.5 ft) is post middle Holocene based on an ash proposed to be Mazama ash (Gilbert and others, 1983). However, no analyses were done by Gilbert and others (1983) to confirm this interpretation. The west Ola Valley fault zone is responsible for Sehewoki'l Newenee'an Katete Butte standing high above the valleys and surrounding subdued ridges. The remaining poorly exposed faults in the west part of the quadrangle are defined by large escarpments along ridges of tilted volcanic flows, spring alignments, and stratigraphic

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<sup>206</sup>Pb/<sup>238</sup>U dates from single zircon grains analyzed by the chemical abrasion isotope

dilution thermal ionization mass spectrometry (TIMS) method at Boise State



Butte Fire Lookou 4.500 FEET Figure 3. Interpreted section of volcanic flows at Sehewoki'l Newenee'an

to convey actual thickness; and no attempt was made to show sedimentary



interbeds.



\*Franklin and Marshall College reports total iron expressed as Fe<sub>2</sub>O<sub>3</sub>.

number Latitude Longitude Unit name lower Columbia River Basalt Group Tcrl lower Columbia River Basalt Group Tcr lower Columbia River Basalt Group Tcr BX6206 Grande Ronde Basalt N<sub>1</sub> Grande Ronde Basalt N<sub>1</sub> as seen in Figure Grande Ronde Basalt N<sub>1</sub> Tcgr Iron andesite of Four Mile Road Tiaf Grande Ronde Basalt N, BX6210 Iron andesite of Four Mile Road Tiat Grande Ronde Basalt N<sub>1</sub> Grande Ronde Basalt N<sub>1</sub> lower Columbia River Basalt Group Tcr lower Columbia River Basalt Group Tcrl lower Columbia River Basalt Group Tcrl lower Columbia River Basalt Group Tcrl lower Columbia River Basalt Group Tcr lower Columbia River Basalt Group Tcr lower Columbia River Basalt Group Tcr lower Columbia River Basalt Group Tcrl lower Columbia River Basalt Group Tcrl lower Columbia River Basalt Group Tcrl lower Columbia River Basalt Group Tcrl



\*Washington State University Geoanalytical Laboratory reports total iron as FeO.

Samples with prefix BX taken by James Fitzgerald in 1978 and 1979, analyzed at WSU Geoanalytical Laboratory in 2015, unable to verify location data.



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

	Major elements in weight percent												Trace elements in parts per million																
SiO <sub>2</sub>	TiO <sub>2</sub>	$Al_2O_3$	$Fe_2O_3^*$	MnO	MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	$P_2O_5$	Total	LOI	Ni	Cr	Sc	V	Ba	Rb	Sr	Zr	Y	Nb	Ga	Cu	Zn	Pb	La	Ce	Th	Co U
74.33	1.40	8.94	8.22	0.12	0.96	2.86	1.65	1.39	0.40	99.87	3.48	7	34	13	159	592	32.6	207	169	25.6	13.9	14.9	24	100	10	19	36	13.7	23 1.0
54.79	1.78	13.83	13.73	0.19	3.90	7.27	2.97	1.14	0.25	99.85	3.11	10	19	30	314	451	27.3	327	156	33.4	9.3	19.7	32	107	5	18	31	4.0	44 <0.5
73.93	0.20	13.87	1.91	0.08	0.47	1.45	3.87	4.10	0.07	99.95	0.72	6	9	1	21	867	98.3	154	111	28.8	15.7	18.0	17	57	15	26	43	9.3	<1 1.9
66.09	0.95	15.31	8.02	0.09	0.75	2.42	2.98	2.83	0.18	99.62	3.79	15	41	13	95	1014	65.7	205	285	46.2	20.2	22.1	36	133	29	35	73	15.6	15 0.5
51.19	1.35	19.36	10.17	0.13	2.71	10.67	3.28	0.53	0.27	99.66	1.71	61	103	26	244	216	8.30	415	118	26.5	4.7	19.6	147	81	12	13	23	< 0.5	31 <0.5
53.21	2.01	14.74	12.60	0.20	3.84	7.91	3.53	1.32	0.39	99.75	3.20	47	71	24	298	601	25.7	402	211	40.8	13.0	20.9	130	103	5	21	37	3.7	33 0.5
57.03	1.85	15.64	9.88	0.21	2.24	5.59	4.23	2.51	1.04	100.22	1.15	6	25	15	119	935	39.0	488	279	54.6	18.2	22.3	32	128	12	31	56	2.2	23 1.6
55.65	1.69	14.19	10.92	0.33	4.31	7.90	3.24	1.41	0.25	99.89	0.52	9	33	29	320	673	29.0	344	168	32.1	10.7	21.1	40	108	<1	19	32	7.1	44 1.1
50.95	1.67	16.78	12.03	0.21	4.44	9.75	3.02	0.58	0.26	99.69	3.45	60	86	24	291	292	11.3	399	141	30.3	7.3	20.0	155	82	2	17	26	0.5	39 <0.5
57.95	1.96	13.42	11.93	0.31	2.13	5.32	3.81	2.29	0.78	99.9	0.65	7	16	21	93	916	44.5	367	254	48	17.5	21.6	20	136	13	33	61	11.2	23 1.9
61.84	2.12	14.65	8.63	0.16	0.50	4.13	4.06	2.55	0.91	99.55	1.30	3	13	23	104	1030	58.8	379	290	43.5	21.8	24.1	15	154	2	32	54	14.8	21 3.1
54.67	1.79	14.59	12.30	0.20	3.99	7.61	3.28	1.31	0.26	100	1.78	10	14	29	329	474	27.4	337	168	30.9	10.5	20.8	30	103	9	20	33	4.8	38 <0.5
53.64	2.13	14.58	12.69	0.19	4.07	8.00	3.20	1.07	0.38	99.95	2.19	30	46	27	288	704	17.2	441	200	32.6	15.3	20.9	36	130	<1	18	33	3.2	40 <0.5
52.91	1.57	14.47	11.83	0.20	5.63	9.05	2.84	0.94	0.33	99.77	1.97	47	96	28	258	534	17.8	351	150	33.5	10.3	19.0	91	105	1	19	35	0.5	39 0.8
59.05	2.01	13.51	10.95	0.23	2.32	5.41	3.52	2.38	0.51	99.89	1.10	10	18	20	168	920	47.0	350	247	42.3	16.1	21.6	27	123	10	24	49	10.0	26 1.5
58.55	1.99	13.68	11.3	0.33	2.40	5.56	3.19	2.81	0.52	100.33	1.06	10	14	22	191	870	49.6	331	236	41.3	16.5	20.6	15	130	11	25	53	10.1	25 <0.5
57.71	2.01	13.57	12.21	0.27	2.30	5.28	3.52	2.21	0.52	99.6	1.85	1	26	23	182	857	43.7	326	238	38.9	15.9	21.2	29	127	8	23	46	14.5	28 1.2
50.74	1.68	16.91	11.57	0.22	4.48	9.99	3.17	0.60	0.27	99.63	2.03	52	95	28	290	316	10.3	402	145	31.9	7.1	20.4	163	82	3	15	25	<0.5	37 <0.5
51.04	2.37	13.83	15.30	0.22	3.77	7.75	3.75	1.19	0.54	99.76	1.29	29	50	30	295	451	15.0	445	203	39.8	12.9	19.1	158	138	24	19	28	6.6	43 <0.5
53.35	2.09	14.52	13.20	0.22	4.43	7.86	3.14	1.15	0.37	100.33	0.63	26	66	29	285	645	25.5	432	197	32.4	14.7	20.3	49	130	1	19	31	5.6	40 0.9
53.20	1.92	15.08	12.47	0.20	3.78	8.02	3.37	1.14	0.38	99.56	4.58	1	68	22	197	836	59.2	374	237	48.4	18.0	20.3	21	147	4	31	59	15.9	23 0.5
57.63	1.93	13.34	12.27	0.37	2.02	5.15	3.51	2.53	0.81	99.56	1.57	3	21	21	143	787	63.9	327	257	43.4	23.1	23.4	60	150	14	25	45	18.2	37 1.1
51.12	2.15	14.49	13.56	0.23	5.31	9.04	3.02	0.89	0.32	100.13	1.73	2	156	11	264	772	43.8	304	173	28.7	14.8	18.3	25	95	11	23	45	16.0	21 <0.5
52.78	1.89	13.98	13.35	0.27	4.61	8.53	3.02	1.11	0.36	99.9	3.21	3	42	27	230	820	42.7	383	194	41.6	14.2	20.5	33	130	20	26	55	12.6	27 0.6
51.07	1.35	19.43	10.52	0.19	3.23	10.48	3.24	0.44	0.23	100.18	3.51	30	53	27	245	625	24.6	431	158	31.2	14.7	20.8	43	130	8	18	34	6.6	42 <0.5
57.42	2.03	13.44	11.84	0.34	2.20	5.51	3.42	2.58	0.84	99.62	1.49	1	25	22	98	960	49.5	367	253	46.2	18.5	21.1	28	135	19	27	56	12.8	26 <0.5
57.57	1.96	13.42	12.45	0.25	2.11	5.35	3.58	2.43	0.83	99.95	1.45	44	64	27	174	528	21.5	380	232	39.9	11.5	20.5	149	123	5	19	31	6.1	39 <0.5
50.54	1.39	16.92	12.6	0.25	4.85	9.57	2.86	0.51	0.23	99.72	3.37	59	89	18	271	358	11.8	387	112	26.3	6.5	19.1	86	99	1	13	25	0.8	51 <0.5
55.03	1.79	13.96	13.09	0.19	3.94	7.15	3.22	1.36	0.37	100.10	1.00	7	15	40	322	465	33.8	312	161	31	8.8	19.9	29	119	18	19	36	2.2	37 <0.5
52.46	2.27	14.52	14.01	0.18	3.73	8.08	3.06	1.09	0.41	99.81	3.52	45	77	29	319	408	20.9	409	206	35.8	13.8	19.4	152	121	13	17	31	3.3	43 <0.5
50.76	1.34	16.86	12.35	0.30	4.61	10.11	2.85	0.32	0.21	99.71	5.50	70	88	25	237	232	5.9	411	107	26.2	6.2	18.8	98	82	<1	19	30	4.2	51 <0.5
55.77	2.59	13.19	13.55	0.19	2.35	6.02	2.90	2.74	0.53	99.83	2.08	6	24	19	216	757	55.1	308	337	44.2	23.7	22.9	59	153	20	30	53	18.6	37 2.3
57.73	2.01	13.51	12.01	0.27	2.16	5.37	3.33	2.52	0.84	99.75	2.81	1	16	24	98	1244	44.7	381	255	49.4	17.2	21.2	23	137	15	29	60	17.0	27 <0.5
52.84	2.01	14.50	13.05	0.29	4.51	8.24	3.19	1.19	0.39	100.21	1.04	27	46	29	306	672	21.5	417	181	33.1	12.6	20.3	61	124	1	21	37	4.2	39 <0.5
53.63	1.95	14.70	11.49	0.23	4.33	8.57	3.22	1.14	0.39	99.65	1.43	35	54	30	301	984	22.0	429	184	34.3	12.1	20.8	75	118	1	21	41	1.8	41 0.5

Samples with prefix 16 were analyzed by Dr. Stanley Mertzman at Franklin and Marshall College X-Ray Laboratory

Tabl	e 2. Major oxid	e and trace element c	hemi	stry o	f sam	ples o	collec	ted fr	om tv	vo se	ction	s by	Jame	s Fitz	zger	ald i	in tł	ne Ch	nerr	y Gı	ılch	ı qu	adr	ang	le (S	See F	<sup>:</sup> igs.	. 2 a	nd 3	3).	
pplc			Man				Major	element	s in wei	ight pe	rcent								Т	race e	elem	ents i	n pa	rts pe	er mil	lion					
nber	Latitude Longitude	Unit name	Map unit	SiO <sub>2</sub>	TiO <sub>2</sub>	$Al_2O_3$	FeO*	MnO	MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	$P_2O_5$	Total	Ni	Cr S	Sc N	/ Ba	Rb	Sr	Zr	Y	Nb	Ga	Cu	Zn I	Pb L	.a Ce	Th	Nd	J
201		lower Columbia River Basalt Group	Tcrl	48.87	2.155	15.83	11.44	0.163	6.11	9.95	3.10	0.47	0.308	98.38	113	213 3	4 34	4 275	6	397	140	33	8.7	21	160	120 4	4 1.	2 31	2	19	1
203		lower Columbia River Basalt Group	Tcrl	50.87	2.350	13.99	12.85	0.235	4.35	8.40	3.53	1.26	0.508	98.34	32	29 3	6 40	6 515	23	431	190	38	13.1	20	137	136	9 2	5 54	3	31	1
204		lower Columbia River Basalt Group	Tcrl	51.12	2.216	14.40	12.53	0.204	4.61	8.66	3.56	1.15	0.467	98.91	41	43 3	4 39	2 474	19	434	177	36	12.7	21	141	130	7 2	.0 48	3	28	ð
206		Grande Ronde Basalt $N_1$	Tcgn <sub>1</sub>	53.04	2.089	14.68	10.95	0.206	3.79	7.94	3.67	1.38	0.410	98.16	35	72 3	31 31	0 634	23	389 2	217	43	13.7	20	145	131 1	0 2	1 52	3	31	1
207	Big Willow Creek section	Grande Ronde Basalt N <sub>1</sub>	Tcgn <sub>1</sub>	54.18	2.229	14.89	9.98	0.143	2.89	7.98	3.47	1.74	0.454	97.96	33	75 3	3 32	5 658	33	393 2	232	45	14.5	21	132	123	9 2-	4 60	3	32	1
208	as seen in Figure 2.	Grande Ronde Basalt N <sub>1</sub>	Tcgn <sub>1</sub>	54.77	2.246	15.31	10.70	0.160	2.86	8.02	3.63	1.68	0.446	99.82	27	70 3	4 31	6 680	36	400	235	47	15.2	21	166	134	9 2	6 58	4	33	2
209		Iron andesite of Four Mile Road	Tiaf	58.94	2.116	13.86	10.62	0.136	1.53	4.88	3.80	2.26	0.527	98.67	7	10 2	6 16	6 974	66	336	241	42	16.8	21	14	141 1	4 3	2 66	7	37	3
210		Grande Ronde Basalt $N_1$	Tcgn <sub>1</sub>	53.13	2.144	14.65	10.98	0.221	3.98	8.04	3.55	1.68	0.429	98.80	42	84 3	3 31	2 622	30	384	219	43	14.5	21	153	128	9 2	2 54	2	32	0
211		Iron andesite of Four Mile Road	Tiaf	56.39	1.864	15.40	9.02	0.184	2.08	5.50	4.12	2.78	1.039	98.38	13	14 1	8 93	3 994	56	481	273	58	17.8	21	27	138 1	13 3	4 78	5	46	4
212		Grande Ronde Basalt N <sub>1</sub>	Tcgn <sub>1</sub>	51.77	2.345	14.45	12.44	0.201	4.46	8.40	3.34	1.27	0.427	99.12	41	69 3	2 31	6 499	26	387 2	202	40	14.9	20	104	129	91	8 52	3	29	1
213		Grande Ronde Basalt N,	Tcgn,	50.72	1.869	16.99	10.84	0.175	4.41	10.31	3.14	0.64	0.281	99.38	58	101 3	3 31	7 302	12	390 ·	139	32	9.4	20	119	102	51	2 25	2	20	2
215		lower Columbia River Basalt Group	Tcrl	52.08	2.474	15.41	11.32	0.154	3.85	7.58	3.49	1.52	0.565	98.43	55	39 2	2 28	2 723	31	563 2	242	37	18.4	22	30	161 9	93 3	3 66	4	38	1
216		lower Columbia River Basalt Group	Tcrl	48.64	2.174	17.21	13.84	0.207	5.81	9.31	3.32	0.51	0.302	101.31	144	44 3	0 34	3 277	5	484	135	29	10.1	21	134	125	4 1	0 31	2	18	0
217		lower Columbia River Basalt Group	Terl	51.46	2 020	16.82	8 47	0.167	4 99	10.61	3.09	0.75	0 354	98 73	93	125 2	8 29	3 385	13	569	169	31	16.6	21	44	109	6 1	9 47	2	26	0
218		lower Columbia River Basalt Group	Terl	52.07	2.020	15.60	0.1	0.179	4.80	0.01	3.03	1 40	0.507	98.75	87	123 2	.5 29 13 70	5 560	30	556	215	30	18.0	- ' 21	24	127	6 1 6 1	5 64	ے ۸	20	0
210		lower Columbia River Basalt Group	Teul	40.14	1.005	15.00	10.01	0.170	4.00 E 76	10.74	3.02	0.27	0.307	90.70	126	104 2	.5 20	2 202	52	402	126	32	11.0	10	54	100	4 1	2 22	4	20	1
219		lower Columbia River Basalt Group	TCTI	49.14	1.005	15.66	10.61	0.141	5.70	0.56	2.04	0.57	0.271	97.45	120	194 2	.7 20	0 240	5	403	120	27	0.1	19	51	110	+ 1.	5 55	2	20	ว
220		lower Columbia River Basalt Group	I Cri	48.19	1.931	17.72	12.08	0.186	5.20	9.56	3.28	0.50	0.270	98.90	151	34 2	.9 31	9 249	/	493	106	28	9.1	21	143	119 .	/ 8	5 32		19	<u>`</u>
221		lower Columbia River Basalt Group	l crl	48.01	2.244	16.23	13.29	0.196	6.27	9.40	3.27	0.53	0.288	99.72	140	41 3	1 35	1 244	8	452	137	30	9.6	22	149	126	4 14	4 33	0	23	5
222		lower Columbia River Basalt Group	Tcrl	49.41	1.830	15.50	10.82	0.174	7.82	10.15	2.83	0.50	0.279	99.31	221 :	281 2	27 27	9 225	8	487	125	25	11.8	19	66	112	6 1.	5 36	0	21	1
223		lower Columbia River Basalt Group	Tcrl	47.65	2.243	16.21	13.44	0.207	6.01	9.09	3.27	0.54	0.313	98.96	129	38 3	30 34	6 264	7	452	137	29	10.7	21	160	126	4 13	3 32	2	20	2
224		lower Columbia River Basalt Group	Tcrl	48.32	1.691	16.30	10.52	0.168	7.43	10.51	2.83	0.33	0.227	98.34	195	203 2	8 27	1 209	3	495	108	24	8.9	19	83	117 5	51 10	0 27	2	18	2
225		lower Columbia River Basalt Group	Tcrl	51.87	2.625	14.95	11.42	0.170	3.73	7.31	3.19	1.82	0.680	97.77	44	44 2	1 29	5 817	47	570 2	262	39	20.6	23	30	153	8 3	4 74	5	40	1
226		lower Columbia River Basalt Group	Tcrl	50.36	1.680	16.80	10.85	0.191	6.08	9.70	3.20	0.87	0.329	100.07	118	159 3	1 30	0 334	15	469	132	29	12.5	19	148	104	5 1.	2 32	2	18	2
227		lower Columbia River Basalt Group	Tcrl	54.49	2.006	15.71	10.20	0.168	3.61	6.40	4.30	1.99	0.757	99.64	60	30 2	2 23	7 728	43	550 2	233	35	28.3	19	33	107	8 3	4 70	4	38	3
228	Sebewoki'l Newenee'an	lower Columbia River Basalt Group	Tcrl	48.38	1.956	16.21	10.95	0.172	6.97	10.04	3.02	0.52	0.301	98.53	116	98 2	6 27	3 238	7	505	133	26	12.2	20	42	111	5 1	7 34	2	20	1
229	Katete Butte section as	lower Columbia River Basalt Group	Tcrl	49.31	1.956	16.13	11.18	0.185	7.00	10.01	2.99	0.51	0.288	99.55	163	183 2	8 27	2 266	7	515	130	27	11.4	20	68	112	4 1	1 30	2	20	1
230	seen in rigure 5.	lower Columbia River Basalt Group	Tcrl	49.11	1.806	15.40	10.48	0.167	7.96	10.31	2.68	0.44	0.266	98.62	157	285 2	6 26	6 254	6	464	126	25	11.3	20	49	107	4 1	3 30	2	19	1
231		lower Columbia River Basalt Group	Tcrl	50.50	2.521	15.03	11.80	0.168	5.16	8.29	3.25	1.27	0.488	98.48	30	17 2	6 30	9 561	29	508	214	35	16.1	21	21	146	72	5 56	3	32	1
232		lower Columbia River Basalt Group	Tcrl	51.60	2.429	15.23	11.87	0.176	4.86	8.51	3.24	1.31	0.491	99.73	35	24 2	25 29	7 603	27	541	217	35	16.5	22	18	140	72	.1 55	4	33	1
233		lower Columbia River Basalt Group	Tcrl	48.87	1.563	16.57	10.53	0.175	6.21	9.41	2.95	0.83	0.267	97.38	141	78 2	8 28	3 293	15	400	121	28	9.5	19	137	114 6	57 1	1 29	2	18	0
234		lower Columbia River Basalt Group	Tcrl	49.02	1.948	18.53	11.60	0.186	5.22	10.29	3.31	0.45	0.253	100.82	83	57 3	0 31	7 226	6	466	121	27	9.1	21	110	108	4 1	2 29	2	17	1
235		lower Columbia River Basalt Group	Tcrl	48.48	1.996	18.12	11.66	0.189	4.75	10.19	3.26	0.49	0.270	99.41	79	55 3	1 32	3 256	7	466	127	28	9.0	21	132	108	4 1	.0 27	2	17	1
236		lower Columbia River Basalt Group	Tcrl	50.39	1.818	18.29	10.74	0.181	4.69	9.42	3.40	0.86	0.317	100.12	76	65 2	6 28	0 346	16	498	136	29	11.8	21	114	107	5 1	4 33	2	19	1
238		lower Columbia River Basalt Group	Tcrl	47.21	1.570	15.84	10.63	0.175	5.80	8.91	2.88	0.83	0.280	94.14	127	78 2	27 28	6 298	14	383 -	122	29	9.7	19	129	97	4 9	9 30	2	18	0
238®		lower Columbia River Basalt Group	Terl	47.10	1 568	15.80	10.69	0.176	5.82	8.93	2.92	0.83	0.280	94 11	128	76 2	8 28	7 308	15	382	124	28	9.7	20	127	95	3 (	9 30	1	18	0
2300		lower Columbia River Basalt Group	Terl	48.63	1 842	18.35	11.04	0.183	4.97	9.93	3 3 2	0.56	0.324	99.15	91	106 3	10 20	15 362	4	174	1/3	31	11.4	21	148	108	6 1	5 37	2	21	0
235		lower Columbia River Basalt Group	Teul	40.03	1.042	10.55	10.40	0.170	4.97	10.09	2.27	0.50	0.324	00.94	91	110 3	0 30	0 260	4	474	145	22	10.5	21	140	100	4 1	J J/	2	20	í 0
240		lower Columbia River Basalt Group	I Cri	49.93	1.988	18.15	10.40	0.170	4.01	10.08	3.27	0.70	0.332	99.84	94	119 2	9 29	0 369	12	4/1	146	32	10.5	21	144	102	+ I.	/ 33	3	20	י ר
241		iower Columbia River Basalt Group	I crl	50.07	1.627	17.67	10.45	0.181	5.28	9.68	3.37	0.75	0.352	99.42	80	106 2	:9 27	/ 352	11	513	120	28	9.9	19	123	103 3	/ 14	4 34	2	20	-
241®		Iower Columbia River Basalt Group	Tcrl	49.99	1.617	17.65	10.52	0.180	5.29	9.69	3.41	0.75	0.352	99.45	81	107 2	9 27	5 352	11	514	121	29	9.1	19	124	104 8	8 1.	3 30	2	19	2
242		lower Columbia River Basalt Group	Tcrl	49.82	1.551	17.82	10.67	0.183	5.29	9.87	3.24	0.72	0.335	99.52	78	104 2	8 27	7 378	11	518	114	28	8.7	18	120	106	6 14	4 28	2	18	2
243		lower Columbia River Basalt Group	Tcrl	48.42	1.485	16.37	11.23	0.175	6.88	10.25	2.89	0.40	0.219	98.32	135	155 3	3 29	7 224	5	422	90	26	5.0	19	125	97	57	7 18	2	14	I
244		lower Columbia River Basalt Group	Tcrl	48.92	1.998	16.93	12.93	0.210	5.64	10.10	3.11	0.50	0.306	100.63	115	117 3	3 36	1 311	7	453	131	33	8.5	22	150	114	3 9	9 26	1	18	1
245		lower Columbia River Basalt Group	Tcrl	48.06	1.960	16.31	12.40	0.191	6.01	9.68	3.10	0.52	0.293	98.51	107	113 3	3 33	7 274	7	434	130	31	9.7	20	113	132 4	47 1 <i>1</i>	0 30	2	19	3
199	44.1059 -116.4377	lower Columbia River Basalt Group	Tcrl	50.97	1.694	18.70	9.85	0.156	3.61	10.11	3.25	0.78	0.256	99.38	50	78 3	30 26	52 314	14	405	131	33	8.8	20	123	102 4	4 1!	5 29	2	20	)
280	44.0397 -116.4899	Iron andesite of Four Mile Road	Tiaf	56.55	1.834	15.29	9.36	0.156	2.65	5.06	4.26	2.63	1.068	98.86	16	17 1	8 8	3 991	56	461 2	271	59	17.5	21	21	290 1.	21 3'	9 78	4	48	2

#### Table 3. U-Pb Zircon TIMS Analyses Sample Latitude Longitude Unit name Map Unit Lithology $(Ma) \pm 2s$ MSWD n 17RL250 44.10835 -116.43584 tuff of Willow Ridge Ttwr tuff 16.448 ± 0.014 0.24 Samples analyzed by Dr. Vincent Isakson at the Boise State University Isotope Geology Laboratory.

REFERENCES Barry, T.L., Kelley, S.P., Reidel, S.P., Camp, V.E., Self, S., Jarboe, N.A., Duncan, R.A., and Renne, P.R., 2013, Eruption chronology of the Columbia River Basalt Group, in Reidel, S.P., Camp, V.E., Ross, M.E., Wolff, J.A., Martin, B.S., Tolan, T.L., and Wells, R.E., eds., The Columbia River Basalt Province: Geological Society of America Special Paper 497, p. 45-66. Böhme, M., 2003, The Miocene climatic optimum: evidence from ectothermic vertebrates of central Europe: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 195, p 389-401. Camp, V.E., Ross, M.E., Duncan, R.A., Jarboe, N.A., Coe, R.S., Hanan, B.B., and Johnson, J.A., 2013, The Steens Basalt: Earliest lavas of the Columbia River Basalt Group, in Reidel, S.P., Camp, V.E., Ross, M.E., Wolff, J.A., Martin, B.S., Tolan, T.L., and Wells, R.E., eds., The Columbia River Basalt Province: Geological Society of America Special Paper 497, p. 87-116. Capps, S.R., 1941, Faulting in western Idaho, its relation to the higher placer deposits: Idaho Bureau of Mines and Geology Pamphlet 56, 23 p. Carmichael, I.S.E., 1964, The petrology of Thingmuli, a Tertiary volcano in eastern Iceland: Journal of Petrology, v. 5, issue 3, p. 435-460. Cohen, K.M., and Gibbard, P.L., 2019, Global chronostratigraphical correlation table for the last 2.7 million years version 2019 QI0500: Quaternary International, v. 500, p. 20-31. Feeney, D.M., Wood, S.H., R.S. Lewis, Phillips, W.M., Cooley, S.W., and Garwood, D.L., 2018, Geologic map of the Northeast Emmett guadrangle, Gem County, Idaho: Idaho Geological Survey Digital Web Map 185, scale Feeney, D.M., and Schmidt, K.L., 2019, Geologic map of the Crane Creek Reservoir quadrangle, Washington County, Idaho: Idaho Geological Survey Digital Web Map 187, scale 1:24,000. Feeney, D.M., Wood, S.H., Lewis, R.S., Phillips W.M., Cooley, S.W., and Garwood, D.L., 2018, Geologic map of the Northeast Emmett quadrangle, Gem County, Idaho: Idaho Geological Survey Digital Web Map 185, scale 1:24.000Feeney, D.M., Wood, S.H., Sundell, A.I., Lewis, R.S., and Love, R.L., 2023, Geologic map of the Paddock Valley Reservoir 7.5' quadrangle, Payette and Washington counties, Idaho: Idaho Geological Survey Digital Web Map 194, scale 1:24,000. Fitzgerald, J.F., 1981, Geology and basalt stratigraphy of the Weiser embayment, west-central Idaho: University of Idaho Ph.D. dissertation, 121 p. Fitzgerald, J.F., 1982, Geology and basalt stratigraphy of the Weiser embayment, west-central Idaho, in Bill Bonnichsen and R.M. Breckenridge, eds., Cenozoic Geology of Idaho: Idaho Bureau of Mines and Geology Bulletin 26, p. 103-128. Garwood, D.L., Othberg, K.L., and Kauffman, J.D., 2010, Geologic map of the Indian Valley quadrangle, Adams County, Idaho: Idaho Geological Survey Digital Web Map 121, scale 1:24,000. Gilbert, J.D., Piety, Lucy, and LaForge, Roland, 1983, Seismotectonic study Black Canyon Diversion Dam and Reservoir Boise Project, Idaho: U.S. Bureau of Reclamation Seismotectonic Report 83-7, 73 p., 3 appendices, 3 Godchaux, M.M., and Bonnichsen, B., 2002, Syneruptive magma-water and post eruptive lava-water interactions in the Snake River Plain, Idaho, during the past 12 million years, in Bill Bonnichsen, C.M. White, and Michael McCurry, eds., Tectonic and magmatic evolution of the Snake River Plain Volcanic Province: Idaho Geological Survey Bulletin 30, p. 387-434. Hamilton, W., 1962, Late Cenozoic structure of west-central Idaho: Geological

Society of America Bulletin, v. 73, p. 511-516.

Hooper, P.R., Binger, G.B., and Lees, K.R., 2002, Ages of the Steens and Columbia River flood basalts and their relationship to extension-related calc-alkaline volcanism in eastern Oregon: Geological Society of America Bulletin v. 114, no. 1, p. 43-50. Idaho Department of Water Resources (IDWR), 2017, Water well data. Available at: https://research.idwr.idaho.gov/index.html#GIS-Data (accessed March 28, 2017). Jarboe, N.A., Coe, R.S., Renne, P.R., and Glen, J.M.G., 2010, Age of the Steens reversal and the Columbia River Basalt Group: Chemical Geology, v. 274, p. 158-168. Kasbohm, J. and Schoene, B., 2018, Rapid eruption of the Columbia River flood basalt and correlation with the mid-Miocene climate optimum: Science Advances, v. 4, issue 9, 8 p. Kessler, M.A., and Werner, B.T., 2003, Self-organization of sorted patterned ground: Science, v. 299, p. 380-383. Kirkham, V.R.D., 1931: Revision of the Payette and Idaho formations: Journal of Geology, v. 39, issue 3, p. 193-239. Lambert, R.S., Chamberlain, V.E., and Holland J.G., 1995, Ferro-andesites in the Grande Ronde Basalt: their composition and significance in studies of the origin of the Columbia River Basalt Group: Canadian Journal of Earth Sciences, v. 32, p. 424-436. 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. Love, R.L., Feeney, D.M., Lewis, R.S., and Wood, S.H., 2023, Geologic map of the Hog Cove Butte quadrangle, Gem and Payette counties, Idaho: Idaho Geological Survey Digital Web Map 196, scale 1:24,000. Malde, H.E., 1964, Patterned ground in the western Snake River Plain, Idaho, and its possible cold-climate origin: Geological Society of America Bulletin, v. 75, p. 191-208. Martin, B.S., 1984, Paleomagnetism of basalts in northeastern Oregon and west-central Idaho: Washington State University M.S. thesis, 151 p. Nash, B.P. and Perkins, M.E., 2012, Neogene fallout tuffs from the Yellowstone hotspot in the Columbia Plateau region, Oregon, Washington and Idaho, USA: PloS ONE, v. 7, no. 10, p. 1-13. Reidel, S.P., Camp, V.E., Tolan, T.L., and Martin, B.S., 2013, The Columbia River flood basalt province: Stratigraphic, areal extent, volume, and physical volcanology, in Reidel, S.P., Camp, V.E., Ross, M.E., Wolff, J.A., Martin, B.S., Tolan, T.L., and Wells, R.E., eds., The Columbia River Flood Basalt Province: Geological Society of America Special Paper 497, p. 1-43. Savage, C.N., 1961, Geology and mineral resources of Gem and Pavette counties: Idaho Bureau of Mines and Geology County Report 4, 50 p., scale 1:125.000Smiley, C.J., Shah, S.M.I., and Jones, R.W., 1975, Guidebook for the later Tertiary stratigraphy and paleobotany of the Weiser area, Idaho: Idaho Bureau of Mines and Geology Information Circular 28, 12 p. Swanson, D.A., Wright, T.L., Hooper, P.R., and Bentley, R.D., 1979, Revisions in stratigraphic nomenclature of the Columbia River Basalt Group: U.S. Geological Survey Bulletin 1457-G, 59 p. Walker, J.D., and Geissman, J.W., compilers, 2022, Geologic Time Scale v. 6.0: Geological Society of America, https://doi.org/10.1130/2022.CTS006C. Witkind, I.J., 1975, Preliminary map showing known and suspected active faults in Idaho: U.S. Geological Survey Open-File Report 75-278, 71 p., scale 1:500,000.