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Preliminary Geologic Map of the Southern Lake Range, Washoe County, Nevada

by

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DESCRIPTION OF MAP UNITS

Quaternary Deposits

Qf Alluvial fan and recent alluvium Undivided fans that typically form at the base of steep slopes, issuing from drainage catchments or on the floor of wider drainage channels. These fans are generally clast-supported, composed of subangular to angular pebbles to boulders, (which form levees and lobes), and are locally derived from Pyramid sequence volcanic rocks. Distal portions of many fans are generally inactive, composed of abandoned lobes, and generally have well developed soils. Larger fans generally contain some active alluvium, which were not mapped in detail. The active alluvium consists of migrating ephemeral stream channels composed of unconsolidated sands and subrounded gravels including locally derived pebbles to boulders of Pyramid sequence volcanic rocks.

Qc Colluvium and talus Unconsolidated locally derived, poorly sorted, matrix- and clast-supported, angular and subangular cobbles and boulders with variable amounts coarse sand and immature soils. Colluvium is generally monolithologic and forms at the base of steep slopes and cliffs of basaltic andesite and dacite units, and to a lesser extent beneath conglomerate and tuff units. The southern Lake Range contains a significant amount of colluvium, which obscures many lithologic contacts.

Qtu Tufa A calcium carbonate rock, precipitated from springs and the waters of ancestral Lake Lahontan (Benson, 1994), crops out extensively along the base of the range below the Lake Lahontan high-stand (1,332 m). The tufa forms thick crusts on outcrops of Mesozoic and Miocene rocks, fills pore space within some underlying conglomerates, and locally marks ancestral and currently active hydrothermal springs.

Qlg Lahontan gravels Moderately sorted, well-rounded pebble-to cobble-sized gravel of generally Pyramid sequence basaltic andesites and dacite intermixed with areas of light-colored lacustrine silts, sands, and clays. Deposits form gravel bars and terraces, which mark multiple stages of ancestral Lake Lahontan shorelines. The highest Lake Lahontan terrace in the southern Lake Range reaches an elevation of 1,332 m. This terrace forms a nearly unbroken ribbon of gravel, which can be traced continuously around the southern tip of the range from the shores of Pyramid Lake to the Winnemucca basin. This terrace and several lower terraces are locally broken by younger alluvial fans (Qf), stream channels (Qa), colluvium (Qc), and locally covered by shifting eolian dunes.

Qls Landslide deposits Slope-failure-derived unconsolidated debris, poorly sorted, matrix-supported slump deposits dominated by cobble- to boulder- size clasts of Pyramid sequence basaltic andesite and dacite in a coarse pebble and sand matrix. The original headwall scarps are commonly unrecognizable.

Qrf Recent rockfall Clast-supported deposits of angular cobble- to boulder-size blocks of Pyramid sequence basaltic andesite and dacite. Rockfall is localized and shed from steep escarpments.

QTf Alluvial fan (late Miocene-Pliocene) Unconsolidated to locally moderately indurated, poorly sorted, matrix-supported deposits of subrounded to subangular cobble- to boulder-size blocks composed of Pyramid sequence volcanic rocks in a sandy soil matrix. Deposits generally form broad rounded low-relief hills covered by immature soil horizons and incised by younger streams of active alluvium (Qa) and alluvial fans (Qf). QTf deposits on the west flank of the eastern ridge are locally cut by Quaternary faults.

Pyramid Sequence

Tps_2 Upper Pyramid sequence basaltic andesite lavas The upper Pyramid sequence consists of a succession of roughly 15 to 20 basaltic-andesite flows that most commonly rest on the middle (Tpmm) or upper (Tpmu) cooling units of the tuff of Mullen Pass but locally overlie conglomerate (Tpc). The upper Pyramid sequence was mapped as a single unit (Tps_2). It contains flows compositionally similar to the lower Pyramid sequence (Tps_1), including finely porphyritic (Tppb') to aphanitic (Tpb) lavas. The coarsely porphyritic (Tppb) flows, abundant in the lower sequence, are less common in the upper sequence. Along the base of the upper sequence in many locations is a single flow, ~2–5 m thick, of olivine-rich basalt ($Torb_2$). A flow within the upper part of this unit (Tpb_2) yielded an 40Ar/39Ar age of 13.16±0.25 Ma (Drakos, 2007).

$Torb_2$ Olivine-rich basaltic lava Dark gray to black, finely porphyritic olivine-rich basaltic andesite. Consists of a single to possibly multiple flows that commonly rest on the middle (Tpmm) or upper (Tpmu) cooling units of the tuff of Mullen Pass. Individual flow(s) are generally 2–4 m thick, heavily jointed, and oxidized to a deep reddish-brown; interiors are massive with no distinct flow foliation. Contains fine aggregated grains of olivine to subequant, anhedral phenocrysts of olivine (10–15%, ~1 mm long), and fine-to medium-grained subeuhedral plagioclase phenocrysts (7%, 1–3 mm). Groundmass consists of pilotaxitic plagioclase, olivine, pyroxene, and opaque minerals.

Tpc Conglomerates A massive to well-stratified, matrix-supported, light brown volcaniclastic conglomerate and sandstone. Stratified sequences have a planar to cross-bedded structure of finely-bedded (1–10 cm thick), moderately to well-sorted, generally matrix-supported beds of subangular to subrounded pebbles within a fine-grained sandstone matrix. The more massive beds are generally poorly sorted, matrix- to locally clast-supported conglomerates with clasts up to 30 cm in diameter. The finely-bedded conglomerates probably originated as fluvial deposits, and the more massive beds probably originated as debris flows on alluvial fans. Clasts within the conglomerates mainly consist of Pyramid sequence basaltic andesite and dacite lavas, with some areas containing fragments of the lower tuff of Mullen Pass, rhyolite, and minor Mesozoic granitic rocks. Exposures vary from a few meters to laterally continuous outcrops nearly 1 km in length. Locally overlies the tuff of Mullen Pass or porphyritic dacite but more commonly forms thin lenses a few tens of meters long intercalated throughout the Pyramid sequence. This unit varies from less than a meter to more than 20 m thick.

Tpmu Upper tuff of Mullen Pass Single upper cooling unit of the tuff of Mullen Pass is a moderately welded, relatively resistant, commonly friable, light gray to yellowish-green dacitic tuff with prominent large, flattened, glassy black porphyritic fiamme ranging from 1–40 cm in length. Size and distribution of fiamme varies in some areas, with a few sections devoid of fiamme laterally over tens of meters; generally, fiamme make up ~5% to 35% of the rock. Evenly distributed throughout are small (0.5–4 cm long) white pumice (5%) and small (0.5–2 cm long) subangular basaltic andesite lithics (10%). This tuff is crystal rich and contains plagioclase (20–25% in matrix; 30–35% in fiamme; to 3 mm long), hornblende (5%), and biotite (3%) phenocrysts. Thickness is generally ~5 m with a maximum thickness of ~20 m. Hornblende yielded an $^{40}Ar/^{39}Ar$ age of 13.64±0.19 Ma (Drakos, 2007).

Tpmm Middle tuff of Mullen Pass Single middle cooling unit of the tuff of Mullen Pass separates lower (Tpml) and upper (Tpmu) cooling units. Tpmm is a poorly welded, slightly friable, white to light gray pumiceous tuff (5%), containing no fiamme. It is generally massive but locally displays faint planar to cross-bedded structure. It contains angular to subrounded basaltic andesite and minor dacite lithic fragments (10%, 0.1–10 cm long) and locally subangular fiamme fragments presumably from Tpml (?). The tuff is crystal rich and contains plagioclase (7–10%, to 2 mm long) and biotite (7%, 1–2 mm long) phenocrysts. Tpmm ranges from a few meters to more than 45 m thick.

Tpml Lower tuff of Mullen Pass Lower cooling unit of the tuff of Mullen Pass is a dark-gray to brown, densely to poorly welded dacitic tuff, which contains extensive small (5–9 cm long) lenticular-shaped fiamme. The black sparsely-porphyritic fiamme define a well developed compaction foliation. The base of the lower unit is an ~1 m thick, densely welded, hackly fractured zone, with a dark purple matrix and no fiamme. This tuff is crystal-poor, with plagioclase (~5%; to 3 mm long) phenocrysts, biotite (~1%) phenocrysts, hornblende (~1%) phenocrysts, and abundant angular felsic and mafic volcanic lithic fragments (10%). The tuff forms steep columnar jointed escarpments. Tpml ranges from a few meters to ~30 m thick.

Tts Tuffs, reworked tuffs, and sandstones A series of light brown to white, slightly friable, crystal-poor pumiceous tuffs, interbedded with thin layers of glassy tuff, reworked tuffs, moderately indurated tuffaceous sandstones and unconsolidated volcaniclastic sands. The tuffs contain 5–10% subrounded to subangular basaltic andesite, dacite and minor granitic lithics. Commonly, large blocks of Td lie within Tts, indicating erosion of the dacite prior to deposition. This unit contains a significant amount (~10%) of silicified wood ranging from small fragments to large trunks and stumps. Fragments of

fossilized wood, the most resistant parts of this unit, are commonly found as float in light colored soils indicating outcrops of this unit in poorly exposed areas. This unit varies from a few meters to more than 10 m thick.

Td Porphyritic dacite Composed of flows, domes, and/or sill structures, this unit can be readily identified by its characteristic platy flow foliation, which subparallels contacts within the interior of the unit but is typically steeply inclined within a few meters of the upper contact. The dacite is the thickest (~80 m) single unit in the southern Lake Range. Outcrops are generally resistant and weather to a dark maroon or brown color. The dacite contains altered phenocrysts of plagioclase (15–20%), hornblende (1–2%) up to 1 cm long, and biotite (~1%) in a medium-gray matrix. The high peaks on Anaho Island, mapped by Faulds et al. (2003) as a dacite dome, correlate with the dacite in the southern Lake Range. This unit varies from a few meters to ~ 80 m thick.

Tpt_2 Scoracious and pumiceous ash-flow tuff This scoriaceous and pumiceous ash-flow tuff is massive and contains ~60% mafic scoria and white to brown pumice fragments, ~25% fine white ash, and ~15% subangular mafic clasts. Overall, this unit is crystal-poor; however, some scoria and pumice fragments contain minor amounts of plagioclase phenocrysts (1–4 mm long). The Tpc' and Tpt_2 units are generally laterally continuous throughout the map area and commonly preserved beneath the porphyritic dacite flow. Thickness ranges from a few centimeters to 3 m.

Tpc' Volcaniclastic conglomerate and sandstone Tpc' includes two distinct sequences, each 2–3 m thick, of matrix- to clast-supported volcaniclastic conglomerate and sandstone. The Tpc' sequence consists of distinct planar, laterally continuous, stratified beds that exhibit variations in lithology and lithofacies. Individual beds are generally massive and poorly sorted. However, some beds are diffusely stratified and/or internally cross laminated and display various degrees of normal to reverse sorting. The beds are moderately indurated and composed of angular to subrounded mafic to andesitic clasts in a sandstone matrix. Thickness ranges from a few centimeters to 3 m.

Tps_1 Lower Pyramid sequence basaltic andesite lavas The base of the Tertiary section consists of a succession of roughly 20 to 25 basaltic-andesite flows that rest disconformably on the Oligocene tuffs and nonconformably on Mesozoic basement. This succession of flows was correlated with the lower Pyramid sequence and mapped as a single unit (Tps_1) in some locations and divided into separate units in others. Three subgroups of basaltic-andesite lavas were distinguished by size and volume of plagioclase phenocrysts; coarsely porphyritic ($Tppb_1$), finely porphyritic ($Tppb'_1$), and aphanitc units (Tpb_1). A crystal-poor basaltic agglomerate (Tba_1) and a basaltic scoria (Tbs_1) are also subdivided in this lower sequence. The individual basaltic andesite flows form steep ledges from 1–5 m in height. No obvious unconformities occur within the lower sequence, providing evidence for rapid deposition of lava flows. However, thin lenses of scoria, tephra, and conglomerate of limited lateral extent are locally sandwiched between flows. The lower Pyramid sequence (Tps_1), as a whole, has a maximum thickness of ~200 m.

Tbs_1 Basalt scoriaceous breccia A clast-supported basalt breccia with a fine lapilli matrix oxidized to a light yellowish-tan color. Breccia beds are massive and poorly sorted containing dark gray basaltic scoria, lapilli, and subangular clasts of basaltic andesite (1–15 cm long). A large outcrop is located in the S ½ of section 36 (T25N, R22E), where a 20 m thick fluted exposure is cut by a fault and intruded by a thick (~15 m wide) rhyolite dike (Tri).

Tba_1 Basalt agglomerate A coarse-grained, angular, blocky, oxidized, and massive basalt agglomerate; sparsely porphyritic containing 1–2% plagioclase phenocrysts. This unit varies from a few meters to ~ 60 m thick.

Tpb_1 Aphanitc to finely porphyritic basaltic andesite lavas Medium to dark gray aphanitic to sparsely porphyritic basaltic andesite lavas. Individual flows are generally 2–3 m thick, hackly fractured and massive to faintly flow banded. Flows near the summit of Cui Ui Peak exhibit distinct light- and dark-gray flow bands. Upper surface of many flows are vesicular (5-20%) with spherical to elliptical shaped vesicles. The flows contain phenocrysts (<5%) of plagioclase (≤2%; 1–2 mm long) and olivine (0–2%; 1 mm). Groundmass consists of pilotaxitic plagioclase, pyroxene, and opaque minerals. Age: ~15.50 Ma.

$Tppb'_1$ Finely porphyritic basaltic andesite lavas A variant to the coarsely porphyritic (Tppb) basaltic andesite flows. These flows are medium to dark reddish gray finely porphyritic flows with abundant plagioclase phenocrysts less than 5 mm long. Individual flows are generally 2-3 m thick, hackly fractured, and massive to faintly flow banded. Flows range from non-to highly-vesiculated (0–15%) with elliptical shaped vesicles 0.5–3 cm in diameter. Contains fine-to medium-grained euhedral to subeuhedral plagioclase phenocrysts (10–15%, 2–5 mm long), pyroxene (augite) (7%, 1–2 mm), and olivine (2% 1–2 mm). Groundmass consists of microcrystalline plagioclase, pyroxene and opaque minerals.

$Tppb_1$ Porphyritic basaltic andesite lavas Dark gray to maroon coarsely porphyritic (15–40%) flows contain characteristic coarse-grained, euhedral to subhedral, tabular plagioclase 5–30 mm long. Flows range from moderately-to highly-vesiculated (5–15%), and individual

flows are generally 3–4 m thick with several flow complexes over 100 m thick. Outcrops are generally massive and highly fractured with a granular texture. Tabular plagioclase phenocrysts typically display a flow foliation, which is chaotic to aligned subparallel to flow surfaces. Thickness is generally ~2 m with a maximum thickness of ~4 m Plagioclase yielded an $^{40}Ar/^{39}Ar$ age of 16.09±0.34 Ma (Drakos, 2007).

Tpt_1 Unnamed tuffs of the lower Pyramid sequence A sequence of tuffs sandwiched between the mafic flows of Tps_1 within the western ridge of the map area (W ½ of section 35, T25N, R22E). The tuffs pinch out to the south and wrap around the north-end of the western ridge. This sequence of tuffs displays distinct variations in lithology and lithofacies, including in ascending order: 1) a basal, ~2–3 m thick, tuff breccia with pebble- to boulder-size clasts of basalt (Tps_1) and a semi-glassy light brown matrix; 2) a pumiceous, crystal-poor tuff ~3–4 m thick, containing in one location a fossilized tree ~15 m long; 3) an ~1 m thick sequence of thinly bedded, cross-laminated, light brown volcaniclastic sandstone; 4) ~5 m of crystal-rich pumiceous white tuff, with massive to diffusely stratified zones containing 2–50% lithics of basalt (Tps_1) ranging from 1–30 cm long; 5) an upper ~4 m thick, densely welded, columnar jointed tuff with a compaction foliation defined by black porphyritic fiamme. The contact between the upper two zones is gradational. Both of these zones are crystal-rich with similar phenocryst assemblages, which include ~10% plagioclase and up to 5–7% biotite. Though well defined and laterally continuous in this location, no other outcrops of Tpt_1 were discovered within the southern Lake Range. Thickness ~20 m.

Intrusions

Tbd Basalt dikes Several thin (~1 m) north-to northwest-striking basaltic dikes intrude basaltic (Tbi) and rhyodacite (Trd) domes in the southern intrusive zone and the middle tuff of Mullen Pass (Tpmm) within the southern escarpment. The dikes are aphanitic to finely porphyritic with 10–15% plagioclase phenocrysts 0.5–1 mm in length. Aligned phenocrysts generally parallel the near vertical dips of the dikes. Compositionally similar lava flows, a spatter cone, and other near-vent agglutinate deposits proximal to the dikes in the southern intrusive zone suggest that these dikes served as feeders to numerous flows.

Tbi Basalt intrusions A series of basaltic plugs and cones composed of a mixture of scoria beds, lava flows, and to a lesser extent spatter cones comprise the western and northern extent of the southern intrusive zone. These domes rise tens of meters from the valley floor below the eastern ridge of the map area and cut the rhyodacite dome (Trd), and the lower (Tpml) and middle (Tpmm) cooling units of the tuff of Mullen Pass. Atop the northernmost dome several north-striking basaltic dikes (Tbd) form resistant spines as much as 2.5 m in height.

Trd Porphyritic rhyodacite intrusion A single medium gray to medium brown porphyritic rhyodacite dome cuts lower Pyramid sequence (Tps_1) in the southern intrusive zone. Phenocrysts in the rhyodacite are fine-grained plagioclase (~7%, 1–3 mm), sanidine (~2%, 1–2 mm), quartz (~2%, 1–3mm), and hornblende (1%, 2–3 mm) in an aphanitic to glassy medium-gray matrix.

Tri Porphyritic rhyolite intrusion Three porphyritic rhyolite intrusions are found in the southern Lake Range. One in the northern half of the southern Lake Range is a north-striking rhyolite dike, which intrudes a basaltic scoria flow (Tbs_1), a thin series of conglomerates (Tpc'), and scoriaceous and pumiceous tuffs (Tpt_2) in the SW ¼ of section 36 (T25N, R22E). The second is a large northwest-trending porphyritic rhyolite plug, which cuts lower Pyramid sequence basaltic-andesite flows along the southern margin of the southern intrusive zone. The third is a rhyolite intrusion, which crops out in patches amid substantial colluvium at the base of the eastern ridge at the northern extent of the southern intrusive zone. Phenocrysts in the rhyolite are fine- to medium-grained euhedral plagioclase (5–7%) ~1-5 mm long, sanidine (~3%), quartz (~2%), and biotite (1%) in a white to light pink aphanitic groundmass. Sanidine from the northwest-trending plug yielded an $^{40}Ar/^{39}Ar$ age of 15.30±0.05 Ma (Drakos, 2007).

Oligocene Ash-Flow Tuffs

Tt? Unnamed Oligocene ash-flow tuff A cream to pink colored, moderately to densely welded, porphyritic ash-flow tuff forms an ~80 m diameter mound along the southern base of the large rhyolite plug (Tri) located in the SW ¼ of the NE ¼ of section 18 (T24N, R23E). The tuff is massive with no distinct compaction foliation. Evenly distributed throughout are small subangular basaltic andesite lithics (7–10%, 0.5–3 cm) and flattened white pumice (5%, 0.5–6 cm) containing biotite phenocrysts (~3%, 1–3 mm). This tuff is relatively crystal-rich and contains fine- to medium-grained plagioclase (10%, 1–5 mm), biotite (5%, 1mm), and quartz (2–3%, 2 mm) phenocrysts. Thickness at least 5 m.

Tnh Nine Hill Tuff A moderately welded, sparsely porphyritic (1–2%) ash-flow tuff containing fine-grained phenocrysts of sanidine, plagioclase, quartz, and anorthoclase. The sparse phenocrysts indicate a correlation with the lower of two phases of the Nine Hill Tuff (Deino, 1985; Henry et al., 2004; Hinz, 2004). This tuff has been altered to a pale reddish color, and flattened lenses of white pumice are visible but altered. The only

exposure of this tuff in the southern Lake Range is located in the SE ¼ of section 7 (T24N, R23E) on the north slope of the rhyodacite dome (Trd). Age: 25.3 Ma. Thickness ~15 m.

Tcc Tuff of Campbell Creek (Henry et al. 2012) White to cream colored, densely welded, and sparsely porphyritic ash-flow tuff contains fine-grained phenocrysts of smoky vermicular quartz and minor sanidine. This tuff forms a very small (few square meters) inconspicuous outcrop located in the N ½ of the NE ¼ of section 18 (T24N, R23E). Age: 28.8 Ma. Thickness is only a few meters.

Tac Tuff of Axehandle Canyon A white to medium-gray ash-flow tuff resting nonconformably atop the Cretaceous quartz monzonite (Kqm). The tuff is densely welded and contains phenocrysts of sanidine, plagioclase, quartz, and biotite in decreasing order of abundance. The outcrop is located in the SE ¼ of the SW ¼ of section 34 (T25N, R22E). Age: 31.28 Ma. Thickness 10–15 m.

Mesozoic Rocks

Kqm Quartz monzonite A light gray, medium- to coarse-grained, equigranular, quartz monzonite intrusion. Contains abundant plagioclase, alkali feldspar, quartz, biotite, and hornblende. Genetically related to granitic plutons that are generally regarded as continuous with the Sierra Nevada batholith (Bonham and Papke, 1969). Regionally intrudes Jurassic (?) metasedimentary rocks (Jms) and carbonates (Jc).

Kd Granodiorite A dark gray to greenish, fine- to medium-grained, granodiorite intrusion. Contains abundant plagioclase, quartz and biotite and occurs as a smaller body within the larger quartz monzonite intrusion.

Jms Metasedimentary rocks A broad range of sedimentary rocks including quartzites, and argillites as roof-pendants up to tens of meters across within the quartz monzonite (Kqm). Bonham and Papke (1969) identified these rocks as part of the Nightingale sequence.

Jc Carbonate rocks Medium to dark gray, recrystallized limestone and dolomite as roof-pendants within the quartz monzonite (Kqm). Bonham and Papke (1969) identified these rocks as part of the Nightingale sequence.

REFERENCES

Benson, L., 1994, Carbonate deposition, Pyramid Lake Subbasin, Nevada: 1. Sequence of formation and elevational distribution of carbonate deposits (Tufas): Paleogeography, Paleoclimatology, Paleoecology 109, p. 55–87.

Bonham, H. F., and Papke, K. G., 1969, Geology and mineral deposits of Washoe and Storey Counties, Nevada: Nevada Bureau of Mines and Geology Bulletin 70, 139 p.

Deino, A. L., 1985, Stratigraphy, chemistry, K-Ar dating, and paleomagnetism of the Nine Hill Tuff, California-Nevada; Miocene/Oligocene ash-flow tuffs of Seven Lakes Mountain, California-Nevada; improved calibration methods and error estimates for potassium-40-argon-40 dating of young rocks: Berkeley, University of California, Ph.D. dissertation, 457 p.

Drakos, P.S., 2007, Tertiary stratigraphy and structure of the southern Lake Range, northwest Nevada: Assessment of kinematic links between strike-slip and normal faults in the northern Walker Lane [M.S. thesis]: University of Nevada, Reno, 165 p.

Faulds, J.E., dePolo, C. M., and Henry, C. D., 2003, Geologic map of the Sutcliffe Quadrangle, Washoe County, Nevada: Nevada Bureau of Mines and Geology Open-File Report 03-17.

Henry, C. D., Faulds, J. E., and dePolo, C. M., 2004, Geologic map of the Dogskin Mountain Quadrangle, Washoe County, Nevada: Nevada Bureau of Mines and Geology Map 148, scale 1:24,000.

Henry, C.D., Hinz, N.H., Faulds, J.E., Colgan, J.P., John, D.A., Brooks, E.R., Cassel, E.J., Garside, L.J., Davis, D.A., and Castor, S.B., 2012, Eocene-early Miocene paleotopography of the Sierra Nevada – Great Basin – Nevadaplano based on widespread ash-flow tuffs and paleovalleys: Geosphere, v. 8, p. 1–27. doi:10.1130/GES00727.1.

Hinz, N.H., 2004, Tertiary volcanic stratigraphy of the Diamond and Fort Sage Mountains, northeastern California and western Nevada – Implications for development of the northern Walker Lane [M.S. thesis]: University of Nevada, Reno, 110 p.

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