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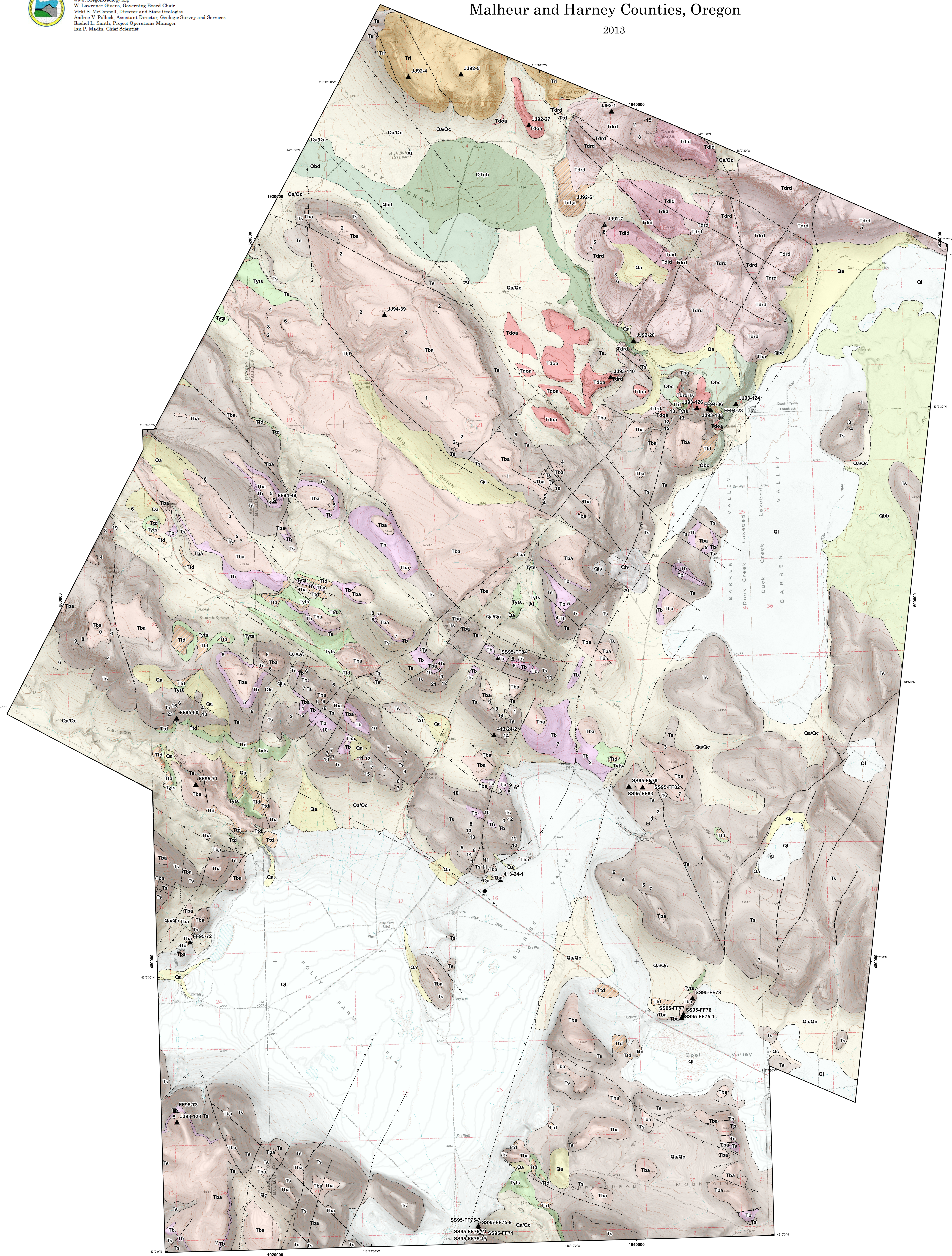
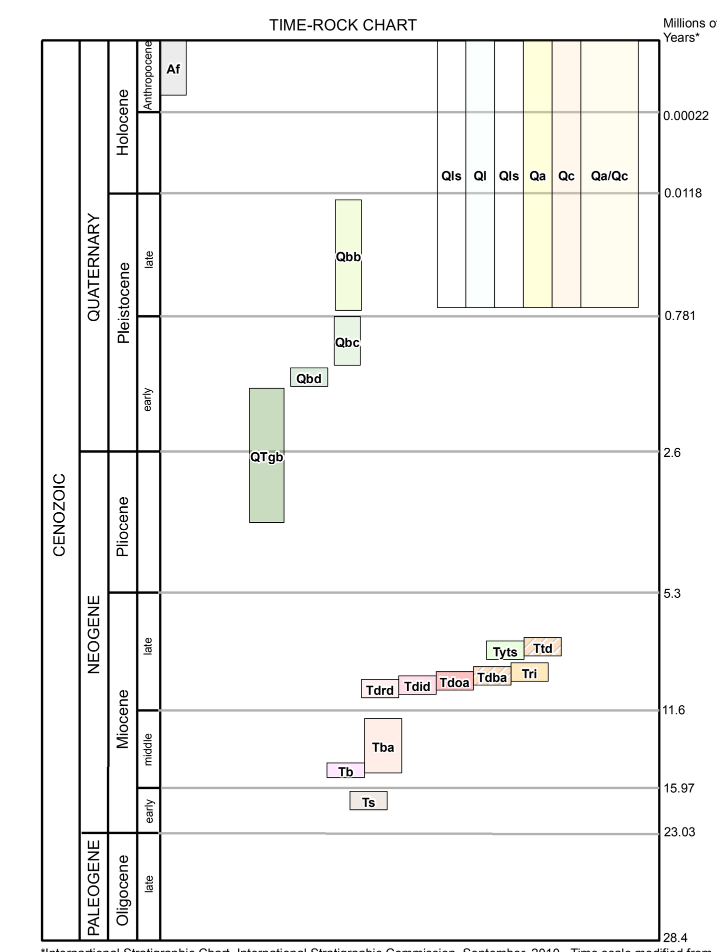
Reconnaissance Geologic Map of the Folly Farm 7.5' Quadrangle and Vicinity, Malheur and Harney Counties, Oregon

2013

This map plate accompanies
ARRA Geothermal Report 2013
This geologic map was funded in part by the Department of Energy's Geothermal Technologies Office and the Arizona Geological Survey under Prime Award No. DE_EE0002850 and Sub-Award No. OR-EE0002850

PLATE 3





*Internartional Stratigraphic Chart, International Stratigraphic Commission, September, 2010. Time scale modified from Gradstein and others (2004) and Ogg and others (2008), www.stratigraphy.org/column.php?id=cChart/Time%20Scale

EXPLANATION OF MAP UNITS

- Af — Manmade fill, construction material, and disturbed ground (Anthropocene)
- Qls — Landslide deposits (late Pleistocene and Holocene)
- Ql — Lacustrine deposits (late Pleistocene and Holocene)
- Qa/Qc — Alluvium and colluvium, undivided (late Pleistocene and Holocene) - Locally divided to show:
  - Qa — Alluvium (late Pleistocene and Holocene)
  - Qc — Colluvium (late Pleistocene and Holocene)
- Qbb — Basalt of Barren Valley (late Pleistocene) - Vesicular, diktytaxitic olivine basalt. Normal polarity.
- Qbc — Basalt of Cord (early Pleistocene) - Diktytaxitic; 1% each olivine and plagioclase phenocrysts. Reverse polarity.
- Qbd — Basalt of Duck Creek Flat (early Pleistocene; 1.36 Ma) - Diktytaxitic; 2-3% olivine 1-2 mm in diameter.
- QTgb — Glomeroporphyritic olivine basalt (Pliocene or early Pleistocene)
- Ttd — Devine Canyon Ash-Flow Tuff (late Miocene; 9.7 Ma)
- Tyts — Tuffaceous sedimentary rocks (Miocene)
- Tri — Rhyolite of Indian Creek Buttes (late Miocene, 10.3 Ma)

Duck Butte Eruptive Center

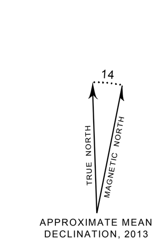
- Tdba — Basaltic andesite (late Miocene)
- Tdoa — Olivine andesite (late Miocene)
- Tdid — Inclusion-rich dacite (late Miocene)
- Tdrd — Biotite-pyroxene rhyodacite (late Miocene; 10.4 Ma)

- Tba — Basaltic andesite (middle Miocene)
- Tb — Basalt (middle Miocene; 14.73 Ma)
- Ts — Steens Basalt (early Miocene; ~16.6 Ma)

SYMBOLS

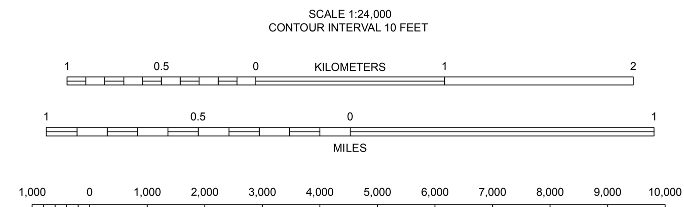
- Horizontal bedding
- Inclined bedding — showing strike and dip.
- Lidar-derived inclined bedding — showing approximate strike and dip.
- FF-1 Geothermal temperature gradient well drilled during 2013
- Geochemical sample with number see: http://www.oregongeology.org/sub/gtilo/data/supplemental/Oregon
- 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.

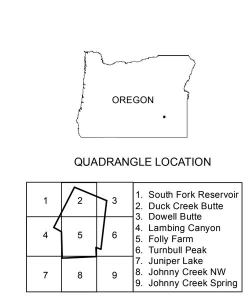
Base map by U.S. Geological Survey 1974
Control by USGS and NOS/NOAA
Topography compiled from aerial photographs taken 1973
Field checked 1974
Oregon State Plane South (Lambert conformal conic projection)
Vertical datum - National geodetic vertical datum of 1929
Horizontal datum - 1927 North American datum
Reprojected to Oregon Lambert Conformal Conic
Horizontal datum - 1983 HARN
Covers NAD 27 and NAD 83 quadrangle extents in Oregon State Plane South
20,000 foot state grid ticks, 2' 30" grid ticks
2012 magnetic north declination, 15 degrees east
Software used: Esri ArcMap 10.1, Adobe Acrobat 9 Pro



APPROXIMATE MEAN DECLINATION, 2013

SCALE 1:24,000
CONTOUR INTERVAL 10 FEET





QUADRANGLE LOCATION

Geology by Jenda A. Johnson and David R. Sherrod, U.S. Geological Survey, and Thomas J. Wiley, Oregon Department of Geology and Mineral Industries

Field work conducted 1992-1998, 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.

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Map Unit Explanation for the Geologic Map of the Folly Farm Quadrangle and Vicinity, Malheur and Harney Counties, Oregon

INTRODUCTION

This text of Explanation of Map Units accompanies Plate 3, Reconnaissance Geologic Map of the Folly Farm Quadrangle and Vicinity, Malheur and Harney Counties, Oregon. Figure 1 shows the location of the quadrangle. The geologic map also covers parts of the adjacent Lambing Canyon, Duck Creek Butte, and Turnbull Peak 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 FF-1 (Figure 1).

The Folly Farm quadrangle is located in southeastern Oregon in the High Lava Plains Province along the Steens Mountain's eastern escarpment. This quadrangle covers part of Baker Pass which is parallel to what may be a zone of east-west extensional transfer faulting (i.e. cross-faults) between two range-fault segments of the Steens eastern escarpment: the Crowley fault section to the north and Mann Lake fault section to the south (Personius, 2002a). This zone lying between the two fault sections is marked by tilted fault blocks of Steens basalt and the association of structural basins filled with Quaternary sediments. These observations attracted our attention for it was quite evident that elsewhere in Oregon similar structural relationships of extensional transfer faulting between two range-front fault segments were an important control of geothermal fluids, e.g. Alvord Valley, southern Malheur County and Paisley, Lake County.

Geology shown on this geologic map was largely provided by Jenda A. Johnson and David R. Sherrod with the United States Geological Survey, Cascade Volcano Observatory, Vancouver, Washington. Tom Wiley with DOGAMI complied the map and modified some geologic contacts to fit newly collected lidar topographic data and also drew a few entirely new contacts that depict the distribution of surficial geologic units or that use lidar topographic signatures to project bedrock units into areas outside that mapped by Johnson and Sherrod. The compilation of Ma and others (2009) was used to fill in areas outside those mapped by Johnson and Sherrod. The map was prepared to facilitate correlation of rocks encountered in a geothermal temperature well to be drilled in the southern part of the Folly Farm quadrangle with rocks exposed elsewhere at the surface. Mapping by Johnson and Sherrod was conducted by collecting samples and conducting geologic traverses along passable roads and selected foot traverses.

Abbreviated descriptions of the geologic units are provided below. More complete information on bedrock units in this area is contained in Johnson (1995) and Johnson and Grunder (2000).

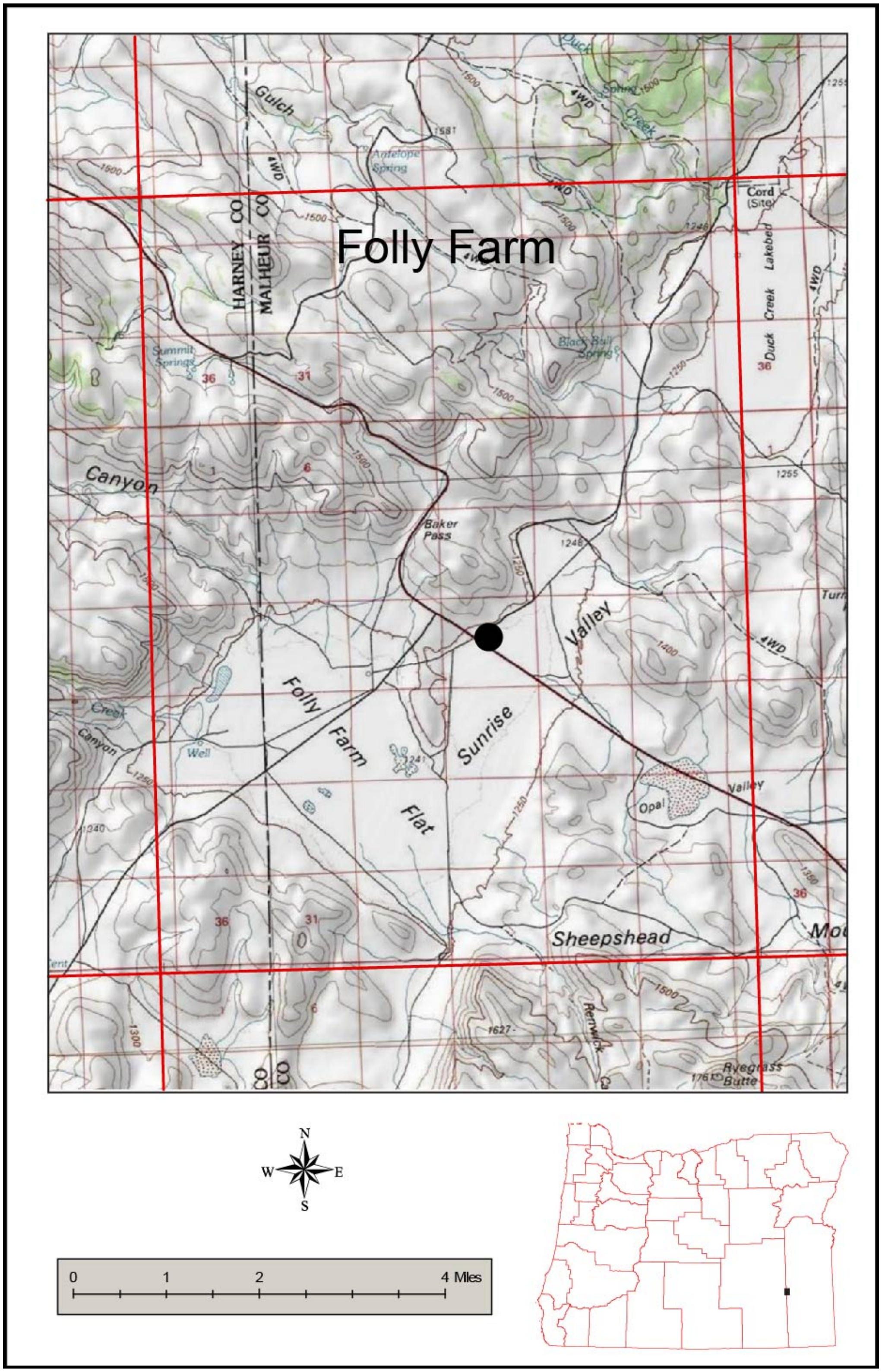

Figure 1. Location map. Showing location of the Folly Farm 7.5-minute quadrangle (outlined in red). The black dot is the location of drilling the thermal gradient well ARRA FF-1

EXPLANATION OF MAP UNITS

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 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. Also includes bulldozed ground. The unit is mapped on the basis of topographic features interpreted from 1-m lidar DEMs, 2009 NAIP orthophotographs, and, locally, field observations

Qls **Landslide deposits (Late Pleistocene and Holocene)** — Unconsolidated, chaotically mixed masses of rock and soil deposited by landslides

Ql **Lacustrine deposits (Late Pleistocene and Holocene)** — Predominantly fine-grained silt and clay with sand and gravel deposits concentrated on shorelines and beaches where they often preserve small terraces. Diatomite is common in lake centers and may form significant accumulations. Typically isolated from regional drainage by lava dams or fault blocks. May include unmapped exposures of bedrock and deposits of wind blown sand including isolated sand dunes

Qa/Qc **Mixed alluvium and colluvium (Late Pleistocene and Holocene)** — Locally divided to show:

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

Qbb **Basalt of Barren Valley (late Pleistocene)** — Vesicular, medium- to dark-gray, diktytaxitic, high alumina, olivine basalt that flowed into map area from the southeast. Normal-polarity remanent magnetization and stratigraphic position suggest age is late Pleistocene.

Qbc **Basalt of Cord (early Pleistocene)** — Diktytaxitic, ophitic olivine basalt with 1% each of olivine and plagioclase phenocrysts. Reverse-polarity remanent magnetization and stratigraphic position suggest age is early Pleistocene.

Qbd **Basalt of Duck Creek Flat (early Pleistocene; 1.36 Ma)** — Diktytaxitic, ophitic olivine basalt with 2-3% phenocrysts of olivine 1-2 mm in diameter. Fine groundmass includes 3-9% iron-titanium oxides. Covers about 4 km2 with at least two flows that have a combined thickness of 5 to 30 m. Radiometric age of 1.36+/-0.07 Ma and reverse-polarity remanent magnetization indicate an early Pleistocene age.

QTgb **Glomeroporphyritic olivine basalt (early Pleistocene or Pliocene)** — Diktytaxitic, ophitic basalt characterized by glomerocrysts of olivine and plagioclase. Contains 2 percent each of olivine and plagioclase phenocrysts. Fine groundmass contains 5-8% iron-titanium oxides. Vesicles commonly make up 10-15% of the rock. Minimum thickness of 2 to 6 m, but base not exposed. Age based on stratigraphic position.

Ttd **Devine Canyon Ash-Flow Tuff (late Miocene; 9.7 Ma)** — Rhyolitic crystal-rich welded ash-flow tuff that erupted near Burns and originally covered about 20,000 km2 of southeastern Oregon. Preserved where deposited in drainages and faultbound valleys. Locally pumiceous. Phenocryst content ranges from 7 to 30% and include alkali feldspars, quartz, pyroxene, and olivine (Wacaster and others, 2011)

Tyts **Tuffaceous sedimentary rocks (Miocene) —** Poorly exposed tuffaceous sedimentary beds commonly found beneath the Devine Canyon Ash-Flow Tuff

Unconformity

Tri **Rhyolite of Indian Creek Buttes (late Miocene, 10.3 Ma) —** The rhyolite of Indian Creek Buttes (Johnson, 1995) forms a thick pile of aphyric to sparsely porphyritic lava flows. Early flows are aphyric and compositionally more evoloved than capping flows, which have 0.5-2% crystals. Phenocrysts include normally zoned subhedral and embayed sanidine and anorthoclase, anhedral and embayed quartz, and subhedral hornblende

Duck Butte Eruptive Center (late Miocene, 10.3-10.4 Ma) — Rocks of the Duck Butte Eruptive Center of Johnson and Grunder (2000) include silicic to mafic lithologies many of which show evidence of mixing. They range in age from 10.3 to 10.4 Ma based on the 10.3 Ma age of the younger Rhyolite of Indian Creek Buttes and the 10.4 Ma age of the basal (oldest) biotite-pyroxene rhyodacite. Locally divided to show:

Tdba **Basaltic andesite —** Basaltic andesite lava flows that vary from olivine basaltic andesite, with 15% phenocrysts of plagioclase, olivine, and iron-titanium oxides, to aphyric basaltic andesite

Tdoa **Olivine andesite —** Andesite flows that erupted on the southern margin of the Duck Butte Eruptive Complex are considered younger than the inclusion-rich dacite. They contain 5-9% subhedral to anhedral, equant, zoned or sieve textured plagioclase as large as 3 cm and 0.5% subhedral to euhedral olivine in a cryptocrystalline or glassy groundmass.

Tdid **Inclusion-rich dacite —** An inclusion rich dacite conformably overlies the rhyodacite. Inclusions of quenched basaltic andesite range from 0.2 to 7 cm in diameter and form 3-30% of the rock. The dacite matrix contains 3-5% anhedral microphenocrysts of plagioclase, iron-titanium oxides, orthopyroxene, clinopyroxene, and less common hornblende, biotite, and olivine. The inclusions are fine-grained, vesicular, and commonly have glassy rims and dendritic iron-titanium oxides indicative of rapid quenching.

Tdrd **Biotite-pyroxene rhyodacite (late Miocene; 10.4 Ma) —** Biotite-pyroxene rhyodacite was deposited initially by a block-and-ash flow, then by followed by lava flows. Late lava flows contain andesitic inclusions. Plagioclase forms 5-10% of the rock and occurs as euhedral microphenocrysts and anhedral to subhedral phenocrysts that are zoned and commonly sieve-textured or resorbed. Euhedral to subhedral biotite makes up 1-3% of the rock. Clinopyroxene, orthopyroxene, and ilmenite are each less than 1%. Biotite yielded ages of 10.42+/-0.02 and 10.37+/-0.02 Ma (Johnson, 1995)

Tba **Basaltic andesite (middle Miocene) —** A section of 4-100m thick aphyric to sparsely phyric basaltic andesite, andesite, and basalt lava flows that cap the older units with slight angular unconformity and thicken northward.

Tb **Basalt (middle Miocene, 14.73 Ma) —** Diktytaxitic basalt with reverse magnetic polarity. Similar to, but locally separated from underlying Steens Basalt by a thin, unmapped, discontinuous tuff thought to be the 16.1 Ma tuff of Oregon Canyon (Rytuba and McKee, 1984, as cited in Johnson and Grunder, 2000). Basalt has a radiometric age of 14.73 +/- 0.09 Ma (J.A. Johnson and R.A. Duncan, unpublished data cited in Johnson and Grunder, 2000)

Ts **Steens Basalt (early Miocene, ~16.6 Ma) —** Olivine and plagioclase-rich basalt flows similar to those cropping out in the upper part of the type section at Steens Mountain (Johnson et al., 1998)

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