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Preliminary Geologic Map of the Northern Lake Range, San Emidio Geothermal Area, Washoe County, Nevada

by

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DESCRIPTION OF MAP UNITS

Anthropogenic Features and Deposits

Qx Disturbed and modified areas Highly disturbed, modified, and graded areas including the Wind Mountain open-pit mine (T30N R23E Section 34) and the U.S. Geothermal power plant (T29N R23E Section 16).

Playa and Related Deposits

Qp Playa deposits (latest Holocene to late Pleistocene) White to yellow-white, fine-grained silt, sand, and clay form very flat, whitish, sparsely vegetated surfaces and cover much of the floor of the San Emidio Desert; also fill small closed depressions. Desiccation cracks are common as well as eolian deposits clustered around sparse vegetation. Generally little to no soil development, but commonly moderate salt (gypsum) accumulation. Thicknesses poorly known due to lack of exposure, but generally thin (<1 m).

Qpf Playa fringe deposits (Holocene to late Pleistocene) Whitish to light grey silts, sands, and pebble gravel; typically mantled by eolian deposits derived from adjacent playa surfaces. Form very gently sloping, smooth surfaces; typically gradational with playa deposits and located at the transition from fan alluvium to playa deposits. Thicknesses poorly known, but generally thin (<1 m).

Hillslope Deposits

Qc Colluvium (Holocene to Pleistocene) Colluvial and talus deposits generally occurring at the base of steep slopes. Deposits typically consist of poorly sorted, angular to subangular, clast-supported cobbles and boulders. Deposits are generally less than 5 m thick.

Alluvial Deposits

Qa Young alluvium, undivided (Holocene to late Pleistocene) Alluvium in recently to annually active washes generally consisting of poorly to well-sorted sands to cobble-pebble gravels; locally contain boulders. Surfaces have rough bar-and-swale morphology. Clasts are generally subangular to subrounded. Little to no soil development. Thicknesses poorly known, but generally a few meters or less.

Qfy Young active fan alluvium and recently abandoned active alluvial surfaces (Holocene) Poorly to well-sorted pebble to cobble gravel and sands with angular to subangular clasts; locally contain boulders, especially at fan heads. Surfaces slightly to fully smoothed. Minimal to cambic soil development. Deposits are up to 1 m thick.

Qfy_1 Young active fan alluvium (late Holocene) Poorly to well-sorted pebble to cobble gravel; locally contain boulders, especially at fan heads. Surfaces generally slightly smoothed. Little to no soil development and thin (5–10 cm) silt caps. Poorly to moderately stratified, matrix-supported deposits with angular to subangular clasts. Surfaces commonly have bar-and-swale morphology. Deposits are as much as 2 m thick.

Qfy_2 Young fan alluvium, undivided (Holocene to late Pleistocene) Poorly to well-sorted pebble to cobble gravel with isolated boulders; poorly to moderately stratified, matrix-supported deposits with angular to subangular clasts. Surfaces are generally fully smoothed with poorly to moderately developed pavements and sparse cobble or boulder gravel bars. Typically have cambic soils and 10–20 cm silt caps. Deposits are as much as 3 m thick.

Qf Fan alluvium, undivided (Holocene to late Pleistocene) Small- to large-size, deeply incised fans. Poorly to well-sorted pebble to cobble gravel; locally

contain boulders, especially at fan heads; typically matrix supported and dominated by subangular to angular clasts. Variable surface morphology and soil development. Surfaces range from smooth to rough. Well-developed desert pavement. Deposit thickness may locally exceed 15m.

Qfi Intermediate fan alluvium, undivided (late to middle Pleistocene) Cobbly, pebbly, silty, coarse sands with isolated boulders. Generally weakly indurated, poorly to moderately stratified, moderately sorted, matrix-supported deposits with angular to subangular clasts. Surfaces are generally fully smoothed, erosionally rounded near surface edges, and well dissected. Typically have argillic soils and Stage III–IV carbonate horizons. Thicknesses poorly known, but up to 6 m.

Qfo Old fan alluvium, undivided (middle to early Pleistocene) Poorly to well-sorted pebble to cobble gravel; locally contain boulders, especially at fan heads; poorly to moderately stratified, matrix-supported deposits with angular to subangular clasts. Surfaces broadly rounded and moderately to well dissected. Stage IV carbonate horizons up to a meter or more thick with upper soil horizons typically stripped. Deposits are up to 5 m thick.

Qss Silicified alluvium, undivided (Holocene to Pleistocene) Well-indurated, poorly sorted, matrix-supported silicified alluvial fan deposits. These deposits include siliceous sinter and opal, as well as silicified reeds and gastropods. These are only exposed along a north-south trending zone of alteration, known as the San Emidio fault, along the eastern edge of the San Emidio Desert. T29N R23E Sections 4, 9, 16, 21.

Qas Acid-sulfate altered alluvium, undivided (Holocene to Pleistocene) Non-indurated, poorly sorted, matrix-supported acid-sulfate altered alluvial fan deposits. These deposits include clay alteration (kaolinite), as well as native sulfur, cinnabar, and gypsum. These are only exposed along a north-south trending zone of alteration, known as the San Emidio fault, along the eastern edge of the San Emidio Desert. T29N R23E Sections 4, 9, 16, 21.

Qasfg Acid-sulfate altered fanglomerate (Holocene to Pleistocene) Well indurated, weakly acid-sulfate altered, light-gray pebbly to bouldery alluvial fan deposits dominated by clasts of Mesozoic phyllite (TrJn). This unit is only sparsely exposed along a north-south trending zone of alteration, known as the San Emidio fault, along the eastern edge of the San Emidio Desert and consists of poorly stratified, matrix-supported, poorly sorted, fanglomerate with subangular to subrounded clasts of phyllite and quartzite with lesser aphanitic basaltic andesite (Tpb). These deposits include clay alteration (kaolinite), as well as native sulfur, cinnabar, and gypsum. T29N R23E Sections 4, 9, 16, 21.

Qtg Terrace gravels, undivided (late Holocene to Pleistocene) Poorly sorted gravels that form a thin lens, ~5 m thick, above the Tertiary rhyolitic tuff (Tr). These gravels consist of subrounded to rounded aphanitic basaltic andesite (Tpb), phyllite and quartzite (TrJn), and weathered, subrounded granite cobbles from the nearby Selenite Range. These gravels are only found above the identified Late Pleistocene Lake Lahontan highstand.

QTa Basin fill alluvium, undivided (late Holocene to late Miocene/Pliocene) Undivided sedimentary strata, including Quaternary alluvium and silicified and unsilicified late Miocene to Pliocene sandstone, siltstone, and clay-rich mudstone (Tss and Ts). Sandstone is light-tan to brown, thinly bedded, poorly- to well-indurated, poorly- to moderately-sorted, clast-supported litharenite with angular to subrounded grains up to ~3 cm long of fine-grained volcanic rocks and metasedimentary rocks (TrJn).

Quaternary Lacustrine Deposits

Qtu Subaqueous spring-related tufa deposits (Holocene to late Pleistocene) Light-brown dendritic tufa mounds crop out along a north-south trending zone of alteration, known as the San Emidio fault, along the eastern edge of the San Emidio Desert. These deposits are spatially associated with a north-trending Holocene fault scarp. T29N R23E Sections 4, 9, 16, 21.

Qtu/s Subaqueous spring-related tufa and siliceous sinter deposits (Holocene to late Pleistocene) Light-brown dendritic tufa mounds along with lenses of siliceous sinter crop out along a north-south trending zone of alteration, known as the San Emidio fault, along the eastern edge of the San Emidio Desert. These deposits are spatially associated with a north-trending Holocene fault scarp. T29N R23E Sections 4, 9, 16, 21.

Ql Shallow lake sediments (Holocene to late Pleistocene) Generally fine-grained, white to light-tan, well sorted, very weakly indurated silty sand, silt, and clay associated with pluvial Lake Lahontan. Thinly bedded <1 mm. Generally little to no soil development due to eolian deflation. Deposits are up to 3 m thick.

Qb Beach deposits (Holocene to late Pleistocene) Shoreline beach berms associated with Ql lake levels consisting of well sorted cobble pebble gravel to coarse sand. Clasts consist of well-rounded gray phyllite, white to pink quartzite, and aphanitic dark gray basalt. Typically have cambic soils with Stage II carbonate. Deposits are up to 6 m thick.

Tertiary Rocks

Tgc Fault related gypsum and calcite deposits Gypsum and calcite forming an unstratified crust within alluvium near a mapped fault. This unit only crops out in the northwestern part of the map area. This crust is 1–4 cm thick. T30N R23E Section 23.

Tcv Fault related sheeted calcite veins In the northwest part of the map area, mapped faults are commonly associated with topographically elevated sheeted calcite veins. The fabric of these veins matches the dip of the related fault. Calcite in these veins is generally in rhombohedral form up to 15 cm long. The veins range in thickness from 1 cm to ~20 m.

Tsf Sediments and fan alluvium This unit crops out in only the northwest part of the map area and consists of unconsolidated Tertiary sediments (Ts) and alluvium. Thickness ~5 m.

Tss Silicified sediments with siliceous sinter Pervasively silicified clastic Tertiary sedimentary rocks (Ts) with intercalated sinter horizons of probable fluvial and lacustrine origin. This unit makes up the majority of the Wind Mountain deposit. These rocks are white to light tan and gray with some red oxidation. The intense silicification of these rocks has erased sedimentary textures other than faint bedding. Individual beds range in thickness from <1 cm to more than 10 m. The entire unit is roughly 200 m thick.

Tr Rhyolitic tuff Isolated exposure of partially welded and slightly silicified, glassy, light-pink rhyolitic tuff. Dominantly glass with pumice and lithic fragments (up to ~1 cm long), of aphyric dacite and basaltic andesite. Phenocrysts (<5%) consist of fractured, slightly resorbed plagioclase (up to ~1 mm long) and lesser biotite and sanidine. This flow, ~5 m thick, has limited exposure at the top of the late Miocene-Pliocene sedimentary section (Ts) just east of the Wind Mountain epithermal mineral deposit and outside of the pervasive silicification. Plagioclase has yielded an $^{40}Ar/^{39}Ar$ age of 4.8±0.9 Ma (sample R09–49).

Ts Sedimentary rocks (late Miocene to Pliocene) Light-tan to brown, fine- to coarse-grained clastic sedimentary strata, including sandstone, clay-rich siltstone and mudstone, and conglomerate. Sandstone is thinly bedded, poorly- to well-indurated, poorly- to moderately-sorted, clast-supported litharenite with angular to subrounded grains up to ~3 cm long of fine-grained volcanic rocks and metasedimentary rocks (TrJn). Conglomerate is moderately-indurated, poorly-sorted, and matrix-supported with subangular to subrounded clasts of Tpb and TrJn up to ~5 cm long. These rocks crop out east of Wind Mountain and are locally weakly silicified. Thickness – 450 m.

Tcla Clay-rich sedimentary rocks Poorly-indurated, poorly stratified, white to light-tan, clay-rich alluvium of probable lacustrine origin exposed along the northeastern side of Wind Mountain; includes montmorillonite and gypsum that may be related to argillic alteration of late Miocene-Pliocene clastic sedimentary rocks (Ts). Individual beds are difficult to identify but are generally marked by cross-fiber gypsum deposits. Thickness – 30m.

Tapb Hydrothermally altered lower Pyramid sequence volcanic rocks Light gray aphanitic basaltic andesite, which has been hydrothermally altered to clay and iron oxides. Thickness – 10 m.

Thbr Hydrothermal breccia White to light-blue silicified breccia exhibiting hydrothermal flow textures and rounded clasts of chalcedony and Mesozoic metasedimentary rocks in a chalcedony matrix (TrJn). This unit is only exposed near mapped fault zones in the northwestern part of the map area. Pyrite up to 2 mm long can be found in the matrix and lithic fragments. Thickness – 1–10 m.

Pyramid Sequence

Tpd Dacite Aphyric to sparsely porphyritic, medium gray dacite containing <10% phenocrysts of plagioclase up to 1.5 mm long. Contains xenoliths of gray aphanitic andesite up to 5 cm long. These lavas crop out in only the eastern part of the map area and form Falcon Hill near State Highway 447. Plagioclase has yielded an $^{40}Ar/^{39}Ar$ age of 14.4±1.6 Ma (sample R10–60). Thickness – 50 m.

Tpts' Tuffaceous and volcaniclastic sedimentary rocks Heterogeneous package of well stratified, matrix and clast-supported, poorly to well sorted, light-brown to yellow and gray tuffaceous sandstone with lesser conglomerate. Sandstone is thinly to thickly bedded, moderately-indurated, non-calcareous to slightly calcareous, coarse-grained litharenite with tuffaceous matrix and subrounded to angular clasts of basaltic andesite, dacite, and pumice up to ~1 cm long. Beds range in thickness from less than ~2 cm to more than ~1 m. Sandstone exhibits some cross-bedding and scour marks with local soft-sediment deformation. Conglomerate is clast-supported and moderately sorted with angular clasts of aphanitic basalt (Tpb') up to ~10 cm long. These beds occur as lenses within the Pyramid sequence lavas (Tpb'). The cross-bedding and scour marks in the sandstone and conglomerate suggest a fluvial origin. Thickness – isolated lenses up to 3 m.

Tpb' Sparsely porphyritic basaltic andesite This unit consists of numerous flows and flow breccias of aphyric and aphanitic to sparsely porphyritic basaltic andesite with lesser olivine basalt. Flows are dark gray to red-brown and typically foliated. This foliation is more apparent in glassy aphyric lavas. Individual flows are ~2 to 25 m thick and

generally laterally continuous. Phenocrysts (generally <5%) consist of plagioclase (sparsely up to ~4 mm long), augite, and lesser olivine (typically altered to iddingsite) and orthopyroxene. Groundmass consists of fine- to coarse-grained plagioclase laths and olivine with fine-grained interstitial pyroxene. Glassier flows exhibit slightly flattened vesicles. Flow breccias contain lithics of mainly angular to subangular aphanitic basalt and scoria. Flow foliation indicates ~30° of tilting to the east. Plagioclase has yielded an $^{40}Ar/^{39}Ar$ age of 15.1±0.2 Ma (sample R09–167). Thickness – 700 m.

Tpts Tuffaceous and volcaniclastic sedimentary rocks Heterogeneous package of massive to well stratified, matrix- and clast-supported, poorly to well sorted, light-brown to gray tuffaceous sandstone and non-welded ash-flow tuff with lesser conglomerate and ash-fall tephra. Sandstone is thinly to thickly bedded, moderately indurated, non-calcareous to slightly calcareous, coarse-grained litharenite with tuffaceous matrix containing subrounded to angular clasts of basaltic andesite, dacite, and pumice up to ~1 cm long. Beds range in thickness from less than ~2 cm to more than ~1 m. Sandstone exhibits some cross-bedding and scour marks with local soft-sediment deformation. A non-welded pumiceous ash-flow tuff up to 5 m thick lacks bedding and contains basaltic and dacitic lithics up to ~10 cm long, angular pumice up to 5 cm long with lesser fiamme and vitrophyric clasts, and <5% phenocrysts of biotite, hornblende, and plagioclase. Conglomerate is clast-supported and moderately sorted with angular clasts of fine-grained oxidized basalt (Tpb) cobbles up to ~50 cm long. Ash-fall tephras are slightly reworked and up to ~15 cm thick with some rounding and flattening of vitrophyric shards. The sandstone and conglomerate indicate a fluvial origin for much of the Tpts unit. These rocks locally pinch out against paleo-topographic highs in the Triassic-Jurassic Nightingale sequence and occur in a north-trending topographic saddle between Mesozoic metasedimentary rocks (TrJn) to the west and Pyramid sequence lavas (Tpb') to the east. Thickness – 300 m.

Tptsu Tuffaceous and volcaniclastic sedimentary rocks, undivided Same heterogeneous package as Tpts but includes three semi-continuous basalt to basaltic andesite lenses (Tpbl', Tpp, Tpb) that crop out in a north-trending topographic saddle in the northern Lake Range.

Tpbl' Sparsely porphyritic basaltic andesite Dark gray to black, glassy, aphanitic basaltic andesite flow with typically sparse phenocrysts (<5%) of partially resorbed elongate plagioclase phenocrysts up to ~3 mm long and lesser augite and olivine. Olivine (<2 mm long) is typically altered to iddingsite. This flow, up to ~5 m thick, is a semi-continuous lens in the Pyramid sequence tuffaceous sedimentary unit (Tpts). Weak alteration of this flow has produced calcite in voids and disseminated cubic opaque minerals (most likely pyrite) throughout the groundmass.

Tpp Porphyritic basaltic andesite Dark gray to black, glassy, slightly vesicular, slightly porphyritic granular basalt with ~15% phenocrysts of slightly resorbed plagioclase laths up to ~2 mm long with lesser olivine altered to iddingsite. Groundmass is comprised primarily of fine-grained plagioclase and glass. This flow, up to ~10 m thick, is a semi-continuous lens in the Pyramid sequence tuffaceous sedimentary unit (Tpts). Plagioclase has yielded an $^{40}Ar/^{39}Ar$ age of 16.1±0.4 Ma (sample R09–39).

Tpb Basalt Black, aphanitic, aphyric basalt flows with <1% altered plagioclase phenocrysts up to ~2 mm long. This flow, up to ~10 m thick, is highly oxidized with a yellow and red staining and is a semi-continuous lens intercalated in the Pyramid sequence tuffaceous sedimentary unit (Tpts).

Lower Miocene Volcanic Rocks

Td Dacite Poorly exposed, light-gray porphyritic dacite with ~40% phenocrysts of hornblende (~40% of total phenocrysts; up to ~1 cm long), plagioclase (~35%, up to ~5 mm long), and biotite (~15%, up to ~3 mm long). This flow crops out in only the south-central part of the map area (T29N R23E Section 34). Faulting prevents an accurate estimate of the thickness. Hornblende yielded an $^{40}Ar/^{39}Ar$ age of 24.1±0.4 Ma, (sample R10–48).

Cretaceous Intrusions

KTr Flow-banded rhyolite dikes Poorly exposed, light-tan, slightly porphyritic rhyolite (<15% phenocrysts) with quartz phenocrysts up to ~2 mm. These dikes, up to 10 m thick and 30 m long, cross-cut the foliation in the Mesozoic metasedimentary rocks (TrJn) with generally an east to west strike with a weak flow-banding that generally parallels dike margins. The dikes do not cross-cut the overlying Pyramid sequence.

Triassic and Jurassic Nightingale Formation

ŦRJn Metasedimentary rocks, including phyllite, quartzite, and marble Metamorphosed and folded low-grade, argillaceous, dark gray phyllite, with some black slate and schist and intercalated light gray carbonate and light-tan to pink quartzite horizons. Phyllite and slate are highly micaceous with an average foliation dipping roughly 50° west. Quartzite horizons are up to 10 m thick, typically cross-cut by quartz veins, and have sparse micaceous lenses. Individual quartz grains have recrystallized and have a glassy appearance. Quartzite weathers to a reddish-brown due to iron-oxide content. Carbonate lenses, up to 1 m thick, are medium-grained with stringers of finer-grained more resistant sandy carbonate. White bull quartz is common as veins throughout ŦRJn.

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