WASHINGTON STATE DEPARTMENT OF NATURAL RESOURCES
WASHINGTON GEOLOGICAL SURVEY

Geologic Map of Candy Mountain Preserve and Surrounding Area
Benton County, Washington

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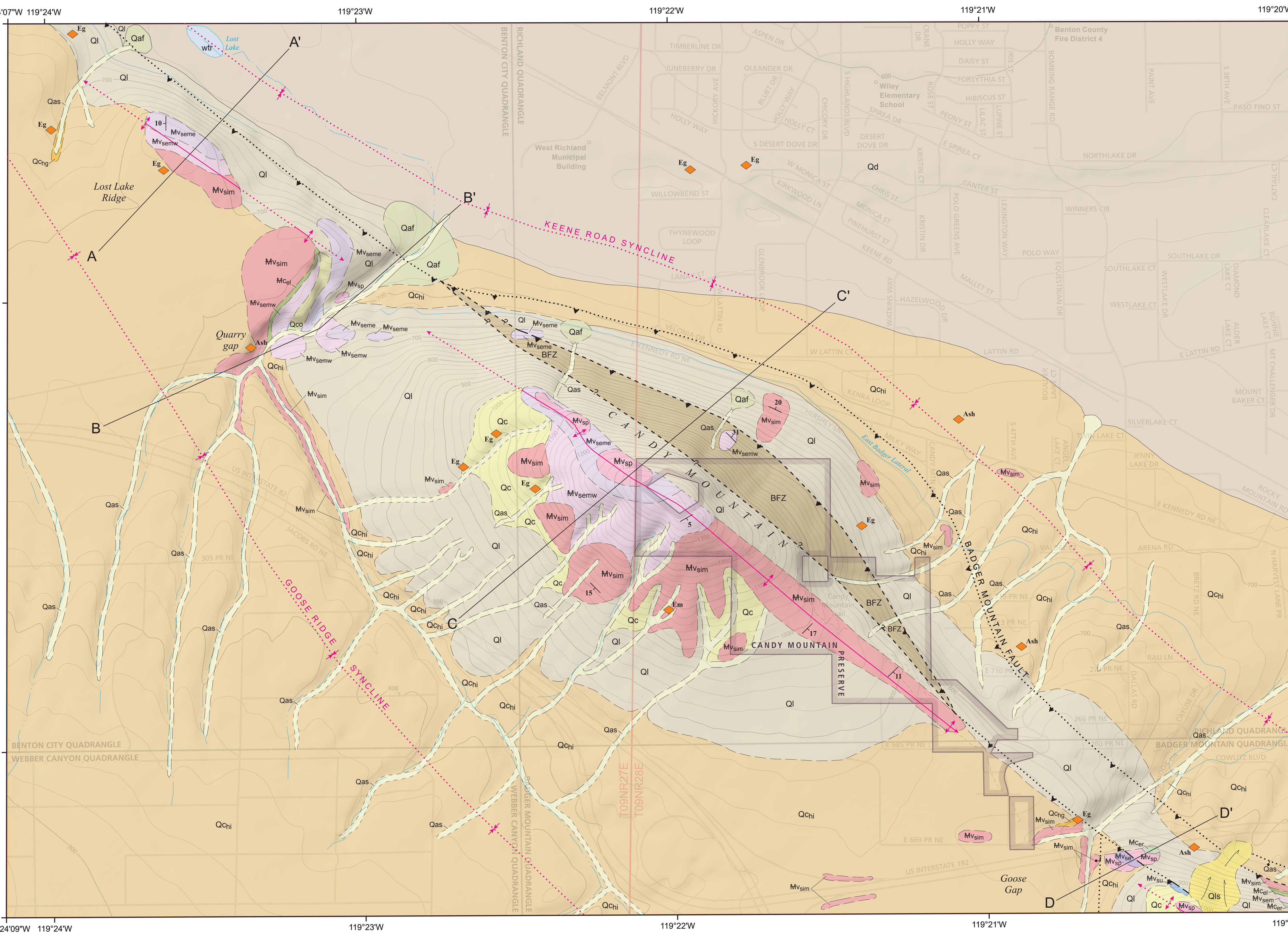
MAP SHEET 2 of 2
Geologic Maps of Badger Mountain and Candy Mountain



GEOLOGIC SYMBOLS

Contact—Solid where location accurate; long-dashed where approximate; short-dashed where inferred; hashed where gradational

Fault, unknown offset (upper limit of brecciated fault zone)—Long-dashed where approximate; short-dashed where inferred; dotted where concealed; queried where identity or existence questionable

Normal fault—long-dashed where approximate; dotted where concealed; bar and ball on downthrown block

Thrust fault—Solid where location accurate; long-dashed where approximate; short-dashed where inferred; dotted where concealed; queried where identity or existence questionable; sawteeth on upper plate

Anticline—Solid where location accurate; dotted where concealed; arrows on line indicate plunge direction

Syncline—Location concealed

A —— A′ Cross section line

Perennial stream

Intermittent stream

Candy Mountain Preserve boundary

Direction of downslope movement of landslide

Inclined bedding—showing strike and dip

Ash Horizons

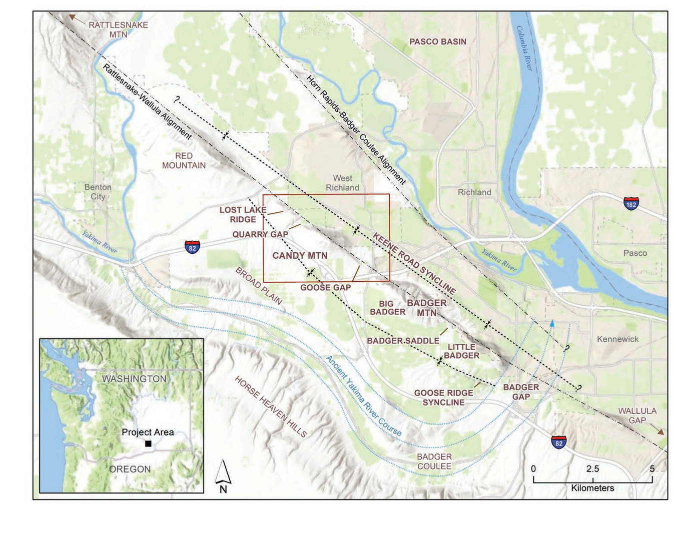
Ash Mount St. Helens Set S ash

Erratics (selected)

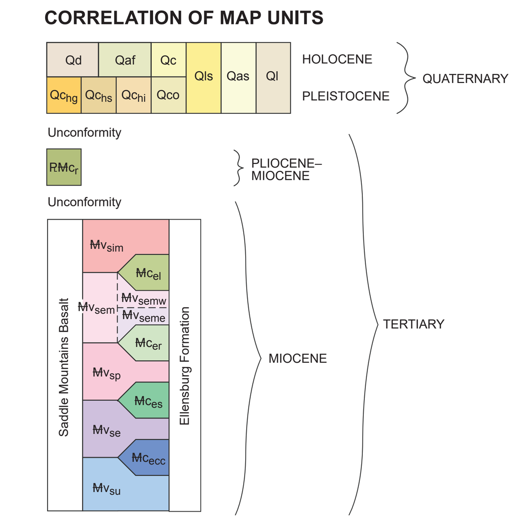
Eg Granitic erratic

Em Metamorphic erratic

LOCATION MAP



CORRELATION OF MAP UNITS



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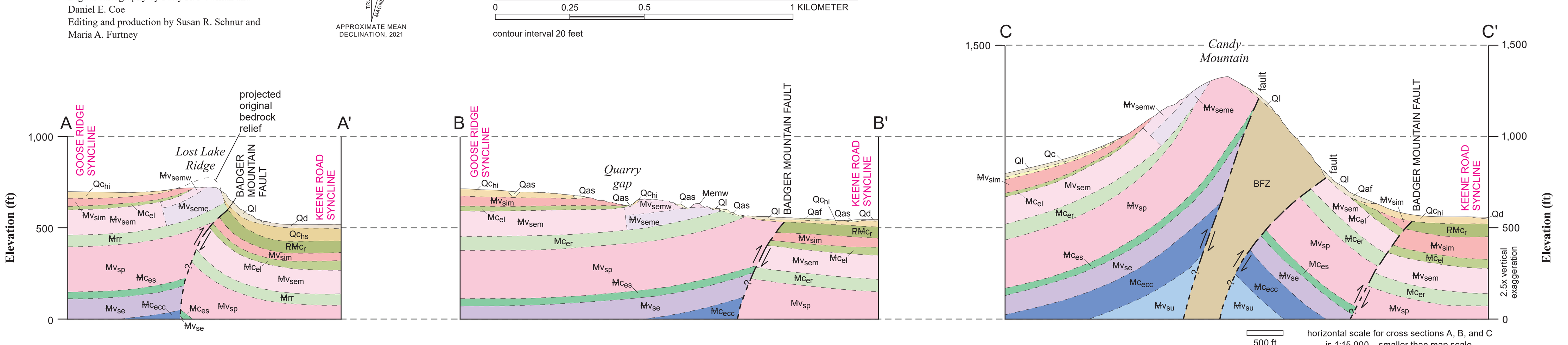
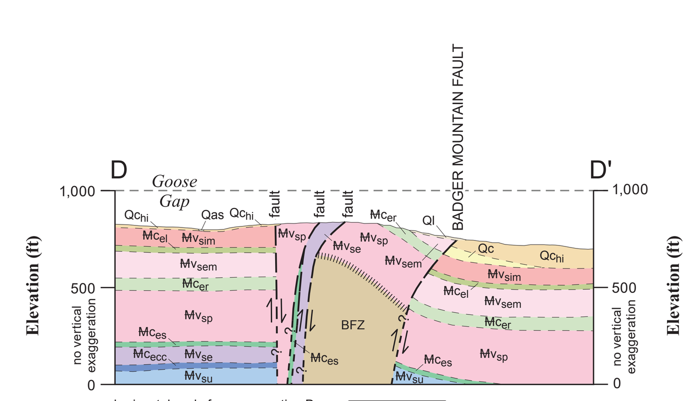
Lambert conformal conic projection, NAD 83 HARN
The map is located in portions of the U.S. Geological Survey Benton City, Richland, Badger Mountain, and Webber Canyon 7.5-minute quadrangles—see map for boundaries.
GIS by Patty R. Newman and J. Eric Schuster
Digital cartography by Patty R. Newman and Daniel E. Coe
Editing and production by Susan R. Schnur and Maria A. Furtney

APPROXIMATE MEAN DECLINATION, 2021

SCALE 1:12,000

contour interval 20 feet





INTRODUCTION

The geologic map of the Candy Mountain Preserve and vicinity was developed to provide Benton County Parks Department and park visitors updated insights into the rock units, sedimentary deposits, and structural features of the Preserve area. Understanding the geology is important for protecting the natural habitat of Candy Mountain, as rocks and sediments have a direct influence on the biodiversity of the native ecosystem. The characteristics and extent of rocks and sediments are key components that control the distribution of habitat and species in the Preserve area.

The Preserve area is rich in geologic history. This history includes a dramatic landscape formed of (1) volcanic flows with interbedded sediments that have been uplifted and faulted to form anticlinal ridges and synclinal valleys; (2) multiple ice-age floods that scoured the Preserve area and deposited sediments during waning flow, and; (3) a thin blanket of wind-blown sediments covering much of the Preserve area, attesting to the area's arid climate. The landscape of the Preserve area is dynamic, with geologic processes continually reshaping earth landforms and surfaces.

Many aspects of stratigraphy and structural geology of the Candy Mountain Preserve and vicinity can be observed along the 2.6 km (1.6 mile) Candy Mountain Trail and in road cuts along Kennedy Road and Interstate 182.

FIELD INVESTIGATIONS

The field investigation phase of the Candy Mountain mapping project was completed during the 2018 field season. The mapping project also incorporated results from previous geologic investigations. Earlier investigations included reconnaissance resource mapping (Shedd, 1925) and a regional stratigraphic and structural geology study (Laval, 1956). Interest in neotectonics of the Yakima fold and thrust belt to support nuclear facility activities resulted in numerous studies of the area (Jones and Deacon, 1966; Brown, 1968; Farooqui, 1977; Geoscience Research Consultants, 1978; Myers and others, 1979; Woodward-Clyde Consultants, 1981; Washington Public Power Supply System, 1981). In 1994, the geologic map of the Preserve area was revised as part of the compilation of 1:100,000-scale geologic mapping of the Richland quadrangle (Reidel and Fecht, 1994).

GEOLOGIC SUMMARY

GEOGRAPHIC SETTING

The Candy Mountain Preserve and surrounding area is located along the southwest boundary of the Pasco basin in the southern part of the Yakima fold and thrust belt. The landscape of the mapped area is dominated by two aligned ridges, Candy Mountain and Lost Lake ridge. The ridges are part of an alignment of ridges extending from Rattlesnake Mountain to Wallula Gap. Candy Mountain and Lost Lake ridge are separated along trend by topographic lows at Quarry gap and Goose Gap. The ridges are bound by the thinly sediment-mantled Goose ridge syncline to the southwest and the sediment-filled valley of the Keene Road syncline to the northeast. The Candy Mountain Preserve encompasses much of Candy Mountain and a portion of Goose Gap.

STRATIGRAPHY

Bedrock in the mapped area consists of basalt flows of the Miocene Saddle Mountains and Wanapum Basalts of the Columbia River Basalt Group and intercalated sediments of the Ellensburg Formation. The bedrock crops out on the anticlinal ridges and in the intervening gaps. Field identification of Columbia River basalt units was supplemented with major-and minor-element X-ray fluorescence (XRF) spectroscopy. Overlying the bedrock in the Keene Road syncline are valley-filling fluvial and lacustrine deposits of the Pliocene-Miocene Ringold Formation. The Ringold sediments consist mainly of the stratigraphically lower Wooded Island member. Missoula cataclysmic flood deposits of the Pleistocene Hanford formation overlie Ringold sediments in the Keene Road syncline and blanket the lower slopes of the ridges as well as the Goose Ridge syncline. Gullies eroded into the ridge slopes and within the gaps are partially filled with Holocene alluvial debris. At the mouth of gullies, alluvial debris locally has accumulated as alluvial fans that spread out as conical landforms onto the valley floor of the Keene Road syncline. The ridges and intervening gaps are mantled with a veneer of Holocene and Pleistocene loess and colluvial debris. Across the valley floor of the Keene Road syncline, Holocene eolian sands developed extensive dune colonies. However, agrarian activity has destroyed the colonies except around Lost Lake.

STRUCTURAL GEOLOGY

Candy Mountain and Lost Lake ridge form narrow, doubly plunging, open, non-cylindrical anticlinal folds. The anticlines have a north-vergent asymmetrical shape, are aligned toe-to-toe, and are elongated along a northwest–southeast trend. The ridges are part of the Rattlesnake–Wallula stuctural alignment segment of the Olympic–Wallowa lineament (Reidel and others, 2020).

Quarry and Goose gaps form synclinal and topographic depressions in the convergence zone between the doubly plunging anticlines. The land surface through the gaps forms a gentle-to-moderate slope from the Goose ridge syncline into the valley of the Keene Road syncline.

The Keene Road and Goose ridge synclines form shallow topographic and structural lows that bound the ridges and gaps. The Keene Road syncline formed as the Candy Mountain/Lost Lake ridge anticlinal structures were thrust up and onto the east-dipping limb of the syncline. Below the lower thrust fault the syncline shows little evidence of deformation on the lengthy, gentle, eastward-dipping limb and within the trough. The Goose Ridge syncline forms a narrow, shallow low between Candy Mountain–Lost Lake ridge anticlines and Goose Hill to the southwest. The Goose ridge syncline loses definition to the northwest near the northern boundary of the mapped area.

Faults have been mapped along the forelimb of Candy Mountain and Lost Lake ridge with faults striking northwest–southeast, parallel to the trend of the anticlines. The lower fault is buried at the base of the forelimbs of Candy Mountain and Lost Lake ridge and below Quarry and Goose gaps (see Cross Sections A–A′, B–B′, C–C′, and D–D′). The fault forms a thrust that displaces bedrock and likely older colluvial and Ringold sediments. The discontinuity separates the anticlinal structures and gaps from the Keene Road syncline. The lower fault is the northwest extension of the Badger Mountain fault of Geoscience Research Consultants (1978). Above the lower fault is an upper thrust sheet/zone that displaces Saddle Mountains Basalt flows and Ellensburg sediments. The upper fault crosses the mid-slope of the forelimb of Candy Mountain and extends southeast, spanning across Goose Gap. The fault is exposed in road cuts in Goose and Quarry gaps, but is mostly obscured beneath a veneer of unit Ql and hillslope terracettes over the face of Candy Mountain. The lower boundary of the fault is moderately well delineated by a distinct break in slope low along the forelimb. The upper boundary is poorly defined by several subtle benches high on the forelimb. The lower and upper forelimb thrust faults likely converge.

Candy Mountain and Lost Lake ridge anticlinal growth is mainly due to horizontal compressional stresses that caused crustal shortening and resulted in bedrock being thrust up and onto adjacent bedrock. The Candy Mountain structure experienced greater shortening and more internal rotation than Lost Lake ridge, Quarry gap, and Goose Gap, as attested by the presence of an upper thrust zone and greater structural and topographic relief.

The initial emergence of the anticlinal structures began prior to emplacement of the Saddle Mountains Basalt (~13 Ma) based on thinning of basalt flows and interbedded sediments onto and over the structures. The anticlines continued their growth after cessation of volcanism with much of the present structural relief occurring after emplacement of the basalt (8.5 Ma).

Faults in the Preserve area have influenced the geometry of the anticlines. The lower thrust fault aligns along the northwest–southeast trending Rattlesnake–Wallula structural alignment segment and primarily influenced the anticlinal elongated shape, north vergence, and northwest–southeast trend. The upper thrust fault on Candy Mountain is responsible for much of the topographic and structural relief of the ridge.

Candy Mountain and Lost Lake ridge are continuing to emerge, but little evidence was found for ridge growth or fault displacement or movement since the Pleistocene. This fault movement is associated with emplacement of Pleistocene-age clastic dikes found in the upper fault zone at Goose Gap and in the hanging wall of the lower fault near the base of Candy Mountain.

DESCRIPTION OF MAP UNITS

Surficial Quaternary Units (Holocene to Pleistocene)

Qas **Sidestream Alluvium/Gully Facies (Holocene to Pleistocene)**—Sidestream channel-fill debris and associated entrenched gullies; alluvium is unconsolidated, poorly sorted rock debris that is infilled with eolian sandy silt in mid-to-lower reaches; includes remnants of older alluvium commonly capped by a petrogenic carbonate horizon.

Qaf **Alluvial Fan Deposits (Holocene)**—Mainly unconsolidated, poorly sorted sandy basaltic gravel; locally, fan interfluves include gravelly sand to silty sand; conically shaped landforms; the fan at Quarry gap becomes sand-dominated near mid fan.

Qc **Colluvium (Holocene)**—Largely unconsolidated, poorly sorted rock debris deposited through hillslope processes; interstices locally infilled by eolian sandy silt; includes remnants of older colluvium.

Qco **Older Colluvium (Pleistocene)**—Compact rock debris deposited by hillslope processes; interstices locally infilled with eolian sandy silt; typically capped by pedogenic carbonate horizon.

Qd **Dune Sands (Holocene)**—Mainly loose, moderately well sorted, coarse to fine sand; deposited as dune landforms by eolian processes; mainly stabilized dunes with some active blow outs; many dune colonies destroyed by agrarian activities. Mainly overlies unit Qc_{hs}.

Ql **Loess (Holocene to Pleistocene)**—Mainly massive, unconsolidated, homogeneous, moderately well sorted fine sand to sandy silt; light gray (10YR 7/2) to very pale brown (10YR 7/3); deposited by eolian processes; contains discontinuous horizon of Mount Mazama tephra (~7.7 ka) (Bacon and Wright, 2017); includes remnants of older loess that is compact, very pale brown (10 YR 7/3) capped by pedogenic carbonate horizon.

Qls **Landslide Deposits (Middle to early Late Pleistocene)**—Rotational and translational debris slumps and associated debris flows consisting of loose, moderately sorted, generally unstratified clay, silt, sand, and basaltic gravel. Arrows indicate direction of movement. Mass wasting also occurs in the form of soil creep (Holocene) on steep, loess-covered slopes; typically forms terracettes with occasional shallow tension cracks and (or) small slumps; creep features too limited in size to include as mapping unit.

Missoula Cataclysmic Flood Deposits (Pleistocene to Miocene)

HANFORD FORMATION (PLEISTOCENE)

Deposits mainly from Missoula floods, but may include deposits from other Pleistocene glacial outburst floods.

Qc_{hg} **Gravel-Dominated Facies**—Three main units that include a small, isolated, multi-lithologic sandy gravel bar exposed on the lower, southeast flank of Candy Mountain, a small isolated exposure of multi-lithologic conglomerate with a petrocalcic cap buried beneath the north and east flanks of Lost Lake ridge, and unconsolidated basalt-boulder deposits buried beneath the north flank of Lost Lake ridge. Gravel units are older than the youngest Pleistocene cataclysmic flood deposits of the Preserve area.

Qc_{hs} **Sand-Dominated Facies (cross section only)**—Predominantly horizontal to plane-laminated, fine to coarse sand beds, locally ripple cross-laminated, moderately sorted, commonly with lenses and laminae of finer-grained sand and silt; occasional gravel lenses; clastic dikes common throughout facies; discontinuous Mount St. Helens Set S tephra (~15.5 ka) (Berger and Busacca, 1995) near top of facies; grades laterally to interbedded sand- and silt-dominated facies.

Qc_{hi} **Interbedded Sand- and Silt-Dominated Facies**—Rhythmic and graded beds of unconsolidated silt and fine to coarse sand; mainly plane-laminated and ripple cross-laminated; very pale brown (10YR 7/3) to pale brown (10YR 6/3); clastic dikes ubiquitous throughout facies and discontinuous Mount St. Helens Set S tephra (~15.5 ka) (Berger and Busacca, 1995) common near top of facies; grades laterally to sand-dominated facies.

RINGOLD FORMATION (PLIOCENE-MIOCENE)

RMc_r **Ringold Formation (undifferentiated) (cross section only)**—Formed of mainly clay and sandy clay beds with lenses of sand, sandy gravel, and gravel clay in varying colors (gray, yellow, blue green); mainly deposited in low-energy overbank and lacustrine environments with occasional higher energy main-channel sediments; encountered during drilling in valley of Keene Road syncline. Equivalent to lower units of Lindsey (1995, 1996).

Columbia River Basalt Group (Miocene)

SADDLE MOUNTAINS BASALT

Mv_{sim} **Ice Harbor Member, Martindale Basalt Flow**—Single flow, black to gray, weathers reddish brown; fine to medium grained, coarsely phyric with abundant plagioclase crystals and scattered glomerocrysts of clinopyroxene, plagioclase, and olivine; entablature mostly eroded and highly weathered where present (forming grus), basal colonnade with large, dense columns 1 to 1.2 m (3 to 4 ft) in diameter; reversed magnetic polarity (Choiniere and Swanson, 1979); K-Ar age ~8.5 Ma (McKee and others, 1977).

Mv_{sem} **Elephant Mountain Member (undifferentiated)**—Two aphyric flows; fine to coarse-grained; abundant microphenocrysts of plagioclase; normal to transitional magnetic polarity (Rietman, 1966; Choiniere and Swanson, 1979; Reidel and Fecht, 1981); K-Ar age ~10.5 Ma (McKee and others, 1977).

Mv_{semw} **Ward Gap Flow**—Black, weathers reddish brown; upper blocky flow top, thick lower colonnade with large columns 45 to 60 cm (18 to 24 in) in diameter, thin, glassy selvage flow bottom.

Mv_{seme} **Elephant Mountain Flow**—Black, weathers dark gray to brownish gray; upper rubbly flow top breccia, dense columnar entablature, thin basal colonnade with small columns 15 to 30 cm (6 to 12 in) in diameter.

Mv_{sp} **Pomona Member**—One or more flows/flow units; black to gray black, weathers gray to locally black; fine- to medium-grained; phyric with small plagioclase phenocrysts; thin, upper, poorly formed colonnade, thick, hackly entablature, basal colonnade not exposed; reversed magnetic polarity (Choiniere and Swanson, 1979; Reidel and others, 1984); K-Ar age 12 Ma (McKee and others, 1977) and $^{40}Ar/^{39}Ar$ 12 Ma (S. P. Reidel, Wash. State Univ., unpub. data, 1991).

Mv_{se} **Esquatzel Member**—Single flow; blue black, weathers brown; fine- to medium-grained; aphyric with rare, sparse phenocrysts; well-developed hackly entablature, basal colonnade not exposed; normal magnetic polarity (Choiniere and Swanson, 1979; Reidel and Fecht, 1981).

Mv_{su} **Umatilla Member (undifferentiated) (cross section only)**—Single cooling unit; black, weathers yellow orange; glassy to very fine grained; sparsely phyric; thick, hackly entablature and thin, basal colonnade not exposed; normal magnetic polarity (Rietman, 1966).

Ellensburg Formation (Miocene)

Mc_{el} **Levey Interbed**—Overbank deposits with capping red (10YR 5/6), blocky, sandy siltstone unit that overlies a multistory unit of pale yellow (10Y 7/4), normally graded, siltstone-sandstone beds to a light gray (10YR 7/2), massive sandstone unit; thermally baked on top, pedogenically altered, and locally tuffaceous with occasional discrete tephra horizons.

Mc_{er} **Rattlesnake Ridge Interbed**—Overbank sediments that commonly include a thin capping red (10R 6/6) to olive yellow (2.5Y 6/6) baked siltstone, a light gray (10YR 7/2), reworked airfall tuffite, and basal section of epiclastic and volcaniclastic siltstone-sandstone beds that are normally graded yellow (5Y 7/3) to olive yellow (2.5Y 6/6); locally well-developed paleosols (dark gray: 5Y 4/1).

Mc_{es} **Selah Interbed (cross section only)**—Mainly thin, massive overbank mudstone with occasional fine sandstone stringers, pedogenically altered. A capping tuffite commonly found throughout much of the Pasco basin has not been observed in the mapped area.

Mc_{ecc} **Cold Creek Interbed (cross section only)**—Mainly a thin, massive mudstone that outside the map area is known to be pedogenically altered; found along the distal margin of the sandstone-siltstone overbank facies of an ancient fluvial system (Fecht and others, 1987).

BFZ **Brecciated Fault Zone**—Zone of cohesive to noncohesive fault breccia with varying bedrock clast size that commonly includes secondary faults, shears, shatter breccia, rotated clasts, rotated bedrock blocks, Pleistocene clastic injection dikes, and secondary opaline or carbonate mineralization.

OTHER CATACLYSMIC FLOOD FEATURES

Ice-Rafted Debris (see *Erratics (selected)* in the Geologic Symbols)—Clastic material transported within icebergs caught in cataclysmic flooding and then deposited as the icebergs melted (Bretz, 1919). Occur as isolated erratics, erratic clusters, or mounds of diamicton (Fecht and Tallman, 1978; Chamness, 1994; Bjornstad, 2014). Found below 380 m (1,250 ft) elevation, the maximum stand of Lake Lewis (Baker and others, 1991); mainly strewn across top of unit Qc_{hi} on backslope of ridges and Goose Ridge syncline to the southwest and scattered on unit Qd in the Keene Road syncline valley; tops of large debris commonly exposed above surface of unit Qd and Ql. Selected erratics/erratic clusters depicted on geologic map.

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