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Preliminary Geologic Map of the Southern and Central Seven Troughs Range, Potential Geothermal Area, Pershing County, Nevada

by

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INTRODUCTION

The Seven Troughs Range resides in the northwestern Basin and Range province 190 km northeast of Reno and 50 km northwest of Lovelock in western Nevada. There is no known geothermal system in the area. Mesozoic metasedimentary strata and intrusions dominate the northern and southern parts of the range but are nonconformably overlain by a thick sequence (~1.5 km) of Oligocene to Miocene volcanic and volcaniclastic rocks and Quaternary sediments in the central part of the range. The southern part of the range consists of a basement horst block bounded by two major range-front faults, with Holocene fault scarps marking the more prominent fault on the east side of the range. In contrast, several gently to moderately west-tilted fault blocks, with good exposures of the Tertiary volcanic strata and bounded by a series of steeply east-dipping normal faults, characterize the central part of the range. Kinematic analysis of faults in the range and regional relations indicate a west-northwest-trending extension direction. Accordingly, slip and dilation tendency analyses suggest that north-northeast striking faults are the most favorably oriented for reactivation and fluid flow under the current stress field (Forson, 2014; Forson et al., 2014).

Two areas in the Seven Troughs Range have a favorable structural setting for generating permeability and channeling geothermal fluids to the near surface (Forson, 2014): 1) A major right step in the range-front fault and concomitant fault intersection on the east side of the Seven Troughs Range. Slightly elevated 2-m-deep temperatures (~15° C vs. background temperatures of 11–12 ° C) have been found in this vicinity. 2) A left step in the range-front fault and attendant fault termination on the west side of the range in the vicinity of Porter Spring. This area has the highest recorded 2-m-deep temperatures (~19° C). Although the 2-m temperature survey does not reflect the presence of hot geothermal fluids near the surface at these locations, a 2D low resistivity MT (Wannamaker et al., 2011) anomaly and the favorable structural settings warrant further analysis for potentially blind geothermal systems in the area.

DESCRIPTION OF MAP UNITS

Quaternary deposits

Qmw – Mine waste (Historic/Holocene) – Whitish to bluish-gray mine waste. Primarily composed of silt, sand, gravel and cobbles from mine workings. Unit was only broken out on the west side of the field area, where a large area was obscured by workings from tungsten mines. On the east side of the field area in the mining district, small waste piles were not mapped.

Qal – Active stream channels and channel deposits, undivided (latest Holocene) – Seasonally active, anastomosing stream channels and channel deposits dissecting older Quaternary units (Qfy to Qfo_2); characterized by sparse vegetation, low topographic relief and lack of large boulders. Alluvium in these drainages consists of unconsolidated light tan, poorly to well-sorted silt, sand, pebbles, and sparse boulders. Thickness is typically less than a few meters.

Qs – Active spring deposits and older spring deposits, undivided (latest Holocene to late Pleistocene) – Brown, gray, and grayish-blue, fine silt, clay, and sand found at and down slope from active springs on the west side of the Seven Troughs Range. Where spring water has

cut through alluvium, the sidewalls show that beds are undulating and irregular and consist of alternating layers of either fine-grained silty to sandy matrix with fine-grained clasts, or sandy matrix with coarser grains and larger gravel-cobble sized clasts. Beds are not graded and moderately indurated. Clasts range in size from fine sand to cobble. Beds range in thickness from ~5 cm to 20 cm. Clasts are subrounded to rounded and composed of ₮Js, Tbcn, Twt, and quartz. Anomalous vegetation is found around springs, particularly on the west side of Porter Spring, where cottonwood trees and large patches of grass grow around and downhill from springs.

Qc – Colluvium and talus deposits (Holocene to Pleistocene) – Colluvial and talus deposits on, and at the base of, moderate to steeply dipping slopes. This unit is characterized by unsorted, unstratified subangular clasts ranging in size from lesser gravel to boulder. Clasts reside in a poorly consolidated sandy matrix. Clasts are predominately derived from cliff-forming basaltic andesite. Qc is generally less than 5 m thick.

Qfy – Young active fan alluvium and recently abandoned fan alluvium, undivided (late Holocene) – Active and recently abandoned fan alluvium deposits are locally incised by active stream channels (Qal). The surface of these deposits is smoother than Qal but is commonly undulating and exhibits a finely spaced bar and swale morphology with sharp to rounded interfluves. Few boulders and sparse sage brush vegetation are found on the surface of these deposits. This unit contains layers of stratified silt, sand, and subrounded to subangular pebbles, gravel and cobbles. Subrounded to subangular poorly to moderately sorted cobbles and boulders in a silty sand matrix are found locally. Deposits are as much as 3 m thick.

Qfi – Intermediate-age fan alluvium, undivided (Holocene to late Pleistocene) – Intermediate-age fan alluvium is cut by Qal and Qfy, but dissects Qfo. Fan surface is higher topographically than Qal and Qfy, but lower than Qfo. Composed of cobble, pebble, coarse sands, and silt; locally contains isolated boulders and slightly more vegetation than Qfy. Surfaces are generally smooth and moderately rounded with erosionally rounded edges and moderately incised channels with broad, flat interfluves. In air photos these fan surfaces exhibit a more mottled texture than Qfy but less mottled than Qfo. Thicknesses vary but are commonly ~5 m thick.

Qfo – Old fan alluvium, undivided (late Pleistocene) – Older fan alluvium is similar to Qfi but is distinguished by higher, older erosional surfaces approximately 5 m above Qfi. Boulders, cobbles, and coarse- to fine-grained sands are present on the surface, with some desert varnish. Unit has a more mottled texture than younger units in arial photographs. Thickness varies from ~10–15 m.

Qfo_2 – Oldest fan alluvium, undivided (Pleistocene) – Fan remnants characterized by smoothed surfaces, moderate desert pavement, and moderate desert varnish. Large boulders of Tbcn and Kg, as well as cobbles and gravel of Tbcn, ₮Js, and Kg found typically near the fan head in a sandy silty matrix. Unit is distinguished from Qfo, because it is more dissected, slightly higher in elevation, and has a smoother texture in arial photos than younger fan units. Thickness is unknown but ranges up to 15 m.

Qls – Landslide deposits and lesser talus and colluvium, undivided (Pleistocene landslides) – Coarse, unconsolidated debris composed of local bedrock, particularly the basaltic andesite of Tbcn, Tbu_1, Tbu_2, and rhyolite of Tru_1 and Tru_2. Clasts range from cobble to large blocks up to 10 m in diameter. Exact unit thickness unknown but probably as much as 30 m thick. Headwall scarps range from relatively fresh to more degraded and hardly recognizable.

Subunit of Qls

Qls Tru – Landslide deposit consisting of upper Rhyolite (Tru_1 and Tru_2) (Pleistocene) – Coarse, semi-consolidated debris composed of rhyolite from Tru_1 and Tru_2. Clasts range from cobble to large blocks up to 10 m long.

Tertiary volcanic and sedimentary units

Tbr – Sedimentary breccia (Pliocene?) – Light tan to mauve, massive sedimentary breccia. Matrix is composed of fine- to coarse-grained sand. Clasts generally range in size from ~1 cm to ~1 m in diameter with a mode of ~5 cm; locally boulders are up to ~5 m long. Clasts are subangular to angular and are composed of scoria, aphanitic and more porphyritic basalt, and rhyolite. The unit is poorly sorted and generally not bedded. Unit thickness is at least 150 m.

Tbu_2 – Uppermost basalt flows (middle to late Miocene) – Medium gray to black basalt flows. Lower portion is massive aphanitic to slightly porphyritic. Contains ~5–10% phenocrysts composed of ~90% subhedral to euhedral plagioclase ~1–4 mm long and 10%, 1–2 mm long, subhedral to anhedral olivine, generally altered to iddingsite. Groundmass composed of ~90% plagioclase, ~8% olivine, and ~2% pyroxene. Unit thickness is ~60 m. This is the uppermost unit in the Tertiary section; it conformably overlies Tru_2 and is locally overlain by Quaternary sediments.

Tru_2 – Uppermost rhyolite flows (middle to late Miocene) – Medium to light gray and pink, flow-banded rhyolitic flow. Contains ~5% phenocrysts composed of ~80% subhedral plagioclase ~1–2 mm in length, ~10%

subhedral sanidine ~1–2 mm in length, and ~10% biotite laths ~1–2 mm long. Groundmass is mostly glass with some <1 mm microlites of plagioclase and biotite. Unit is overlain by Tbu_2 and overlies Tbu_1. Thickness is ~90 m.

Tbu_1 – Intermediate-age basalt flows (middle to late Miocene) – Gray to brownish black aphanitic to slightly porphyritic basalt flows and flow breccias. Contains ~0–5% phenocrysts composed of ~90% subhedral to euhedral plagioclase <1 mm in length and ~10% ~1–3 mm long subhedral olivine, commonly altered to iddingsite. The low phenocryst percentage distinguishes this unit from Tbu_2. Thickness ranges from ~90–150 m. Tbu_1 is overlain by Tru_2 and Tbu_2, and locally overlies Tru_1 and older units.

Tru_1 – Intermediate-age rhyolite flows (middle to late Miocene) – White to beige and pinkish to red-violet, rhyolitic and rhyodacitic flows. Contains ~0–5% phenocrysts composed of ~95% 1–2 mm long subhedral plagioclase, commonly pitted and slightly altered, ~5% subhedral to euhedral biotite ~2 mm long, and trace amounts of <1 mm long rounded quartz. Groundmass is generally spheroidal devitrified glass. Unit is locally dense and non-vesicular, varying laterally to highly vesicular (vesicles 0–35%, <5 mm, usually round). Locally, the uppermost part of flow, where present, is composed of a friable white non-vesicular rhyolite. Locally, a green-black vitrophyre (<6m thick) crops out at the base of the rhyolite flow. Unit thickness varies but is approximately 60–90 m.

Subunits of Tru_1 – These units are found locally as lenses within Tru, as well as independently in other parts of the field area, predominantly on the west side, and are therefore correlated with Tru_1. Unit Tru_1 and all subunits are locally overlain by Tbu_1, Tbu_2, Tru_2, and Quaternary sediments. Unit Tru_1 is most extensive in the central part of the field area on Seven Troughs Mountain. Subunits Td, Tlt, and Trt are most prominent on the west side of the field area, where they conformably overlie Tbcn.

Td – Diatomaceous sedimentary rocks (middle to late Miocene) – Massive to finely laminated, white to yellowish-white, nonresistant diatomite that forms a discontinuous sequence intercalated with Tlt. The diatomite only crops out on the west side of the field area. Unit thickness ranges from a few meters to ~15 m.

Tlt – Lithic tuff (middle to late Miocene) – Pale gray to white fine-grained, non-welded to poorly welded lithic tuff. Contains fine-grained ash matrix with abundant lithics of volcanic rock that range in size from coarse ash (<2 mm) to lapilli (~2 mm up to 5 mm). Lithic clasts are generally subrounded to subangular and are composed of vitrophyre, rhyolite, basalt, and welded tuff. Phenocrysts include biotite, hornblende, and quartz. Tlt is generally massive, with local interbeds of fine-grained volcaniclastic sandstone and siltstone. Unit thickness is ~70 m.

Trt – Rhyolite tuff and reworked ash (middle to late Miocene) – Pale gray to white fine-grained, rhyolitic ash. Ash is phenocryst poor with less than 1% phenocrysts composed of hornblende and biotite. Unit consists of cross-bedded, ash layers that locally contain interbedded fine grained ash matrix with clasts of rhyolite and basalt up to 10 cm long. Unit varies from ~3 m thick on the east side of the field area to ~20 m on the west side. This unit locally rests directly on basement and therefore could potentially be temporally correlative with Twt, and thus may be older than Tru_1.

Trc – "Cap Rock" rhyolite (middle Miocene) – Pinkish to light brown rhyolitic flows. Flow foliation planar and usually prominent. Contains ~5–10% phenocrysts composed of ~60% subhedral plagioclase 1–2 mm in length (stubby laths to slightly rounded); 30% subhedral hornblende 0.5–1 mm across, and ~10% anhedral biotite <1 mm long, with trace quartz and sanidine. Groundmass is devitrified glass commonly with ~10% vesicles up to 1 mm long. Biotite and hornblende in Trc have yielded $^{40}Ar/^{39}Ar$ ages of 13.77+/- 0.06 and 13.79+/- 0.08 Ma, respectively (Hudson et al., 2006). Unit thickness varies but is as much as 150 m.

Tbcn – Basalt flows, and lesser cinder cones and volcanic necks, undivided (middle Miocene) –
Tbcn flows – Dark gray to greenish black, weathering to brown basalt flows. Contains 15–20% phenocrysts comprised of ~60% subhedral-euhedral plagioclase (some are unaltered and others are fritted) and 38% subhedral-euhedral olivine (some are partly altered to iddingsite), and 2% subhedral-euhedral clinopyroxene phenocrysts ~1–2 mm across. The fritted plagioclase phenocrysts contain calcite and/or sericite in the pits within the grain. Plagioclase phenocrysts vary in size from sub millimeter microlites in the fine-grained matrix to up to 8 mm long. Plagioclase phenocrysts display zoning and twinning). Olivine phenocrysts range in size from ~1 mm-5mm long. Groundmass consists mainly of plagioclase microlites with some olivine and pyroxene. Unit varies in thickness but is approximately 25 m thick in the northeast part of the field area and 300 m thick in the western part.

Tbcn cinder cones – Light greenish-yellow to red basaltic cinder, commonly interbedded with volcaniclastic sedimentary rocks. Individual scoria fragments range in length from <2 cm to 0.5 m. Locally contains reddish basaltic elongate to round bombs up to 2 m long. Thicknesses vary but are typically ~15 m.

Tbcn volcanic necks – Gray, commonly finely vesiculated, basaltic neck, usually in the form of a dike. Tbcn underlies Tru_1 and all upper units, and is locally overlain by Trc.

Subunits of Tbcn – These units are found typically below or in the lower part of the Tbcn section. They are only found on the eastern part of the field area and are not laterally continuous.

Ttss – Tuffaceous sandstone (middle Miocene) – Generally, a volcaniclastic to tuffaceous sandstone, containing sand-sized grains of aphanitic to porphyritic basalt, with a tuffaceous to fine silt matrix. Clasts are mainly angular to subrounded and composed of basalt. Unit thickness is ~10 m.

Tbp – Porphyritic basalt (middle Miocene) – This unit is generally altered and relatively phenocryst-rich dark gray basalt that weathers to grayish brown. Unit is easily distinguished by ~10–20% phenocrysts of large ~5 mm long olivine phenocrysts that have been altered to iddingsite. Tbp locally underlies Tbcn and is as much as 70 m thick.

Tbi – Basaltic dikes (middle Miocene) – Dark gray weathering brown, typically propylitically altered, aphanitic basalt dikes and endogenous domes. Thick dikes are likely multiple dikes or endogenous domes, which were not broken out on map. Dikes are generally aphanitic with ~5% phenocrysts ranging from 1–2 mm long of ~0.5% plagioclase, olivine, and pyroxene, and ~4.5% altered mafic mineral phenocrysts ~0.5 mm in diameter. The groundmass consists primarily of very fine grained plagioclase microlites (95%). Locally, unmapped calcite veins ranging in width from ~1–5 mm to 2 m cut Tbi. The calcite veins are a distinguishing characteristic in this unit. Locally, this unit is propylitically altered. Dikes intrude the older units (ꝶJs, Kg, Twt, Tbl, Tra and possibly Tbcn). Groundmass concentrate from Tbi has yielded an $^{40}Ar/^{39}Ar$ age of 14.1 Ma (Hudson et al., 2005, 2006).

Tra – Rhyolite flows, domes, and interbedded epiclastic sedimentary rocks, hydrothermally altered (middle Miocene) – Pinkish-purple to white and locally green, rhyolitic flows, breccias, vitrophyre, and dome deposits (units are extensively hydrothermally altered and were not broken out on map). Lenses of epiclastic sedimentary rocks and conglomerates crop out locally. This unit is typically hydrothermally altered with abundant clay content (smectite, illite, montmorillonite). Generally, the rhyolite flows and dome deposits contain ~3–5% phenocrysts composed of ~70% subhedral to euhedral biotite ~1–2 mm in length, ~29% subhedral plagioclase 1–2 mm long but locally up to 4 mm, and <1% subhedral hornblende ~1 mm across. Locally, this unit is a spherulitic rhyolite flow with spherules ranging in size from ~1–5 mm in diameter in a matrix of greenish glass. The epiclastic sedimentary rocks (conglomerate) are poorly sorted and poorly to moderately bedded; they may be part of an explosion outflow breccia. Angular to subrounded clasts up to 5 cm long consist primarily of rhyolite but include some basalt in a matrix of sand, silt, and clay. The conglomerate is locally interbedded within the rhyolite flows and was not broken out on the map from Tra. The domes typically contain a greenish-gray silicified vitrophyre at the base. This unit locally underlies Trc, Tbcn, Tru_1, Tru_2, Tbu_1, Tbu_2, and all Quaternary units; it is intruded by Tbi and rests locally on Tbl, Twt, and ꝶJs. This unit is confined to the eastern part of the field area in a bimodal volcanic center. Biotite and sanidine in Tra have yielded $^{40}Ar/^{39}Ar$ ages ranging from 14.27 +/- 0.04 to 14.11 +/- 0.04 Ma, respectively (Hudson et al., 2005, 2006). Tra thickness varies from ~100–150 m.

Tbl – Lowest basalt flow (middle to early Miocene) – Dense dark gray, generally massive aphanitic basalt flow. Contains ~1–2% phenocrysts composed of subhedral plagioclase <1 mm in length. Groundmass consists of plagioclase microlites with some alteration to sericite and clays. Tb_l is not laterally extensive, as it has only been observed in the mining district on the east side of the field area. Hudson et al. (2006) mapped this unit more extensively to the northeast (just outside the map area). This unit locally underlies Tra, Trc, Tbcn, Tru_1, Tru_2, Tbu_1, Tbu_2, and all Quaternary units; it is intruded by Tbi. A disconformity lies between this unit and the Oligocene (?) Twt below. Thickness varies from 10–30 m in the southeast part of the field area to up to 100 m in the northeast.

Twt – Welded ash-flow tuff (late Oligocene?) – Gray to purplish-beige and locally orangish-brown, moderately-welded ash-flow tuff. Contains ~10% phenocrysts composed of ~58% subhedral to euhedral sanidine ranging in size from <1 mm to 2 mm long, ~20% subhedral plagioclase 1–2 mm across, ~10% subhedral clinopyroxene (augite) phenocrysts ~1 mm long, ~2% anhedral to subhedral biotite, and trace quartz. The groundmass consists of pumice and volcanic glass. There are abundant fiamme (5–6 mm long to less than 1 mm) and pumice fragments throughout the unit. Thickness varies drastically throughout the field area, as Twt probably filled paleotopographic lows and pinched out near paleotopographic high points. Thickness ranges from 0 to 50 m. This unit rests nonconformably on the underlying ꝶJs and is overlain by all younger units.

Cretaceous intrusive rock

Kg – Granodiorite Intrusion (Late Cretaceous) – Medium-grained, equigranular, hypidiomorphic granodiorite. Contains ~20% mafics, consisting of anhedral to subhedral hornblende 1–5 mm in length (~50%), and euhedral to subhedral biotite 1–2 mm in length (~50%). The remainder of the rock is composed of euhedral to subhedral plagioclase and potassium feldspar (~1–4 mm long), and anhedral quartz (~1–4 mm long). Kg intrudes the metasedimentary (ŦJs) basement rocks in the Seven Troughs Range; it is locally intruded by Tertiary basalt dikes and is overlain locally by Quaternary sediments. Thickness unknown, but width of unit in map view is ~1.6 km.

Mesozoic metasedimentary rocks of the Auld Lang Syne Group

ŦJs – Interbedded slate, phyllite, argillite and sandstone (Late Triassic to Early Jurassic) – Greenish-brown to gray interbedded argillite, sandstone, slate, and phyllite, locally containing layers of quartzite, quartz breccia, and marble. This unit displays well-developed slaty cleavage and is strongly foliated, with a generally friable texture. It is deformed into northwest-trending folds. Locally, the unit contains andalusite, 5 mm–2 cm in length, associated with contact metamorphism from the intrusion of the Cretaceous granodiorite. This unit was extensively eroded prior to late Oligocene time, resulting in significant paleotopography which was later filled in by the Oligocene (?) ash flow tuff (Twt) and later by the Miocene volcanic rocks. Exact thickness of this unit in the field area is unknown, because the base of the section is not exposed. Burke and Silberling (1973) concluded that ŦJs ranges from 30 to over 7000 m thick in the surrounding ranges. ŦJs is the basement rock in the Seven Troughs Range; it is intruded by Kg and overlain by many of the younger units in the field area.

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