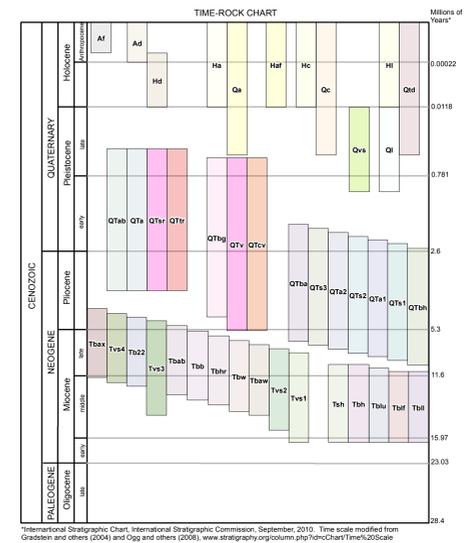
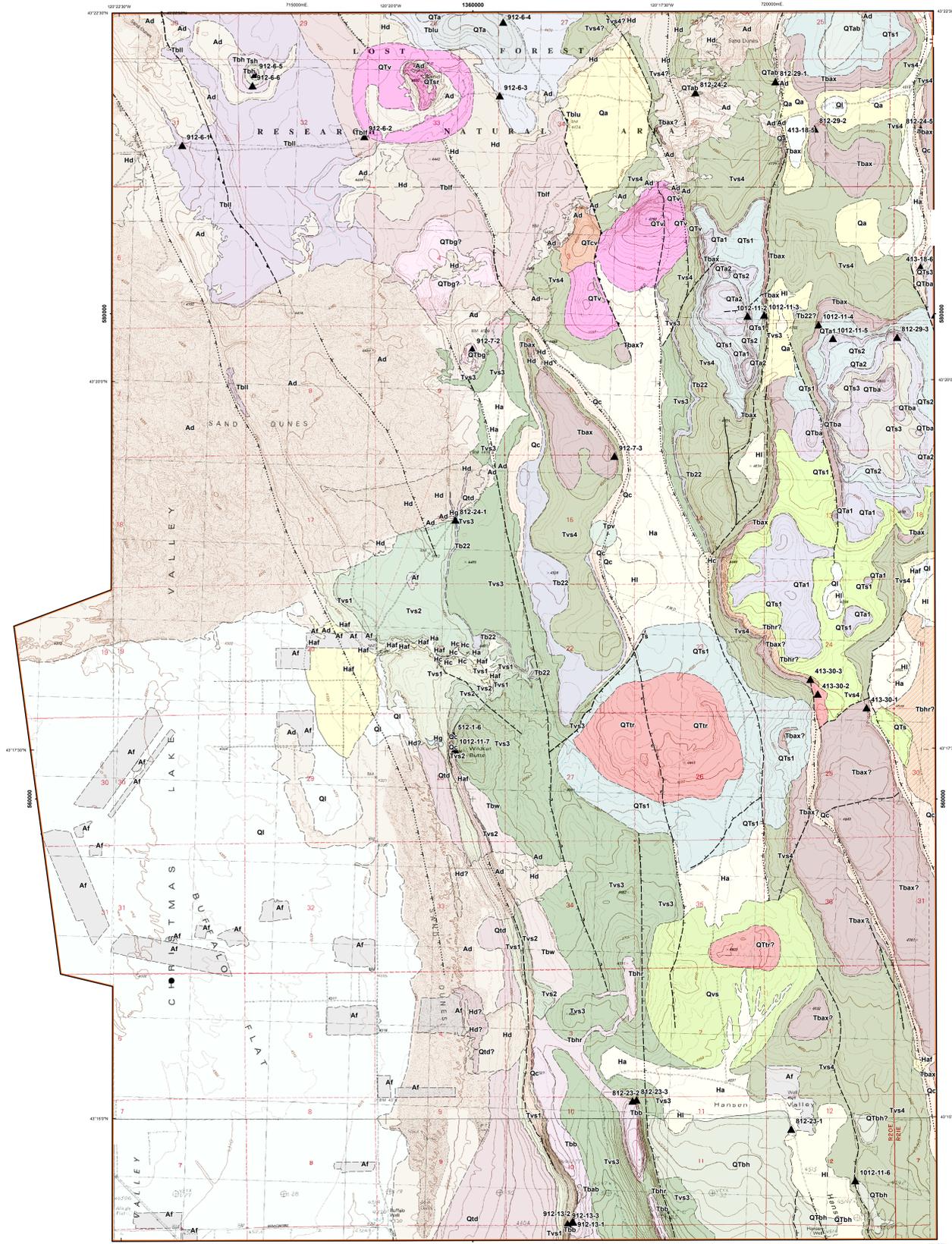


Reconnaissance Geologic Map of the Sand Rock 7.5' Quadrangle and Vicinity, Lake County, Oregon

2013



EXPLANATION OF MAP UNITS

- AF** Manmade fill, construction material, and disturbed ground (Anthropocene)
- Ad** Sand (Anthropocene)
- Ha** Alluvium (Holocene)
- Hc** Colluvium (Holocene)
- Haf** Alluvial fan deposits (Holocene)
- Hl** Lake deposits (Holocene)
- Hd** Sand (Holocene)
- Qa** Alluvium (Quaternary)
- Qtd** Terrace deposits (late Pleistocene and Holocene)
- Qc** Colluvium (Pleistocene)
- Ql** Lake deposits (late Pleistocene)
- Qvs** Volcaniclastic sediment and tuff, undivided (mid- to late Pleistocene)
- Qtr** Tuff rings (Pliocene or Pleistocene) - locally divided to show:
 - Qtr?** Tuff of Sand Rock (Pliocene or Pleistocene)
 - Qtr1** Glomerophyritic orthopyroxene andesite of Section 28, T. 20 S., R. 25 E. (Pliocene or Pleistocene)
 - Qtr2** Pyroxene andesite of BLM Road 6151 (Pliocene or Pleistocene)
 - Qtr3** Basalt of Hansen Valley (late Miocene, Pliocene, or Pleistocene)
 - Qtr4** Vent deposits (late Miocene, Pliocene, and/or Pleistocene)
 - Qtr5** Cinder and related vent deposits (late Miocene, Pliocene, and/or Pleistocene)
- Qtr6** Andesite of BLM Road 6121 (late Miocene, Pliocene, and/or Pleistocene)
- Qtr7** Basaltic andesite
- Qtr8** Sediment and sedimentary rock
- Qtr9** Andesite
- Qtr10** Sediment and sedimentary rock
- Qtr11** Amygdaloidal andesite
- Qtr12** Lake deposits
- Qtr13** Glomerophyritic olivine basalt

- Lava flows, volcaniclastic sediment, and sedimentary rock (Miocene and/or Pliocene)**
 - Tbx** Basaltic andesite of Section 10, T. 28 S., R. 20 E. (middle or late Miocene or Pliocene)
 - Tvs4** Volcaniclastic rocks (middle or late Miocene or Pliocene)
 - Tb22** Olivine basalt of Section 22, T. 28 S., R. 20 E. (middle or late Miocene or Pliocene)
 - Tvs3** Volcaniclastic rocks (middle or late Miocene or Pliocene)
 - Tb21** Basaltic andesite of Buffalo Well (middle or late Miocene)
 - Tb2** Basalt of Buffalo Well (middle or late Miocene)
 - Tb1** Basalt of Hansen Valley Road (middle or late Miocene)
 - Tb2** Olivine basaltic andesite of Wildcat Butte (middle or late Miocene)
 - Tb2** Basaltic andesite of Wildcat Butte (middle or late Miocene)
 - Tvs2** Volcaniclastic rocks (middle or late Miocene)
 - Tvs1** Volcaniclastic rocks and tuff (Miocene)
 - Tb** Terrestrial sedimentary rocks (Miocene)
- Basalt of Lost Forest (Miocene)**
 - Tb1** Basalt of Hill 4475 (Miocene)
 - Tb1** Eastern (upper?) lava flow (Miocene)
 - Tb1** Central (middle?) lava flow (Miocene)
 - Tb1** Western (lower?) hyaloclastite, water-affected basalt, and pillow breccia (Miocene)

SYMBOLS

- Horizontal bedding
- Inclined bedding — showing strike and dip.
- Lidar-derived inclined bedding — showing approximate strike and dip.
- OMD-1 Geothermal temperature gradient well drilled during 2013
- Geochemical sample with number see: <http://www.oregon.gov/ogdi/sub/gilgo/data/supplemental/Oregon>
- Contact — solid line where accurately located, dashed where approximate, dotted where concealed.
- Normal fault — bar on downthrown side, solid line where accurately located, dashed where approximate, dotted where concealed.

Base map by U.S. Geological Survey
Control by USGS and NAD83/NA
Topography compiled from aerial photographs taken 1976
Field checked 1977. Map edited 1981
Oregon State Plane South (uniform conformal scale projection)
Vertical datum - National geodetic vertical datum of 1929
Horizontal datum - 1927 North American datum
1000 meter universal transverse mercator - zone 10.
Reprojected to Oregon Lambert
Horizontal datum - 1983 NAD83
Corner 1002 37 and 1002 38 quadrangle extents in
Oregon State Plane South - 30' grid lines
2000 foot datum grid lines - 30' grid lines
2012 magnetic north declination, 15 degrees east
Software used: ESRI ArcMap 10.1, Adobe Acrobat 9 Pro



Geology by Thomas J. Wiley,
Oregon Department of Geology
and Mineral Industries
Field work conducted in 2012, 2013

NOTICE
This map cannot serve as a substitute for site-specific investigations by qualified practitioners. Site-specific data may give results that differ from those shown on the maps. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. government.

Map Unit Explanation for the Reconnaissance Geologic Map of the Sand Rock Quadrangle and Vicinity, Lake County, Oregon, Plate 1

INTRODUCTION

This text of Explanation of Map Units accompanies Plate 1, Reconnaissance Geologic Map of the Sand Lake Quadrangle and Vicinity, Lake County, Oregon. Figure 1 shows the location of the quadrangle. The geologic map also covers parts of the adjacent Fossil Lake and Buffalo USGS 7.5-minute quadrangles. The Oregon Department of Geology and Mineral Industries (DOGAMI) prepared the map to partially satisfy the Scope of Work, Task 3 for the US Energy Department's (USDoE) Geothermal Technologies Program through the Arizona Geological Survey for new geothermal data collection (expanding Task 2.4 of the project objectives). The purpose of this geologic mapping was to characterize the geology around the location of drilling the thermal gradient well ARRA OMD-1 (Figure 1).

The Sand Rock quadrangle (Figure 1) is located in south-central Oregon, just north of the boundary between the Basin and Range Province (to the south) and the High Lava Plains Province (that contains the quadrangle). Deformation in nearby parts of the Basin and Range Province includes broad folding, extension, and normal faulting developed since middle Miocene time. Although more subdued in the Sand Rock quadrangle than in the Basin and Range Province to the south, structures that parallel nearby Basin and Range structures probably were formed by the same process. These include a suite of normal faults that trends north to northwest, resulting in the presence of small basins with interior drainage into seasonal playa lakes. The faults are likely similar to those that post-date late Miocene (~6.8 to 5.21 Ma, Ricker and Niewendorp, 2013) basaltic lava flows near Egli Rim to the southwest.

The dominant features in the Sand Rock quadrangle are promontories at Wildcat Butte and Sand Rock and the extensive field of sand dunes blowing east off the bed of pluvial Fort Rock Lake. In the center of the quadrangle, Wildcat Butte reveals a sequence of interlayered mafic lava flows and layers of poor to well-sorted, largely unimodal, volcanoclastic sandstone and pebbly sandstone (resedimented hyaloclastite?) that once formed the eastern shore of Fort Rock Lake. It is not clear whether or not this escarpment is faulted. Low exposures of volcanoclastic sandstone crop out well west of the base of the butte and were not distinguished from similar rocks that crop out on the escarpment. This suggests that a fault, if present, is located well west of the modern base of slope. The ancient shoreline of Fort Rock Lake is indicated by parallel or concentric ridges of sand and gravel interpreted as beach facies. Fan-delta deposits are present locally along the margins of the lake.

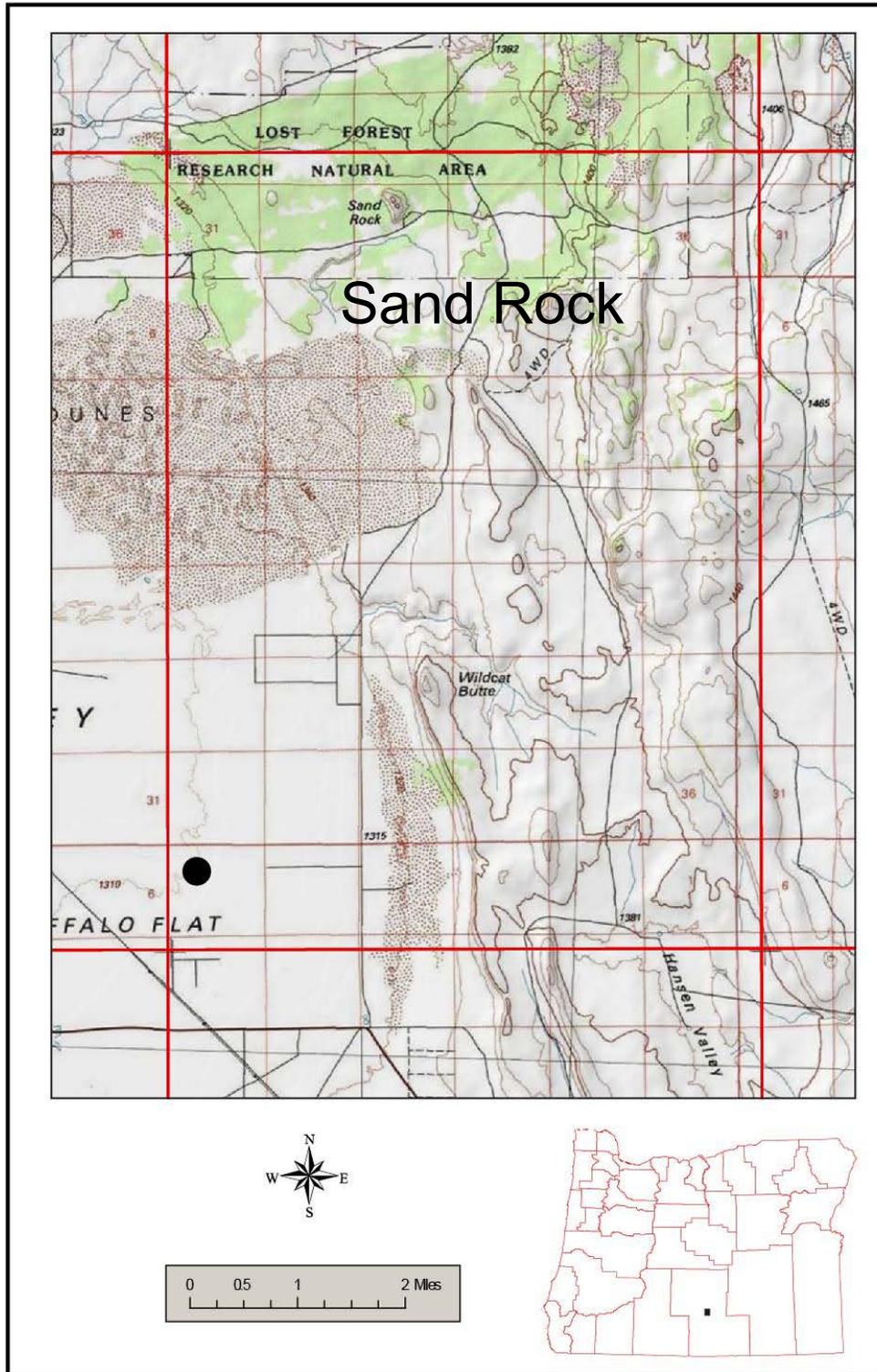


Figure 1. Location map. Showing location of the Sand Rock 7.5-minute quadrangle (outlined in red). The black dot is the location of drilling the thermal gradient well ARRA OMD-1

In the northern part of the quadrangle, Sand Rock is formed by a jagged, curved, outward-dipping ridge that rises 60 m (200 ft) above a field of starved dunes on a bedrock flat. The curved ridge appears on aerial photographs to be part of a larger ring-shaped structure that is interpreted to be composed of hydrovolcanic vent deposits and related lava.

Large fields of active and dormant or stabilized sand dunes cover parts of the Fort Rock Lake bed and adjacent uplands. The distribution of the older (dormant and stabilized) dunes appears to correspond to the distribution of Jeffrey Pine and large Western Juniper that make up the Lost Forest. No time was available for detailed study of the relationship between sandy soils and the extent of the forest. Butte.

METHODOLOGY

Geologic data were collected using digital aerial photographs, USGS 10-m digital elevation models (DEMs), and partial 3 ft (1-m) lidar DEMs and were compiled by combining new mapping with published and unpublished data. Field data were converted into digital format using ESRI ArcGIS™ ArcMAP™ 10.1 GIS software by on-screen digitizing using georeferenced 1:24,000-scale DRG, 10-m DEMs, and a partial lidar DEM as base maps. Geologic interpretations were also aided by GIS analyses incorporating 2009 National Agriculture Imagery Program (NAIP) digital orthophotography. The mapped distribution of surficial deposits is derived in part from soils maps and descriptions published by the Natural Resource Conservation Service (NRCS) of the U.S. Department of Agriculture (NRCS website). Where possible lidar DEMs were used to modify the distribution of both bedrock and surficial geologic units at a maximum scale of 1:8,000. Open water bodies were digitized from 2009 NAIP air orthophotography and 1-m lidar DEMs if available. The geologic time scale used is the September 2010 version of the International Stratigraphic Commission's International Stratigraphic Chart (www.stratigraphy.org/column.php?id=Chart/Time%20Scale.pdf).

Mapping was supported by new and compiled X-ray fluorescence (XRF) chemical analyses of whole-rock samples, new and compiled radiometric age-date determinations, limited thin-section petrography, measurements of natural remnant magnetization (magnetic polarity), and strike and dip measurements of inclined bedding. Samples for whole-rock chemical analysis were prepared and analyzed by X-ray fluorescence (XRF) at the Department of Geosciences, Franklin and Marshall College, Lancaster, Pennsylvania. Analytical procedures for the Franklin and Marshall X-ray laboratory are described by Boyd and Mertzman (1987) and Mertzman (2000), and are available online at <http://www.fandm.edu/x7985>.

In this report, volcanic rocks with fine-grained (<1 mm [0.04 in] average crystal or particle size in the groundmass are described as having "coarse groundmass" if the average size is <1 mm (0.04 in) and they can be determined using the naked eye (>~0.5 mm [0.02 in]); as

having “medium groundmass” if crystals of average size cannot be determined by eye, but can be distinguished using a hand lens (>~0.05 mm [0.02 in]); as having “fine groundmass” if crystals or grains of average size can only be determined using a microscope (or by hand lens recognition of phyllite-like sparkle or sheen in reflected light, indicating the presence of crystalline groundmass); or as having a “glassy groundmass” if the groundmass has (fresh), or originally had (altered), groundmass with the characteristics of glass (conchoidal fracture; sharp, transparent edges; vitreous luster; etc.). Mixtures of crystalline and glassy groundmass are described as intersertal; ratios of glass to crystalline materials may be indicated by textural terms including holocrystalline, hypocrySTALLine, hyalophitic, and hyalopilitic. Microphenocrysts are defined as crystals larger than the overall groundmass and < 1 mm across (0.04 in).

EXPLANATION OF MAP UNITS

ANTHROPOCENE SURFICIAL DEPOSITS

- Af** **Manmade fill, construction material, and disturbed ground (Anthropocene)** — Man-made deposits of mixed gravel, sand, clay, and other debris. Deposits mapped as modern fill and construction material include those that make up dams, road embankments, causeways and culvert fills, and mined or bulldozed land. These deposits are assigned an Anthropocene age on the basis of inclusion of man-made debris or artifacts, or geomorphic evidence indicating man-made surface modifications. Modern (post-1950) engineered fill is generally stable, but older uncontrolled fill may liquefy, spread, or slump during strong earthquake shaking. The unit is mapped on the basis of topographic features interpreted from 3-foot lidar DEMs, 2009 NAIP orthophotos, and, locally, field observations
- Ad** **Sand (Anthropocene)** — Unvegetated to little vegetated accumulations of sand in fields and active or recently active dunes that bury young manmade features and/or bury young vegetation and tree trunks. Small, thin accumulations are locally present on many bedrock units but have not been mapped separately

HOLOCENE SURFICIAL DEPOSITS

- Ha** **Alluvium (Holocene)** — Sand, gravel, silt, and clay deposited along streams and on valley floors
- Hc** **Colluvium (Holocene)** — Hillwash, talus, rockfall, and small landslide deposits preserved on steep slopes
- Haf** **Alluvial fan deposits (Holocene)** — Sand and gravel deposited in fan-shaped accumulations where stream gradients flatten abruptly. May include unmapped sand dunes and patches of older bedrock

HI Lake deposits (Holocene) — Sand, silt, clay, and evaporite deposited in lakes and pluvial or ephemeral lakes. May include unmapped gravel deposits at beaches, small deltas, and fan deltas. May include lake bed deposits of Anthropocene age.

In small, isolated, pluvial lake basins sediment appears to be bimodal, with marginal deposits at higher elevations surrounding light-colored deposits at lake centers. In this report, the marginal deposits have been mapped as older (Unit Ql), perhaps related to a wetter climate, and the central deposits have been mapped as younger, related to more recent climate (this unit). The age/lithology relationships are undoubtedly more complicated.

Hd Sand (Holocene) — Vegetated (partly to entirely stabilized?) accumulations of sand in fields, individual dunes, and dune fields. Holocene age is poorly constrained, based largely on stabilization of sand by vegetation and presence of late Pleistocene Fort Rock Lake in the basin prior to the Holocene. Distribution corresponds closely to that of *Pinus jeffreyi*, the Jeffrey Pine (locally described as “Ponderosa Pine” but distinguished by vanilla or butterscotch smell of attached bark and inward turned spines on cones), and large Western Juniper (*Juniperis occidentalis*) in the Lost Forest. May include unmapped, recently vegetated, sand deposits of Anthropocene age. Small, thin sand accumulations are present on many bedrock units but have not been mapped separately

QUATERNARY SURFICIAL DEPOSITS

Qtd Terrace deposits (late Pleistocene and Holocene) — Gravel, gravelly sand, and sand deposited in terraces and bands at near constant elevations around the margins of Pleistocene Fort Rock Lake. Age based on high stand date of 21 ka (high water date reported for Fort Rock Lake at Fort Rock) and dewatering date of about 13 ka for Fort Rock Lake

Ql Lake deposits (Pleistocene) — Predominantly fine-grained clastic sediment and evaporites with less common sandy gravel, gravel, and diatomite. Preserved in the basin of Fort Rock Lake. May include unmapped deposits of wind blown sand including isolated sand dunes. Age based on reports that Fort Rock Lake reached its maximum elevation about 21 ka and essentially dried up by about 13 ka (Negrini and others, 2001). Lake bed may include scattered exposures of bedrock, tufa, or other features including a low, elongate, rise located west of UTM 714500E., 4792000N. Also includes fine-grained clastic sediment and evaporites deposited in small pluvial lakes in areas with internal drainage. Typically isolated from regional drainages by lava dams or fault blocks.

- Qa Alluvium (Quaternary)** — Sand, gravel, silt, and clay deposited along streams and on valley floors
- Qc Colluvium (Quaternary)** — Hillwash, talus, rockfall, and small landslide deposits preserved on steep slopes

PLIOCENE OR PLEISTOCENE MAAR VOLCANOES, VENT COMPLEXES, VALLEY FILLING LAVA FLOWS, AND RELATED ROCKS

- Qvs Volcaniclastic sediment and tuff, undivided (mid- to late Pleistocene)** — Fine- to coarse-grained clastic rocks (cold) and tuff (hot) interpreted to have been deposited by hyperconcentrated flows (cold) and lahars (hot) erupted from mafic hydrovolcanoes and transported across lake bottoms and marshes. May include unrecognized hyaloclastite and remobilized hyaloclastite, pillow breccia, small lava flows of water affected basalt, and vent deposits. Age based on position above lava flows with reversed polarity and normal polarity of enclosed lava flows
- QTtr Tuff rings (Pliocene or Pleistocene)** — Mafic hydrovolcanic block and ash tuff rings formed by maar volcanos. Age based on range of ages reported for hydrovolcanic maars throughout the Fort Rock basin and relative position of lava flows with reversed magnetic polarity. Based on the amount of erosion and weathering, the Sand Rock Maar, which still stands high above lake level. Locally divided to show:
- QTsr Tuff of Sand Rock (Pliocene or Pleistocene)** — Mafic hydrovolcanic block and ash tuff that forms Sand Rock maar volcano in the northern part of the quadrangle. Crescent shaped remnant(?) of larger ring structure consists of steeply inclined beds that dip north, northeast, east, and east-southeast. A few beds on the western side of the structure dip west. Composed of layered ash, lapilli, and blocks including angular to rounded blocks of mafic lava that appear to have been ejected from a central vent. Elevation of 4430 to 4440 ft (1350 to 1353 m) at the base of the rock is below the maximum surface elevation of 4498 ft (1371 m) of Fort Rock Lake and may be a partly or entirely a wave-cut terrace. Preservation of parts of the maar above maximum lake level is interpreted to suggest a relatively young age
- QTa Glomeroporphyritic orthopyroxene andesite of Section 28, T.20S., R.25E., (Pliocene or Pleistocene)** — Glomeroporphyritic and plagioclase phyrlic orthopyroxene andesite crops out on a low curved ridge, perhaps a partial ring or cone, truncated to the southwest by the ring structure that forms Sand Rock. Lava is platy, vesicular, with a fine groundmass. Sample contains glomerocrysts of green pyroxene and plagioclase as large as 6 mm and clear plagioclase phenocrysts as large as 4 mm. Composition is grossly similar to two other andesite samples

collected a couple miles to the east near the northern edge of the quadrangle. (Sample 912-6-4)

QTab Pyroxene andesite of BLM Road 6151 (Pliocene or Pleistocene) — Pyroxene andesite that crops out north of BLM Road 6151 in T. 25 S., R. 20 E., sections 35 and 36. Lava is platy, vesicular, with a fine groundmass. Sample contains glomerocrysts of green pyroxene and plagioclase as large as 6 mm and clear plagioclase phenocrysts as large as 4 mm. Composition is grossly similar to andesite (unit QTa) collected at a low curved ridge a few miles to the west in section 28. (Sample Numbers 812-24-2 and 812-29-1)

QTbg Glomeroporphyritic olivine basalt (Pliocene or Pleistocene) — Layered/banded, oxidized, diktytaxitic basalt exposed on a low, 20-m hill in the northwestern quarter of the quadrangle. Layering/banding defined by abundance of diktytaxitic vesicles. Olivine microphenocrysts are altered, reddish brown, and seriate to 1.5 mm. Oxidation and vesicularity suggest the hill was once a vent. Glomerocrysts of plagioclase and altered olivine are up to 9 mm across. Plagioclase phenocrysts are as large as 6 mm; olivine phenocrysts to 1.5 mm. Groundmass is fine to medium. Color is dark gray fresh. (Sample number 912-7-2)

QTbh Basalt of Hansen Valley (late Miocene, Pliocene, or Pleistocene) — Two or more thin basalt flows that cover the eastern and western sides of Hansen Valley. Olivine is seriate, as large as 1-2 mm, and enclosed in a coarse groundmass of plagioclase lath, olivine, and pyroxene. Vesicular, locally amygdaloidal with partly to completely filled round or irregular vesicles as large as 4 cm; locally diktytaxitic. In places this rock weathers to a polish that shows groundmass texture. Lithology and major oxide and trace element chemistry for a sample of this lava flow is similar to that of late Miocene or early Pliocene lavas from Egli Rim quadrangle 40 miles to the west-southwest. (Sample number 812-23-1)

QTV Vent deposits (late Miocene, Pliocene and/or Pleistocene) — Palagonite, near-vent lava flows, and minor pyroclastic rocks. Locally divided to show **unit QTcv** which contains cinders.

Andesite of BLM Road 6121 (late Miocene, Pliocene and/or Pleistocene) — Three andesite and pyroxene basaltic andesite lava flows that crop out on ridges in the eastern part of the quadrangle:

QTba Basaltic andesite (late Miocene, Pliocene, or Pleistocene) — Thin, aphyric to sparsely plagioclase phyric basaltic andesite flow crops out near the top of the sequence along the eastern edge of the quadrangle. Sample is dark gray fresh to brown weathered, platy, with plagioclase phenocrysts and microphenocrysts up to 1.5 mm in a fine to medium granular groundmass.

Contains clear to dark, near spherical amygdules in vesicles with diktytaxitic halos. Thickness about 5 m. (Sample 812-24-4)

QTa2 Andesite (late Miocene, Pliocene, or Pleistocene) — Vesicular plagioclase phyric andesite crops out on hills in the eastern part of the quadrangle. The lava flow has a massive or blocky habit and locally forms rimrock. Color is dark gray fresh, reddish brown weathered. Many hand samples are aphyric with a fine groundmass. Plagioclase phenocrysts are widely disseminated, typically 1-2 mm, rarely as large as 1 cm. Vesicles are irregular to angular and up to 1.5 cm in sample 812-29-3; locally amygdaloidal with partial to complete zeolite fills. (Sample numbers 812-29-3 and 1012-11-2)

QTa1 Amygdaloidal andesite (late Miocene, Pliocene, or Pleistocene) — Sparsely plagioclase phyric amygdaloidal andesite is best exposed on the hill west of BLM Road 6121 where it enters the northeastern part of the quadrangle from the south. Rock from this thin lava flow is dark gray fresh and pinkish gray weathered. It is blocky at the outcrop scale and platy in hand sample with plates typically a few millimeters thick; vesicular to amygdaloidal with many pores partly to entirely filled with zeolite. Platy texture is accented by sub-parallel high aspect-ratio amygdules and vesicles (<1mm perpendicular to plates) and sub-millimeter white (zeolite?) veins. Sparse, clear, tabular plagioclase phenocrysts up to 3 mm are enclosed in a fine to medium groundmass with ~0.1 mm equant, tabular, and lath-shaped plagioclase crystals. Forms rim rock and mid-slope cliffs across several sections. (Sample number 1012-11-5; UTM Zone10 NAD83 721656E., 47801989N.)

Sedimentary rocks (late Miocene, Pliocene, and/or Pleistocene) — Siltstone Sediment and, sandstone, diatomite, claystone, gravel, reworked ash, and volcanoclastic rocks interlayered with andesite flows assigned to Andesite of BLM Road 6121. Oldest is QTs1 which underlies andesite unit QTa1 (see time-rock box for other relationships). Rarely crops out; recognized in float from low road cuts, burrows, colluvium, and soil. Map thickness probably exaggerated. Divided to show:

QTs3 Sediment and sedimentary rock (late Miocene, Pliocene, or Pleistocene) —

QTs2 Sediment and sedimentary rock (late Miocene, Pliocene, or Pleistocene) —

QTs1 Sediment and sedimentary rock (late Miocene, Pliocene, or Pleistocene) —

Miocene and/or Pliocene lava flows, volcanoclastic sediment, and sedimentary rock

Generally east-dipping section of thin basaltic to basaltic andesite lava flows, thin sedimentary interbeds and locally thick volcanoclastic or hydrovolcanic interbeds. This section is interrupted by several hydrovolcanic vent complexes (Maar volcanoes) comprised of proximal(?) mafic hydrovolcanic deposits surrounded by intermediate(?) lahar (hot) to distal(?) hyperconcentrated flow (cold) facies interlayered with lava flows and sedimentary interbeds. May include unrecognized hyaloclastite and remobilized hyaloclastite, pillow breccia, small lava flows of water affected basalt, and vent deposits. Maximum ages could be as old as early Miocene but are considered to be constrained by the absence of early Miocene Steens Basalt or deformed and altered Oligo-Miocene sequences such as those that crop out near Summer Lake and Paisley. Maximum ages could be as young as 6.8 to 5.21 Ma lavas (Ricker and Niewendorp, 2013) that crop on Egli Rim, north of Summer Lake, and dip beneath Fort Rock Lake sedimentary deposits.

Tbax Basaltic andesite of Section 10 (T26SR20E10; middle or late Miocene or Pliocene) — Plagioclase phyric basaltic andesite lava flow or flows interpreted to cover several square kilometers in the northeastern part of the quadrangle. These blocky lava flows locally have a platy base. The unit crops out along valley margins and on high spots on the valley floor. Samples are medium to dark gray fresh and brownish tan to reddish brown weathered. Sparse, medium-gray plagioclase tablets are as large as 4 mm. Locally contains very sparse iddingsitized olivine(?) microphenocrysts and/or small spheroidal vesicles or amygdules with diktytaxitic rims. Granular groundmass is medium to fine. In the southeastern part of the quadrangle, where the unit symbol is queried, another basaltic andesite flow (with distinct chemistry; sample numbers 413-30-1 and 413-30-2) is interpreted to lie at the same stratigraphic level. (Sample numbers 812-24-5, 812-29-2, 912-7-3, 1012-11-3, and 1012-11-4)

Tvs4 Volcanoclastic rocks (middle or late Miocene or Pliocene) — Bedded volcanoclastic sandstone, conglomerate, breccia, and palagonite tuff

Tb22 Olivine basalt of Section 22 (T26SR20E22; middle or late Miocene or Pliocene) — Olivine basalt of Section 22 crops out as a thin, discontinuous lava flow that typically forms a low rise associated with weathered 0.5 to 3 m (2 to 10 ft) diameter boulders. Sparse olivine phenocrysts up to 4 mm, typically 1-2 mm, are supported in a fine groundmass along with lath-shaped plagioclase microphenocrysts. Boulders at the road crossing in Section 16 transition, from east to west across the flow front, from platy at the top of the flow, to vesicular mid-flow,

to massive at the base of the flow. The boulders are associated with a 10 m bench, suggesting the flow thickness is less than 10 m. (Sample number 812-24-1)

- Tvs3 Volcaniclastic rocks (middle or late Miocene or Pliocene)** — Bedded volcaniclastic sandstone, conglomerate, breccia, and palagonite tuff. Best exposures are around the summit of Wildcat Butte. Typically poorly exposed as float at animal burrows
- Tbab Basaltic andesite of Buffalo Well (middle or late Miocene)** — Thin basaltic andesite lava flow that crops out locally along the rim east of Buffalo Well. Plagioclase phyrlic with lath-shaped crystals to 4 mm. Medium gray fresh; brown to reddish brown weathered. Medium groundmass is locally diktytaxitic. Occurs as flow remnants or fills shallow draws on the rim east of Buffalo Well. (Sample number 912-13-1)
- Tbb Basalt of Buffalo Well (middle or late Miocene)** — Forms most of the rim east of Buffalo Well and is the uppermost of two lava flows that form small mesas and ridgebacks west of Hansen Valley and south of Hansen Valley Road. Basalt is massive to diktytaxitic, with seriate plagioclase tablets to 6 mm (typically to 2 or 3 mm), and olivine microphenocrysts to 1 mm. Medium groundmass also contains small (<1 to 2 mm) round vesicles; larger vesicles with round or oval sections are more common in zones at the top of the flow and may be filled or partially filled with zeolite or a distinctive pinkish orange translucent lining. Rock is medium gray fresh; tan weathered. Reverse magnetic polarity. (Sample numbers 812-23-2 and 912-13-2)
- Tbhr Basalt of Hansen Valley Road (middle or late Miocene)** — Diktytaxitic olivine basalt exposed as a thin (3-4m) blocky lava flow. Lower of two flows that form small mesas and ridgebacks west of Hansen Valley and north and south of Hansen Valley Road. Sample contains seriate clear tabular plagioclase phenocrysts to 5 mm. Olivine and plagioclase form glomerocrysts to 4 mm. Vesicles may be partly filled with zeolite and/or surrounded by diktytaxitic halos. Medium groundmass is diktytaxitic with plagioclase lath to 1 mm. Flow has reverse magnetic polarity. It is mapped as a lenticular lava flow enclosed in unit Tvs3. Lithology and major oxide and trace element chemistry for a sample of this lava flow is similar to that of late Miocene or early Pliocene lavas from Egli Rim XX miles to the west-southwest. (Sample number 812-23-3)
- Tbw Olivine basaltic andesite of Wildcat Butte (middle or late Miocene)** — Upper of two mafic lava flows that crop out on the west side of Wildcat Butte. Rock is medium to dark gray fresh, dark brown weathered. Magnetic polarity is normal. Olivine is equant, altered, green to reddish brown (iddingsite?), <<1%, as large as 1.5

mm. Plagioclase is bimodal with ~1%, equant, clear to white, as large as 3 mm and seriate lath less than 1.5mm. Medium groundmass is granular, rock is locally vesicular. Crops out from Wildcat Butte southward to form prominent rim rock for at least 1.5 km. (Sample Number 1012-11-7)

Tbaw Basaltic andesite of Wildcat Butte (middle or late Miocene) — Lower of two mafic lava flows that crop out on the west side of Wildcat Butte. Extends northward toward Lost Forest? (Sample Number 512-1-6)

Tvs2 Volcaniclastic rocks (middle or late Miocene) — Bedded volcaniclastic sandstone and pebbly sandstone interpreted as deposited by hyperconcentrated flows from a nearby hydrovolcanic maar volcano. Composition is consistent with a mafic eruption that interacted with ground or surface water and surrounding formations and soils. Crops out above more massive volcaniclastic rocks assigned to unit Tvs1 and lies beneath the incised(?) basaltic andesite of Wildcat Butte (Unit Tbaw) and the basalt of Wildcat Butte (Unit Tbw) to the south

Tvs1 Volcaniclastic rocks and tuff (middle or late Miocene) — Massive and medium- to thick-bedded volcaniclastic sandstone, conglomerate, breccia, and palagonite tuff interpreted as deposited by lahars and hyperconcentrated flows, respectively. Probably generated by one or more eruptions at a nearby hydrovolcanic maar volcano. Composition is consistent with a mafic eruption that interacted with ground or surface water and with enclosing bedrock formations and soils. Volcaniclastic rocks in this and younger units underly many of the roadbeds with dark- to medium-gray or yellowish coarse sand and subrounded to angular mafic clasts. Crops out at the base of the section exposed at Wildcat Butte. Locally includes small, thin lava flows(?) not mapped separately, including the low rise of diktytaxitic, plagioclase phyric basaltic andesite boulders east of Buffalo Well (Sample number 912-13-3).

Tsh Sedimentary rocks (middle or late Miocene?) — Exposed as disaggregated well-rounded white pebbles and sand on Hill 4475, overlying the lower flow of the Basalt of Hill 4475 and underlying the upper flow of the Basalt of Hill 4475, in the northwestern corner of the quadrangle

Basalt of Lost Forest (Miocene) — Basalt and water-affected basaltic lava flows of similar chemistry that crop out on hills, in road beds, and in shallow gullies in the northwestern part of the quadrangle near of Sand Rock. Overlain in most places by a thin, unmapped veneer of young sand (units Hd and Ad). Divided to show:

Tbh Basalt of Hill 4475 (middle or late Miocene) — The basalt of Hill 4475 includes two chemically and lithologically similar basalt

flows that form a low hill in the northwestern corner of the quadrangle. The flows are separated by a thin sedimentary interval with well-rounded gravel, that has been assigned to unit Tsh. The upper lava flow is exposed as a boulder lag at the top of the hill. It consists of diktytaxitic olivine basalt. In sample 912-6-5 brown olivine is seriate to 2 mm; plagioclase lath are seriate to 2 mm; sparse olivine/plagioclase **glomerocrysts** are as large as 3 mm; round vesicles are as large as 5 mm; color is medium gray fresh, medium gray to reddish weathered; and the medium groundmass is diktytaxitic to massive. The lower lava flow consists of vesicular, diktytaxitic olivine basalt. In sample 912-6-6 amber to brown olivine is seriate to 2 mm; plagioclase is seriate to 2mm; round vesicles to 6 mm have diktytaxitic halos; color is medium gray fresh; and the medium groundmass is diktytaxitic to massive. The lower flow forms the base of the hill, however, the relationship to underlying bedrock units is obscured by sandy soils and dune sand. It probably erupted onto unit TblI (Sample numbers 912-6-5, from the upper flow, and 912-6-6 from the lower flow)

Tblu Eastern (upper?) lava flow (Miocene) — Poorly exposed diktytaxitic olivine basalt flow(s) that crop out in road beds and on a low hill in section 34, T. 25 S., R.20 E. and surrounding areas. Rock is olivine and plagioclase phyric with equant to elongate medium-green olivine phenocrysts to 3 millimeters and gray plagioclase to 2 mm. Olivine phenocrysts contain opaque oxides. Groundmass is coarse, with plagioclase lath, equant (euhedral?) black clinopyroxene, and green olivine to 1 mm. Locally these flows are vesicular to amygdaloidal with rounded vesicles, typically less than 1 cm in diameter, and irregular vesicles to 3 cm and larger partly to entirely filled with zeolite. Probably intruded and overlapped by, the younger(?) round 1.6 km (1 mi) diameter geomorphic feature that includes Sand Rock. (Sample number 912-6-3)

Tblf Central (middle?) lava flow (Miocene) — This unit includes one or more poorly exposed diktytaxitic olivine basalt flows that crop out in road beds southwest of Sand Rock. Flows are olivine and plagioclase phyric with equant to elongate medium-green olivine phenocrysts to 4 millimeters and gray plagioclase to 2 mm. Olivine phenocrysts contain opaque oxides. Groundmass is coarse, with plagioclase lath, equant (euhedral?) black clinopyroxene, and green olivine to 1 mm. Crops out west of the younger(?) round 1.6 km (1 mi)

diameter geomorphic feature that includes Sand Rock. (Sample number 912-6-2)

Tbll **Western (lower?) hyaloclastite, water-affected basalt, and pillow breccia (Miocene)** — This composite unit includes several basaltic lithologies. Probably represents various degrees of interaction between one or more basalt flows and water. Stratigraphic position appears to be similar to that of unit Tvs on the lower western slopes of Wildcat Butte. Basalt sample collected from pillow (spheroid?) exposed in the roadbed is incipiently diktytaxitic with chemistry and mineralogy generally similar to that of diktytaxitic basalt flows exposed farther to the east (units Tblf, Tblu). Plagioclase occurs as seriate lath up to 1.5 mm. (Sample number 912-6-1)

REFERENCES

Ricker, T.R., and Niewendorp, C.A., compilers, 2013, Radiometric Age Information Layer for Oregon, Release 1, Oregon Department of Geology and Mineral Industries Digital Data Series RAILO-1, scale 1:1000000.

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