\*LI/Ph zircon date (Boise State University) \*\*<sup>40</sup>Ar/<sup>39</sup>Ar date (Jarboe and others, 2010) \*\*\*U/Pb zircon date (R. Gaschnig, written Kgdh 84.4 +/- 1.7 Ma\*\*\* INTRODUCTION Alluvial fan deposits (Holocene-late Pleistocene)—Brown sandy silt derived The geologic map of the Northeast Emmett 7.5' quadrangle depicts the rock from loess and Tertiary sediments with lesser pebbles and cobbles of felsic units exposed at the surface or underlying a thin cover of soil or colluvium; porphyry, granitic and basaltic composition. Thickness ranges from < 3 to alluvial and man-made surficial deposits are also depicted where they form 20 m (<10 to 65 ft). significant mappable units. This map is a result of fieldwork conducted in **Boulder deposits** (Pleistocene)—Boulders and cobbles of basalt that mantle the summer and autumn of 2014 and the spring of 2015 by all authors, and upland hillslopes, generally in areas underlain by basaltic bedrock. earlier work in the late 1990s by Spencer Wood. Analysis of thin sections, XRF whole-rock geochemical data (Table 1), U-Pb zircon dating (Table 2), QThg High gravel deposits (Pleistocene-Pliocene)—Gravels containing granitic and and electron microprobe chemistry (Table 3) by the authors supplemented felsic porphyry clasts that discontinuously mantle surfaces as much as 110 the field studies. Naming of intrusive and extrusive igneous rocks is based m (360 ft) above the Payette River valley (Gilbert and others, 1983). on total alkalis versus silica chemical classification of the International Union of Geological Sciences (LeBas and Streckeisen, 1991). Previous

was consulted and incorporated where appropriate. The basement rocks of the Northeast Emmett 7.5' quadrangle are foliated Cretaceous garnet-biotite tonalite found on the east flank of Squaw Butte and Cretaceous hornblende-biotite granodiorite that crops out in a small area in the southeast part of the map. A nonconformity lies between the middle Miocene Lower Columbia River Basalt Group rocks and this granitic basement. An  ${}^{40}$ Ar/ ${}^{39}$ Ar date of 16.85  $\pm$  0.21 Ma (Jarboe and others, 2010) from atop Squaw Butte 200 m (165 ft) north of the quadrangle places these basalts in the older part of Columbia River Basalt Group, most likely Steens Basalt (Camp and others, 2013). On the western and south-central flanks of Squaw Butte are a series of Grande Ronde Basalt flows. A series of younger flows of the andesite of Black Canyon erupted from a vent likely on the southern reaches of Squaw Butte; these flows crossed the Pavette River drainage and form the buttress upon which the Black Canyon Dam was built. They are subhorizontal and appear to be interbedded with the Chalk

work in the area includes the geological mapping of Savage (1961) in Gem

and Payette counties, mapping by Gilbert and others (1983) performed in

support of seismic hazard analysis of the Black Canyon Dam and Reservoir,

fluxgate magnetometer data, XRF analytical chemistry (Table 1), and

posthumous Ph.D. dissertation by James Fitzgerald (1981; 1982); this work

an unpublished field map by Don Adair, and the field maps, field notes,

Fluvial and lacustrine Payette Formation sediments were deposited in the middle Miocene contemporaneous with and subsequent to the Columbia River basalts. The Payette is overlain by the Chalk Hills and the Glenns Ferry Formations of the Idaho Group. The late Miocene to early Pliocene Chalk Hills Formation is predominantly lacustrine with local fluvial sediments. Basaltic tuffs, channelized gravels, and ash locally occur. Dates were obtained from this quadrangle on two non-welded rhyolite tuffs using U-Pb TIMS on zircons by the geochronology laboratory at Boise State University; 9.0057±0.0082 Ma from a pumice tuff west of Haw Creek (lat 43.9642° N., long 116.4879° W.) and 9.041±0.014 Ma from a lapilli tuff east of Emmett (lat 43.886° N., long 116.4343° W.).

Gilbert and others (1983) recognized 6 terrace deposits in the Payette River valley about 9 mi (15 km) upstream and downstream of the Black Canyon Dam. These deposits were labeled in relationship to their height above the Payette River floodplain (unit *Qap*). Terrace ages were defined on the basis of degree of dissection, number of nongravelly (loess) deposits overlying gravelly alluvium, and degree of soil development. We simplified this scheme by including terraces less than 3 m (10 ft) above the floodplain into Qap, and combining the highest two terraces into a single unit, Qtp., Note that we number terraces from the floodplain upward; Gilbert and others

#### SYMBOLS

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

Outcrop-scale fault; ball and bar on downthrown side; arrow

#### Gravel pit.

- Landslide scarp and headwall.  $\searrow$  <sup>20</sup> Strike and dip of bedding.
- Approximate strike and dip of bedding
- ⊕ Horizontal bedding.
- Estimated strike and direction of bedding. Strike and dip of bedding where sedimentary structures show
- Approximate strike and dip of volcanic flows; no dip shown where strike is estimated.
- $\mathcal{L}_{00}$  Strike and dip of foliation.
- → 76 Bearing and plunge of lineation, type unknown.  $\triangle^{\Delta}$  Tectonic breccia.
- Silicified *Tsp, Tsch,* and *Tsgf*.

385598 - Water well showing Well ID number (IDWR, 2017). 15RL015a • Geochemical sample (See Table 1).

15RL015a ■ Geochronology sample (See Table 2) 16DF525 • Geochemical sample (See Table 3).

# DESCRIPTION OF MAP UNITS

ARTIFICIAL DEPOSITS Man-made land (Holocene)— Fill used to elevate roads, railways, and bridge abutments constructed in floodplains; also includes canal berms and small dams on side streams. Thickness is less than 3 m (10 ft). The concrete Black

# MASS WASTING DEPOSITS

Landslide deposits (Holocene-Pleistocene)—Hummocky flows and slumps typically developed on steep slopes adjacent to the Payette River in weakly consolidated sediments of unit Tsp, Tsch, or in lava flows of unit Tabc. Larger deposits are complexes of multiple slope failures. Several deposits show evidence of recent movement and pose hazards to State Highway 52 and the Canyon Canal in secs. 27 and 22, T. 7 N., R. 1 W. Numerous small surficial landslides are also present on west- or southwest-facing slopes of unit *Tsch* east of Emmett but are too small to map at 1:24,000 scale.

# ALLUVIAL DEPOSITS

Alluvium of Payette River (Holocene)—Well-rounded basaltic and granitic cobbles, pebbles, and boulders in an arkosic sandy matrix; consists of the braided river floodplain of the Pavette River and adjacent low terraces less than 3 m (10 ft) above the floodplain. The low terraces are composed of stratified sandy gravels topped by 0.6 to 1.5 m (2 to 5 ft) of fine sands, silts and clays. Pebbles and cobbles are present in approximately equal amounts. Basaltic rocks compose 6 to 80 percent of the gravel (Gilbert and others, 1983). Water wells indicate thickness of about 5 to 14 m (15 to 45

well-rounded basaltic and granitic cobbles derived from Quaternary terrace deposits and Tertiary sediments; thickness generally less than 3 m (10 ft). Lowest terrace alluvium of Payette River (Holocene)—Gravel, sand, and

boulders capped with 1 to 1.5 m (3 to 5 ft) of soil; discontinuous; separated from the Payette River floodplain by a scarp about 3 to 4.5 m (10 to 15 ft) high. Water wells indicate maximum thickness of about 9 m (30 ft). Second highest terrace alluvium of Payette River (Late Pleistocene)—Gravel,

sand, and clay similar in composition to unit Qap; forms the surface underlying most of Emmett and surrounding Emmett Valley. City of Emmett water wells indicate thickness ranging from 4.3 to 9.5 m (14 to 31 ft). Separated from Qtp, by a river-bank scarp 3 to 8 m (10 to 26 ft) high that decreases in height over a short distance in the downstream direction, suggesting deposition of large volume of material at mouth of Black Canyon (Gilbert and

Third highest terrace alluvium of Payette River (Late Pleistocene)—Wellrounded basaltic and granitic cobbles in a coarse to medium arkosic sand matrix capped by 1 to 3 m (3 to 10 ft) of brown sandy silt and sand. Thickness of capping nongravelly sediments increase toward the north where they interfinger with alluvial fan deposits (Qaf). Soil development on nongravelly sediments and degree of dissection (Gilbert and others, 1983) is roughly consistent with a late Pleistocene (Pinedale, circa 14-25 ka) age. This terrace includes Emmett Bench, the major high terrace of the lower Payette River valley. The terrace is separated from lower terraces and the Payette River floodplain by an 18 to 24 m (59 to 79 ft) scarp. Thickness estimated from water wells on Emmett Bench is about 5.5 to 9 m (18 to 30 ft), much less than scarp height because the terrace is underlain at shallow depths by weakly consolidated sands and gravels of unit *Tsch* and/or *Tsp*.

Fourth highest terrace alluvium of Payette River (Late Pleistocene)—Discontinuous remnants of dissected gravelly terrace deposits recognized from Black Canyon Dam upstream to the Anderson Creek area. Consists of gravels similar to Qap overlain by nongravelly silt and sand interpreted to be loess, dunes, and/or colluvium. Some terraces interfinger with adjacent alluvial fans. Deposits have soil development and degree of dissection roughly consistent with a late Pleistocene (early Pinedale-Bull Lake, circa 60-150 ka) age (Gilbert and others, 1983, Table C-1).

Andesite of Black Canyon (Late Miocene-Pliocene)—Red and light- to dark-brown and dark-gray aphyric andesite flows. Microphenocrysts of plagioclase, clinopyroxene, and oxides make up 5 percent of the rock with the remaining being groundmass of plagioclase, glass, and oxides. Vent location unknown. Columnar joint sets along Black Canyon Reservoir are 10 to 15 m (32 to 50 ft) high and greater than 1 m (3 ft) wide and near vertical, implying the andesite is near original emplacement orientation. Formerly mapped as the Weiser Basalt of Black Canyon (Fitzgerald, 1981; 1982). Composed of 1 to 3 flows of normal magnetic polarity as determined from field fluxgate magnetometer (Fitzgerald, unpublished field notes). Our interpretation is that the andesite is a late intracanyon flow interbedded with

undifferentiated (Middle Miocene)—Dark-red, highly weathered, plagioclase-phyric basalt north of Haw Creek. The basalt has a similar appearance to nearby *Trcl* flows. If this basalt is *Trcl* it's presence could be explained by a sliver fault. Only one flow observed but most of the exposure is covered with colluvium. Unit has about 50 m (164 ft) of lateral continuity.

Chalk Hills sediments. Approximate thickness of 150 m (490 ft).

CRETACEOUS

SEDIMENTARY DEPOSITS

Beds common to Chalk Hills and Payette formations

Silicic ash and lapilli tuff deposits (Miocene and Pliocene)—White to

Basaltic ash and lapilli tuff deposits (Miocene and Pliocene)—Green to gray

tuff, typically containing basaltic to andesitic lapilli 1 cm and less across.

Tsgf Glenns Ferry Formation (Pliocene)—Unconsolidated to well-indurated sand

Idaho Group

and sandstone capping three high areas in the quadrangle. Forms the upper

part of the Haw Creek section (Fig. 1) in the western part of the map area

where the basal contact is below an ooid-bearing interval described below.

Overlying unconsolidated to weakly consolidated sand (~30 m; 100 ft)

lacks ooids. Unit thickness is only about 30 m (100 ft) in the Haw Creek

section as the upper part of formation has been removed by erosion. Unit

also caps Little Butte in the N½ sec. 21, T. 7 N., R. 1 W. Here it lacks ooids

and the coarse sand is cemented by silica, forming a resistant subhorizontal sandstone interval about 30 m (100 ft) thick. This cap of near horizontal

sandstone at the top of Little Butte overlies cemented sands that dip 25°

southwest, and we regard this contact as an angular unconformity at the

base of the Glenns Ferry Formation. In the southern part of the map area,

(secs. 1, 2, 11, 12, T. 6 N., R. 1 E.), poorly exposed strata above a prominent

paleosol is tentatively assigned to the Glenns Ferry Formation. Sand-rich

interval above the paleosol is interpreted to be basal Glenns Ferry Forma-

tion, here a maximum of 65 m (200 ft) in thickness. Regionally the Glenns

Ferry Formation is thought to be about 4.2 to 3.2 Ma in the east at Hager-

man (Hart and Brueseke, 1999; Link and others, 2002) and as young as 1.5

to 1.67 Ma in the west near Marsing (Repenning and others, 1995). No age

control in or near this quadrangle but an age of about 4 Ma is suspected for

Ooid-bearing sand of the Glenns Ferry Formation (Pliocene)—Pale yellow-

ish, unconsolidated to weakly consolidated ooids (calcite-coated sand

grains). The ooid-bearing interval is approximately 20 m (65 ft) thick. Grains

range from 1 to 2.5 mm in diameter. Where cemented the ooid-bearing

rock forms light-gray outcrops. Layers of ooids occur discontinuously as

lenses in sandy sediments around the margins of the western Snake River

Plain (Wood and Clemens, 2002; Swirydczuk and others, 1979). They are

interpreted as lenses forming a "bathtub ring" of beach deposits as Lake

Idaho became an alkaline closed-lake basin near its highest stand (Wood,

Paleosol (Late Miocene to Pliocene)—Brown sand, siltstone, and mudstone

with root casts; interval is 10 to 35 m (33 to 115 ft) thick. The base of the

paleosol, just south of the map boundary in the center of sec. 11, T. 6 N., R.

1 W., is ~4 m (13 ft) thick sandy gravel of rounded cobbles and angular granules overlain by 3.6 m (12 ft) of poorly exposed coarse sand. Grains of

both layers are coated and interstices are filled with clay. Above the sand is

10 m (33 ft) of massive and crudely bedded compact brown mudstone with

scattered round pebbles and angular granules. The mudstone interval is

laced with root casts typically spaced 0.2 to 0.5 m apart. Casts are as large

as 4 cm, irregular, and many are subhorizontal. Root casts are filled with a

white (non-calcareous) mineral preserving some of the linear root pattern. The ledge-forming upper part contains rare pockets, 1 m (3 ft) thick, of

mud-supported cobble gravel. The overlying 5 m (16 ft) interval is similar,

root-cast laced, hard mudstone, crudely bedded with variable amounts of angular fragments of darker, yellowish-brown mudstone with the upper 1.5

m (5 ft) also forming a ledge. The uppermost 3 m (10 ft) layer is poorly exposed but in places has a 1.5 m (5 ft) ledge at the top of hard light brown-

ish gray mudstone laced with subhorizontal layers 2-3 cm thick of a hard white mineral as well as root casts. This paleosol formed on gravel deposits

and indicates ancient Lake Idaho was drained from this site for a relatively long period of time. This hiatus may coincide with the Chalk Hills

Formation/Glenns Ferry Formation hiatus observed on the south side of the

moderately consolidated tuffaceous siltstone, tuffaceous claystone, very

coarse to fine sandstone, and conglomerate interspersed with ash intervals.

Generally dipping 7 to 15° with local variations present. Abundance of

tuffaceous material results in overall lighter color than overlying Glenns

Ferry or underlying Payette formations. In Haw Creek area unit is

characterized by sand, siltstone, silty claystone, claystone, and silicic

volcanic ash (Fig. 1). At 104 m (340 ft) in the Haw Creek Section is a silicic

volcanic ash and lapilli tuff marker bed 10 to 20 m (33 to 66 ft) thick. The

bed dips to the southwest 15 to 23°. The lowest 5.5 m (18 ft) is mostly

bedded light-gray coarse ash with scattered lapilli as much as 3 mm in

diameter, within which is a local 0.7 m (2 ft) thick layer composed of ash

and large white pumice blocks as much as 15 cm in diameter. Zircons from

these pumice blocks give a U-Pb TIMS age of  $9.0057 \pm 0.0082$  Ma (Fig. 2). The overlying 3 m (10 ft) is composed of thin-bedded ash and lapilli layers,

with lapilli as much as 3 cm in diameter, and scattered angular basalt

lithics. Next in succession is a ledge-forming, 2 m (7 ft) thick layer of massive fine ash, with shards <0.1 mm. The overlying 10 m (32 ft) is poorly

exposed except for the uppermost 2 m (7 ft) which is crudely bedded

light-gray ash with visible elongate shards to 0.7 mm in length. About 340

m below the Haw Creek ash is a silty sand layer containing leaf fossils. Plant

species identified by Patrick Field (written commun., 2017) are: Quercus

prelobata, Platanus dissecta, Amelanchier subserrata, Populus alexanderi,

Salix hesperia, Salix sp. cf. picroides, and Salix n. sp. (cf. wildcatensis).

Sparse and poorly preserved pollen were identified by Renee Breedlovestrout (written commun., 2017) as Taxodium, and either

Pseudotsuga or Larix. The base of the Chalk Hills Formation is poorly known

at Haw Creek, and may even include the lowermost part of the Haw Creek

section, but the unit likely overlies the Payette Formation near the ridge

crest east of Haw Creek. Contact is drawn at lowermost light-colored

tuffaceous beds. Thickness as measured in Haw Creek is 190 m (630 ft);

overall thickness is complicated by faulting, but may be as much as 300 m

East of Emmett the unit is overall coarser than in the Haw Creek area. Sand

is arkosic, medium to coarse grained, and contains subangular to

subrounded grains of quartz, potassium feldspar, plagioclase feldspar, and

in places trace amounts of biotite and muscovite. Gravel beds are lenticular channel-fill deposits, 0.5 to 4 m (2 to 13 ft) thick of cobble and pebbles of

granitic material, felsic dikes, and felsic volcanic rocks. Several ash beds

are present here as well, and a U-Pb TIMS zircon age of 9.041  $\pm$  0.014 Ma was determined from an ash and lapilli marker bed in the SE1/4 NW1/4 sec.

3, T. 6 N., R. 1 W. (sample 15RL014; Table 2). The lower 1.8 m (6 ft) of the

marker bed is made up of bedded white ash with grayish white pumice

lapilli as much as 2 cm in diameter, and lithic and rare black glass

fragments. The bedded ash is overlain by 1.5 m (5 ft) of massive light bluish

gray fine ash. The uppermost 1.5 m (5 ft) of ash has wavy bedding and

pumice lapilli to 5 mm diameter. Zircons from an ash layer near base of

formation along Anderson Creek in NW1/4 SW1/4, sec. 2, T. 6 N., R. 1. E. in

neighboring Montour quadrangle, gave a range of U-Pb ages by CA-ID

TIMS methods, indicating reworking (Lewis and others, 2016; Mark

Schmitz, written communication, 2016); results indicate a depositional age

A ledge-forming basaltic tuff dipping 13° to the west and 10 m (32 ft) thick

composes another marker bed in the southeast part of the map. The follow-

ing description locale is just above the Black Canyon Canal in SW1/4 NE1/4

sec. 3, T. 6 N., R. 1 W. An unexposed base leads upward to 1 m (3 ft) of

hard, compact, massive, very fine-grained light olive brown tuff that

contains 2 percent <1 mm voids lined with a white mineral. Up section is

2 m (7 ft) of hard, ledge-forming ash and lapilli tuff that contains ~30

percent lapilli as much as 2 cm in diameter; most common are gray scoria

bedded (20-30 cm thick beds). Coarse grains are matrix supported in a fine

ash matrix. Overlying 3.6 m (12 ft) is a ledge-forming lapilli tuff that is thin

bedded (2 to 10 cm beds) with dark scoria lapilli grains (commonly 1 mm

and as long as 1.5 cm), apparently coated to a bluish gray and ~1 percent

clasts of tan siltstone, same size as the lapilli. Tuff is grain supported, and

guite porous; somewhat friable. Overlain by a 1 m (3 ft) ledge-forming

lapilli tuff as below, but with rare 1-2 mm quartz sand grains; lapilli are

grain supported. Some beds are stained yellowish-red with iron oxide.

Deposit is capped by 1 m (3 ft) ledge-forming, massive, compact light-gray

fine ash. More extensive outcrops are found due east of the described

locale where they are cut by a northwest-trending fault and faulted down to

Regionally the Chalk Hills Formation is thought to be about 10 to 8 Ma at

the base and 5 to 6 Ma at the top (Kimmel, 1982; Perkins and others, 1998;

Wood and Clemens, 2002). Here, neither the maximum nor minimum ages

are well constrained. The unit mapped here as the Chalk Hills Formation may include rocks termed Poison Creek Formation south of the western

Snake River plain (Buwalda, 1923; Malde and Powers, 1962) based on the

two relatively old (~9.0 Ma) U-Pb ages presented here. Savage (1961) used

the term Poison Creek Formation in the Emmett area and to the northwest

for some of the rocks we term Chalk Hills Formation. On the basis of

paleontologic work south of the Snake River Plain, Nathan Carpenter

believes 9 Ma sediment is old enough to be correlative with the Poison

Creek Formation (written communication, 2017). Additional mapping and

the west, and to the northeast where ledges dip irregularly from 15 to 34°.

lapilli, less common are black scoria lapilli and tan pumice lapilli. Medium

of 9.9 Ma or younger based on ages of the two youngest zircons.

western Snake River Plain (Malde and Powers, 1962).

Tsch Chalk Hills Formation (Late Miocene-Pliocene)—Unconsolidated to moderately consolidated to moderate to

the basal part of the formation present on this map.

appear to have been reworked.

medium-gray ash with local pumice lapilli and fine laminae. Massive beds

Grande Ronde Basalt N, magnetostratigraphic unit andesite (Middle Miocene)—Two to three aphyric to locally plagioclase-phyric andesite flows. Grande Ronde Basalt Formation has been informally subdivided into magnetostratigraphic units (MSU)  $R_1$ ,  $N_1$   $R_2$ , and  $N_2$ , respectively from oldest to youngest (Swanson and others, 1979). Geochemically classified as andesite by the IUGS classification system (Table 1). Trace-element and major-element oxide analyses indicate the andesite is related to regional Columbia River Basalt Group volcanics and closely related to Grande Ronde Formation. More andesite appears to the north in the Squaw Butte 7.5' quadrangle. Approximate thickness of 7 m (23 ft).

Grande Ronde Basalt N, magnetostratigraphic unit (Middle Miocene)—Dark-gray and mottled olive-green to mottled light-orange, fine-grained, aphyric to plagioclase-phyric basaltic andesite. Fractures conchoidally and is more resistant to weathering than the basalt and basaltic andesite of Tcrl. Grande Ronde Basalt Formation has been informally subdivided into magnetostratigraphic units (MSU) R<sub>1</sub>, N<sub>1</sub> R<sub>2</sub>, and N<sub>2</sub>, respectively from oldest to youngest (Swanson and others, 1979). Six to seven flows of normal magnetic polarity (field fluxgate magnetometer from flows in neighboring quadrangles). Grande Ronde in NE Emmett quadrangle appears to be distal reaches of Grande Ronde Basalt; the flows are laterally discontinuous and 3 to 6 m (9 to 18 ft) thick. Overall thickness is not easy to determine due to faulting, however the unit is as much as 100 m (320 ft) thick to the north in the

Squaw Butte 7.5' quadrangle. Approximate thickness here of 80 m (262 ft).

**Lower Columbia River Basalt Group (Middle Miocene)**—Light-purple or light- to

Grande Ronde dike (Middle Miocene)—Dark-gray with mottled light-orange or yellow-green, fine-grained aphyric basaltic andesite dikes. Dikes are less than a meter wide (3 ft), 45 m (148 ft) and 30 m (98 ft) long, and located at lat 43.9604° N., long 116.4295° W. and lat 43.9992° N., long 116.4657° W

dark-gray, interlayered aphyric and plagioclase-megaphyric basalt. Weathers to a coarse soil; talus is rare. Aphyric flows contain microphenocrysts of plagioclase, olivine, iddingsite after olivine, clinopyroxene, and oxides, along with 40 to 60 percent groundmass. Megaphyric plagioclase crystals range from 1 to 5 cm in length and where present comprise about 40 percent of the rock. Plagioclase crystals typically appear to radiate from a central point like a snowflake. Groundmass in both phyric and aphyric varieties contains plagioclase, olivine, clinopyroxene, and opaque oxides; ophitic intergrowth of plagioclase and pyroxene is common, and ranges from 20 to 70 percent. Fitzgerald (1981; 1982) mapped *Tcrl* as Imnaha Basalt and noted a paleomagnetic transition from reverse to normal on Squaw Butte, along the ridge 200 m (650 ft) north of the quadrangle; Martin (1984) confirmed the paleomagnetic results. Hooper and others (2002) suggested the paleomagnetic transition marks the change from R<sub>0</sub> to N<sub>0</sub>, and the boundary between older Steens and younger Imnaha. Jarboe and others (2010) reported an  ${}^{40}$ Ar/ ${}^{39}$ Ar age of 16.85  $\pm$  0.21 Ma on a megaphyric plagioclase sample at the top of Squaw Butte (lat 44.00571° N., long 116.40825° W.); that age coincides within error with the oldest Imnaha (ca. 16.7 Ma; Barry and others, 2013) but also fits within Steens Basalt ages (16.6 -16.8 Ma; Barry and others, 2013). Camp and others (2013) used XRF chemistry to correlate a section along the Payette River (sec. 24, T. 7 N., R. 1 W.) with lower and upper Steens Basalt. In this map and neighboring Montour quadrangle (Lewis and others, 2016) we collected and analyzed over 40 samples of lower Columbia River basalt by XRF and compared them with 32 analyses collected by Fitzgerald (1981) and 36 samples collected along Black Canyon Reservoir by Victor Camp (written commun., 2013). Samples with megaphyric plagioclase have high Al<sub>2</sub>O<sub>3</sub> content (18.04 to 18.74 percent) and low MgO content (3.2 to 4.3 percent) relative to the aphyric flows. Basalt stratigraphy is complex due to complex interlayering of flows, regional faulting, and widely varied major-element oxide and trace-element geochemistry. Samples of *Tcrl* range from 48.02 to 53.23 percent SiO<sub>2</sub>, fitting within the IUGS classification of basalt to basaltic andesite; samples 14DG504, 14DG505, 14DG507, and 14DG510, are basaltic andesite and bounded by basalt flows. According to Camp and others (2013) basaltic andesite represents the upper part of Steens Basalt, but here it appears to be interbedded. From stratigraphy, geochemistry, paleomagnetism, dating, and petrography we interpret that most if not all the *Tcrl* mapped is Steens Basalt. Exposure at Squaw Butte shows a minimum of 30 flows and an approximate

#### flows with an approximate thickness of 50 m (164 ft). INTRUSIVE ROCKS

thickness of 500 m (1640 ft). South of the Payette River Trcl thins to 3 to 5

Hornblende-biotite granodiorite (Cretaceous)—Light-gray, medium-grained equigranular hornblende-biotite granodiorite. Appears at surface only in a small area in southeast part of map. In cross-section projected from unit mapped to the east on the Montour quadrangle (Lewis and others, 2016). Zircon U-Pb age determination of  $84.4 \pm 1.7$  Ma was obtained from a biotite granodiorite sample ~6 km (4 mi) to the east along State Highway 52 (sample 10RMG022; Richard Gaschnig, written communication, 2015).

Garnet-biotite tonalite (Cretaceous)—Light-gray, foliated, medium-grained, garnet-biotite tonalite. Exposed only on the southeast flank of Squaw Butte. Garnet is relatively abundant and as much as 1 cm across. Age uncertain, but tonalitic composition and presence of foliation indicates that this is either a western border phase of the Late Cretaceous Idaho batholith, or, more likely, an older Middle Cretaceous intrusion along or west of the initial <sup>87</sup>Sr/<sup>86</sup>Sr 0.704/0.706 line (Armstrong and others, 1977) that marks the western cratonic margin in this area.

#### STRUCTURE

With exception to the Black Canyon Canal fault, most faults are not well exposed in the quadrangle. The inferred presence of these faults is based on stratigraphic offsets, discordant dips, spring or drainage alignment, and other geomorphic features.

The Squaw Creek fault (Kirkham, 1931; Anderson, 1934; Capps, 1941; Fitzgerald, 1981, 1982; Gilbert and others, 1983) is a down-to-the-east normal fault, 50 to 55 km (31 to 34 mi) long, with a maximum displacement of 610 to 760 m (2,000 to 2,500 ft). It extends to the north of the quadrangle along the west side of Ola Valley where it shows several hundred meters of offset. The fault displacement decreases to the south. The inferred projection and termination 0.5 km (0.3 mi) north of Black Canyon dam is based on minor offsets in stratigraphy, drainage alignment, and geomorphology. The fault along Long Hollow Creek on the eastern part of the map is likely an en echelon fault of the larger Squaw Creek fault. From a trench dug into surficial deposits along the Squaw Creek fault 19 km (12 mi) northeast of the quadrangle Gilbert and others (1983) determined there was up to 2.4 m (8 ft) of Quaternary displacement, of which about 0.6 to 0.8 m (2 to 2.5 ft) likely postdates middle Holocene Mazama ash.

The Black Canyon Canal fault is a down-to-the-west normal fault that is exposed on both sides of the road in NW1/4 sec. 35, T. 7 N., R. 1 W. North of the road the fault is exposed as an 8 m (26 ft) fault plane dipping 72° to the southwest with vertical slickenlines. At Frozen Dog road the fault plane has shallowed to 57°.

The Haw Creek fault in the northwestern part of the map is an unexposed fault indicated by the truncation of Grande Ronde and Payette formations. Movement along the Haw Creek fault explains the 9.0 Ma ash at Haw Creek (Figure 1) and Chalk Hills Formation in close proximity to 15 to 16

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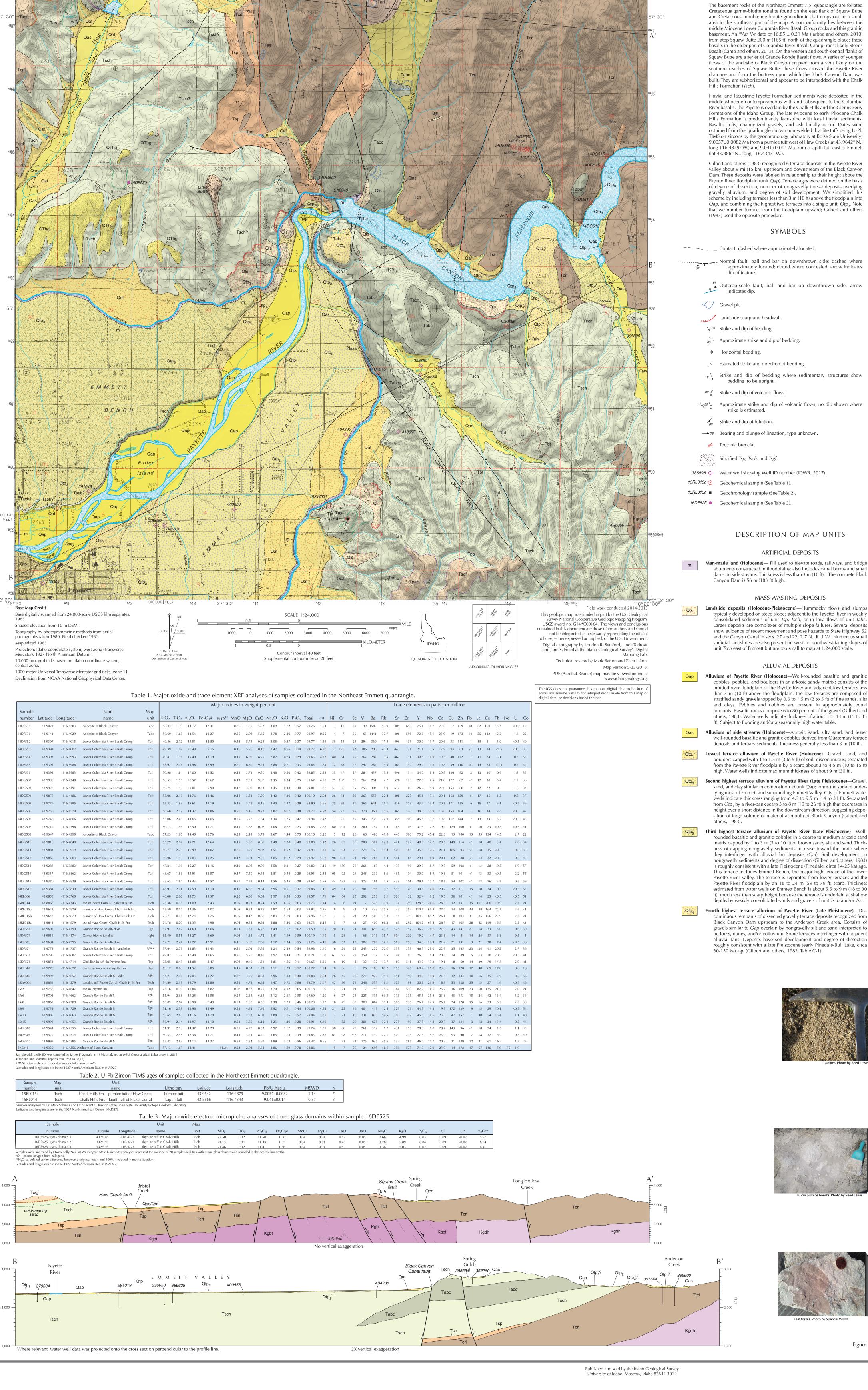
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geochronologic work is required to understand the age relationship between outcrops to the south at Poison Creek and in the type Chalk Hills to the southeast (Malde and Powers, 1962), and how those relate to exposures mapped here as Chalk Hills Formation. Payette Formation (Middle Miocene)—Unconsolidated to well-cemented (highly silicified) tan, dusky red to very pale orange, grayish yellow green, pale greenish yellow, and off-white coarse to fine sandstone with subordinate siltstone and claystone. Generally dipping 12 to 36° with local variations present. These beds generally dip more steeply than the overlying Chalk Hills Formation, but we do not find a sharp unconformity in the map area. Finer intervals are thick- to thin-bedded, olive-green, dusky-red, tan, and white tuffaceous mudstone and volcanic ash deposits. Fine intervals are typically darker and more clay rich than fine intervals in overlying *Tsch*. Sands contain abundant coarse quartz and feldspar, likely derived from oolite, sand, and coated grains (To) silty-sandstone, interbedded fine to medium sand claystone, mostly covered, <1 ft thick calcareous claystone (marl) interbed volcanic ash, white, fine sand, poorly exposed fine sand, poorly exposed silicic volcanic ash (Tas), massive, laminated with interbedded lapill It. greenish gray to It. gray, interbeds with 4% pumice lapilli, U-Pb TIMS zircon date of 9.0057±0.0082 Ma ~3000′ 200′coarse sand, It. gray siltstone, pale yellow coarse to granule sand, pale yellow, well sorted, siltstone, lt. gray, sparse fossil leaves, bedded in lower section Leaf fossils, Photo by Spencer Wood Figure 1. Haw Creek section in NW 1/2 Sec. 8, T. 7 N., R. 1 W.