Text and references accompanying Nevada Bureau of Mines and Geology Open-file Report 21-2

Geologic Map of the Sloan NE Quadrangle, Clark County, Nevada

by

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DESCRIPTION OF MAP UNITS

Quaternary Alluvial-Fan Deposits

Qfy Young alluvial-fan deposits, undivided (Holocene) Coarse-grained alluvial deposits in intermittently active alluvial fans and washes; typically sandy pebble- to cobble-sized gravel with boulders. At range fronts, Qfy grades into and includes young pediment veneers of colluvium. Clasts are subrounded to subangular. Surfaces have complex distributary flow patterns with morphology ranging from fresh bar-and-channel forms to slightly smoothed surfaces with moderately developed gravel pavement and light rock varnish on volcanic clasts. Includes abandoned terraces 0.25–2 m above active washes. Typically has weak to no soil development. If present, soil development is characterized by Stage I, $CaCO_3$ coatings on bottoms of clasts. Exposed thickness of the unit is typically 1–4 m.

Qfi Intermediate-aged alluvial-fan deposits (early Holocene to late Pleistocene) Coarse-grained alluvial deposits in mostly inactive alluvial fans and terraces; typically sandy pebble- to cobble-sized gravel with boulders. At range fronts, Qfi includes abandoned, moderately cemented pediment veneers of colluvium. Clasts are subrounded to subangular. Surface morphology is planar with strongly developed, tightly packed gravel pavement and dark to very dark varnish on volcanic clasts. Very coarse, boulder-rich deposits on the east side of the McCullough Range have a muted bar and swale depositional morphology preserved. Incised drainages have a tributary pattern with channel incision ranging from 1–4 m. Stage II–III $CaCO_3$ horizons up to 1.5 m thick and argillic soil horizons typically erosionally stripped. Exposed thickness of the unit rarely exceeds 5 m.

Qfo Older alluvial-fan deposits (middle to early Pleistocene) Coarse-grained alluvial deposits in inactive or relict alluvial fans and terraces; typically sandy pebble- to cobble-sized gravel with boulders. Clasts are subrounded to subangular. Surface morphology varies from planar and smooth with erosionally rounded margins to fully rounded erosional remnants. Planar surfaces have tightly packed gravel pavement, very dark varnish, and some surface litter of pedogenic carbonate clasts. Surfaces are highly dissected by 2- to 6-m-deep tributary channels. Topographic separation from inset Qfi fans varies from minimal to over 6 m. Upper soil horizons erosionally stripped, Stage III–IV $CaCO_3$ horizons up to 2.5 m thick form a continuous carbonate-rich layer with local development of laminar carbonate structure. Exposed thickness of the unit ranges from 5 to ~10 m.

QTf Oldest alluvial-fan deposits (early Pleistocene to Pliocene) Coarse grained alluvial deposits in relict alluvial fans and high-standing alluvial deposits abandoned by deep dissection. Grain size comprised largely of boulder-gravels with subangular to subrounded clasts. Soils are characterized by Stage IV to VI $CaCO_3$ Bk horizons, with pedogenic carbonate forming a continuous 2–4+ m thick layer with common laminar carbonate structure and local brecciation. Upper soil horizons erosionally stripped. Surface morphology varies from deeply dissected topography with roughly concordant ridge crests to fully eroded, isolated ballenas with discordant ridge crests. At range fronts, high-standing erosional remnants of QTf deposits commonly overlie exposed bedrock erosion surfaces. Desert pavement is rarely preserved. Surfaces are commonly characterized by a surface rubble layer of broken fragments of petrocalcic fragments giving the unit a very light color in aerial imagery. QTf surfaces are commonly 5–15+ m above active washes. Exposed thickness of the unit

ranges from 5 to 50 m. Where QTf overlies Ts contact is approximate and gradational.

Miocene Volcanic and Sedimentary Rocks

Ts Tertiary sedimentary rocks, undivided (Pliocene? to middle Miocene) Tan to red-orange pebbly sandstone, sandstone, and sandy pebble-boulder conglomerate dominated by volcanic lithic fragments, with local interbedded thin non-welded tuffs and reworked tuffs. Sandstones are medium- to very-coarse-grained with mostly poorly sorting and angular to subrounded grains in a locally tuffaceous matrix; they are rarely well sorted with planar to large-scale tabular cross-stratification. Conglomerates are massive to crudely bedded and show mixed matrix- and clast-support; clasts are very poorly sorted and range from mostly subrounded to subangular small pebbles and rare pumice lapilli to boulders. Includes several thin (<1.5 m thick), interbedded, laterally discontinuous trachydacite to rhyolite ash fall tuffs typically composed of homogeneous white ash with conspicuous small (<40 mm) dark gray to purple volcanic lithic fragments and rare white pumice lapilli. Clastic beds are generally structureless, but locally display uncommon channel scours, low-angle cross-stratification, and large-scale (>10-m-wide) channel forms. Lowermost Ts is locally intercalated with Thvba, Tht, and Thd; the limited lateral extent and thickness of these oldest Ts deposits suggest that they irregularly filled topographic lows. The oldest Ts deposits in the map area overlie the Colony dacite (Tcd) and suggest a maximum age of ~14.9 Ma; the youngest overlie the Henderson dacite (Thd), which is undated in the Sloan NE quadrangle. Here we report the age of a tuff intercalated with Ts in the adjacent Boulder City NW quadrangle that has a U-Pb zircon age of 9.31 ± 0.16 Ma (table 1). The upper contact of the youngest Ts deposits is gradational with overlying QTf, suggesting that the deposit may be as young as Pliocene. The maximum exposed thickness of this unit in the quadrangle is ~60 m.

Thd Henderson dacite (late to middle Miocene) Medium gray, pink, or pale purplish-gray, flow-banded, porphyritic dacite lavas with a trachyitic texture and composition, commonly weathered rusty or dark brown. A dense, black, virtophyric dacite porphyry up to 2 m thick is commonly preserved within ~5–6 m of the base of individual flows. Phenocrysts include abundant euhedral feldspar (6–8%; 3–5 mm) and less common black or brassy biotite (2–3%; 1–3 mm), with uncommon glomerocrysts of clinopyroxene (<1–2%; up to 5 mm). The base of Thd is typically composed of ~2–6 m of autobreccia consisting of black vitrophyric dacite porphyry clasts in a pale yellow-green, perlitic matrix. The flow interiors commonly display evenly spaced, cm-scale flow foliations that are subparallel to the base and top of each flow near its margins, and more steeply inclined and variable near the interiors of flows. Thd is depositionally overlies units Thvba, Ts, and Tht, which suggests that the basal contact is at least locally unconformable. Thd is overlain by discontinuous channelized sandstone and tuffs of unit Ts. The age of Thd is uncertain, but it must be younger than the underlying 13.88 Ma tuff of Henderson (Tht). Thd consists of at least three extrusive dacite lava domes and/or lobes. The most completely exposed flow unit occurs in the north-central part of the map, where the single flow reaches a maximum thickness of ~220 m. There, preserved flow fabrics indicate paleoflow toward the west, implying a vent area farther east along the northern edge of the map or in the adjacent Las Vegas SE quadrangle. Thd may be as old as ~14.4–14.0 Ma in the Las Vegas SE quadrangle based on two new U-Pb zircon ages reported here; an $^{40}Ar/^{39}Ar$ age determination for this unit in the Sloan NE quadrangle is in progress (table 1).

Tht Tuff of Henderson (middle Miocene) White, massive, unsorted pumice lapilli trachydacite tuff that weathers tan to pale orange-pink and contains conspicuous euhedral biotite (~2–4%; ~1–2 mm) and up to 3–5% dacite lithic clasts typically up to ~4 cm in diameter. The upper part of the tuff is usually reworked with an excess of volcanic lithic clasts from unit Ts. Tht is laterally discontinuous and is either intercalated with Ts or unconformably overlies Thvba. We report a new U-Pb zircon age of 13.88 ± 0.13 Ma for this unit (table 1). This age is compatible with its stratigraphic position above the Hidden Valley volcanic unit (Thvba) that has a maximum age of ~14.1 Ma in the central McCullough Range to the south (Smith et al., 2010). Tht is typically ~1.5–2.5 m thick and has a maximum thickness of ~4 m in the map area. The vent source of the tuff of Henderson is unknown.

Sloan volcanic units (middle Miocene)

The Sloan volcanic units stratigraphically overlie the Hidden Valley volcanic unit (Thvba) and consists of a group of andesite and dacite volcanic centers located west and southwest of the Sloan NE quadrangle in the vicinity of Hidden Valley (Bridwell, 1991; Smith et al., 2010; Hinz et al., 2015). The ages of the volcanic rocks range from ~14.0 to 12.9 Ma based on stratigraphic relations and two new U-Pb dates from this study (table 1).

Tmsd Mount Sutor dacite (middle Miocene) Gray, porphyritic dacite lava flows and domes, geochemically classified as trachytes (fig. 1). Phenocrysts include abundant biotite (5–10%; 1–4 mm), relatively less plagioclase (up to 2–7%), and accessory clinopyroxene in a dense, medium or dark gray to purplish-gray groundmass. Well-defined cm-scale flow foliations and evenly-spaced subvertical joints are common, particularly in flow interiors. Tmsd is in depositional contact with underlying Mount Hanna andesite (Tmha). This unit is mapped as Mount Sutor dacite (Tss) by Bridwell (1991) and Smith et al. (2010), and as extrusive and intrusive dacite (Td_2 and Tdi_2) in the adjacent Sloan quadrangle (Hinz et al., 2015). We report two new U-Pb zircon dates of 13.35 ± 0.32 and

12.90 ± 0.16 Ma for this unit, both of which were collected from Tmsd in the adjacent Hidden Valley quadrangle (table 1). The maximum preserved thickness of Tmsd in the Sloan NE quadrangle is ~280 m. "Mount Sutor" is an informal place name for peak 4186' in the southwest corner of the Sloan NE quadrangle.

Tmha Mount Hanna andesite (middle Miocene) Black, aphanitic trachyandesite lava flows. Completely aphyric with a glassy, microvesicular groundmass. Tmha only occurs along the southern edge of the map area where it is up to ~30 m thick and overlies olivine-phyric basalt flows of unit Tmhb. These lavas are correlated with the Mount Hanna andesite ('Tsh') of Bridwell (1991), who characterized them as high-silica andesites based on whole-rock geochemistry; a sample from the Sloan NE quadrangle contains similarly high SiO_2 (MD21sne-231; fig. 1). The inferred vent location is ~5 km south of the southwestern corner of the map area. The maximum exposed thickness of Tmha in the map area is ~60 m; farther south it reaches a maximum thickness of ~300 m (Bridwell, 1991). "Mount Hanna" is an informal name for peak 4240' in the northern McCullough Range, to the south of the map area.

Tmhb Mount Hanna basalt (middle Miocene) Very dark gray, microporphyritic olivine basalt flows with a dense, very fine-grained, glassy groundmass consisting of microlitic plagioclase. This unit is distinguished from Tmha by the presence of <1% to 5%, small (<2 mm wide) olivine phenocrysts that are commonly altered to iddingsite, and low SiO_2 (fig. 1). Phenocrystic plagioclase is rare. Lavas are generally massive, locally vesicular, and sometimes display a <2-m-thick, discontinuous basal autobreccia. The contact between Tmhb and underlying Thvba is depositional, with Tmhb onlapping and pinching out eastward over Thvba in the southwest part of the quadrangle. The exact age of Tmhb is uncertain. Individual Tmhb lavas are up to 12 m thick; the unit reaches a maximum thickness of ~30 m in the map area based on estimates from cross sections. "Mount Hanna" is an informal name for peak 4240' in the northern McCullough Range, to the south of the map area.

Hidden Valley volcanic unit (middle Miocene)

This unit was first described and informally named by Bridwell (1991) after good exposures around Hidden Valley, which is located southwest of the Sloan NE quadrangle. In the study, area it was referred to as the "Fog Ridge andesite" by Boland (1996) and the "Hidden Valley andesite" by Smith et al. (2010). Although not directly dated, the age of this unit is inferred to be ~14.1–13.1 Ma based on its stratigraphic position above the tuff of the McCullough Pass and below the Sloan volcanic section (Smith et al., 2010). A new age from the overlying tuff of Henderson (Tht) further constrains the emplacement of Thvba to no later than ~13.9 Ma in the northern part of the quadrangle. This unit is compositionally similar and equivalent in age to the Mount Davis basalt unit in the adjacent Boulder City NW quadrangle (Tdmb; Hinz et al., 2017) and along the lower Colorado River extensional corridor (Tdm; Anderson, 1977; Faulds, 1995; Dee et al., 2016).

Thvba Hidden Valley basaltic andesite (middle Miocene) Medium to dark gray or black vesicular basaltic trachyandesite lava flows with rusty red autobreccias and subordinate agglomerate, tuffs, and block-and-ash flows. Typically weathers light gray to tan. Phenocrysts are usually small (<3 mm) and consist of exclusively clinopyroxene (2–6%), altered red olivine (as iddingsite; 1–4%), and plagioclase (0–3%) in a vesicular, gray aphanitic to microlitic groundmass. In the north-central map area, a single discontinuously exposed olivine-rich (up to ~15%) basalt flow immediately underlies the tuff of Henderson (Tht) and is included in Thvba, although geochemically it may be more similar to Tmhb (R. Johnsen, unpublished data). Vesicles and fractures commonly host secondary chalcedony or white zeolite. The entire unit is composed of at least ~30 individual lava flows that are rhythmically intercalated with massive, red, monomict basaltic or scoriaceous autobreccias. Flow interiors are typically 2–4 m thick, while intervening autobreccias are more variable but generally thinner at ~1–3 m thick. Gently to moderately dipping basaltic tephra and scoria deposits representing the flanks of cinder cones and are observed locally along the eastern flank of the range and near the base of the unit where it overlies Tdpa and Tdptb. Thvba typically forms cliffs or stepped slopes that define the prominent ridgeline of the northern McCullough Range including Black Mountain.

Colony volcanic units (middle Miocene)

The Colony volcanic units consist of numerous overlapping dacite to rhyolite lava domes and flows of the "Colony volcano", which was first described and named by Boland (1996) and refined by Smith et al. (2010). The northern half of the dome complex is exposed in the southeastern part of the Sloan NE quadrangle, and the southern half extends 8–9 km southwest of the map boundary to just north of McCullough Pass. We report two new zircon U-Pb dates of ca. 15.0 Ma from the oldest Colony dacite lava (Tcd) in the map area (table 1). Evident interbedding between the Colony and Dutchman Pass volcanic units and their similar stratigraphic positions below the Hidden Valley volcanic unit (Thvba) indicate that construction of the Colony dome complex was coeval with that of the Dutchman Pass / McCullough stratovolcano.

Tcr Colony porphyritic rhyodacite (middle Miocene) Gray, pink or maroon porphyritic rhyodacite to trachydacite lava flows that weather pale yellow-gray to dark gray, and subordinate autobreccias consisting of coarse dacite blocks. Abundant (8–15%) phenocrysts consist of euhedral plagioclase >

hornblende > biotite > quartz in a pink to medium gray groundmass that varies from dense in flow interiors to frothy near margins. Largely homogeneous flow interiors locally display siliceous flow bands, secondary quartz-filled vugs, and uncommon purple-gray, aphyric, angular volcanic xenoliths up to 7 cm long. Tcr is only exposed in the southeastern corner of the map, where it appears to overlie Tcd and is in turn depositionally overlain by Thvba. Tcr is distinguished from Tcd by the presence of distinct quartz phenocrysts in the former. Exposed thickness is up to ~15 m.

Tca Colony aphanitic andesite (middle Miocene) Gray, dense, aphanitic trachyandesite lava with a 1- to 2-m-thick basal autobreccia. May contain accessory microphenocrystic clinopyroxene and olivine (as iddingsite). This unit appears to consist of a single, resistant lava flow that is only present in the southeastern part of the map area, where it forms a prominent cliff (10–25 m tall x 800 m long). Tca depositionally overlies Tcd and Tdptb, and is overlain by Tdpa. Tca is grouped with the Colony volcanic units based on its occurrence at the northern margin of the Colony volcano, however geochemical similarities with lavas of the Dutchman Pass and Hidden Valley units suggest it may be comagmatic with the latter (fig. 1). Total thickness is up to 35 m.

Tcd Colony porphyritic dacite (middle Miocene) Pink, light gray to purple-gray, flow-banded, porphyritic plagioclase-biotite dacite to rhyolite lava flows and domes, with subordinate yellow to greenish-gray auto-breccias, tuffs, and tuff breccias. Weathers brown, dark gray or maroon. Phenocrysts are euhedral and dominated by conspicuous plagioclase (7–10%, locally up to 30%), less fresh black or brassy biotite (2–4%), and accessory clinopyroxene; most flows also contain inconspicuous purple to maroon, angular dacite lithic fragments (~2–8 cm wide) with phenocrystic plagioclase > biotite. Massive, clast-supported auto-breccias consist of glassy, plagioclase-phyric dacite blocks in a tuffaceous matrix and are common along individual dome/flow margins. Flow interiors are crystalline and commonly host subvertical joints and pervasive, even flow banding, locally in recumbent or sheath fold geometries. Although one sample from Tcd reported here is geochemically classified as a rhyolite, most samples analyzed by Bolland (1996) can be classified as trachydacite or rhyodacite. Tcd laterally interfingers with lavas (Tdpa) and tuff breccias (Tdptb) of the Dutchman Pass volcanic rocks, and is depositionally overlain by Thvba. Tcd forms the prominent, pinkish lower cliffs on the eastern flank of the northern McCullough Range. We report two new U-Pb zircon dates of 15.02 ± 0.19 and 14.96 ± 0.10 Ma for the oldest Tcd lava flow and breccia in the study area (table 1); the age of the youngest lava is unknown. Individual Tcd flows and domes are up to 170 m thick, and the cumulative exposed thickness of Tcd is up to 380 m.

Dutchman Pass volcanic units (middle Miocene)

The Dutchman Pass volcanic units represent a greater than 1000 m thick sequence of mostly andesitic lavas and tuff breccias that were informally named by Hinz et al. (2017) in the adjacent Boulder City NW quadrangle. It was previously mapped and described as the "Farmer Canyon volcanic section" and/or "McCullough stratovolcano" by Boland (1996) and Smith et al., (2010). An age range of at least ca. 14.7 to 13.9 Ma has been established for this unit on the basis of U-Pb and $^{40}Ar/^{39}Ar$ geochronology (table 1; Hinz et al., 2017).

Tdptb Dutchman Pass andesite-dacite tuff breccia (middle Miocene) Tan, pink or pale orange, massive, mostly matrix-supported crystal-lithic andesite and dacite tuff breccias and agglomerate. Clast are variegated, typically ~2–25 cm (up to 1.3 m), angular to subrubrounded, unsorted, and consist of porphyritic trachyandesite (Tdpa) and dacitic lavas and tuffs (Tcd), and subordinate pumice lapilli. The relative abundance of dacitic clasts is very low, yet it increases southward with proximity to the Colony volcano (Tcd, Tcr, Tca). Matrix is tuffaceous and contains euhedral clinopyroxene, hornblende and plagioclase. Bedding is typically absent, although rare partings suggest that much of Tdptb is composed of monotonous, 4- to 5-m-thick, unsorted tuff breccias that likely reflect the collapse of volcanic edifices and domes belonging to the Dutchman Pass / McCullough stratovolcano (Tdpa) and Colony dome complex (Tcd). Crosscutting intrusions (Tdpai, Thvbai, Tai) are typically more resistant than Tdptb, causing them to stand out in relief. Tdptb laterally interfingers with Tdpa, Tcd, and Tca, and the upper contact with overlying Thvba is typically sharp, but locally gradational. Tdptb has a minimum thickness of 370 m as estimated from cross sections.

Tdpa Dutchman Pass andesite (middle Miocene) Light to medium gray to purple, non-vesicular porphyritic trachyandesite lavas, breccias, and agglomerates mapped as the "Lower member of the Farmer Canyon andesite" by Boland (1996) and Smith et al. (2010). Weathers dark gray-purple to maroon. Phenocryst abundance varies from ~3–15% total (uncommonly ~20–35%) and assemblages are dominantly plagioclase >> clinopyroxene > hornblende ± olivine or clinopyroxene > plagioclase in a fine-grained, dense and sometimes glassy groundmass. Many lavas contain moderately developed flow foliations and display ~1- to 5-m-thick, pale orange-purple to black, monomict autobreccias consisting of fine-grained microporphyritic plagioclase-clinopyroxene trachyandesite clasts; monotonous, massive andesitic breccias unassociated with lavas are also common. Tdpa rarely includes compositionally and

texturally similar dacite and basaltic andesite lavas. Individual lavas are typically 5–12 m thick and rarely >20 m thick. Tdpa generally forms slopes and subdued, low-relief topography on the eastern flank of the northern McCullough Range, where it is depositionally overlain by Tdptb or Thvba. Tdpa laterally interfingers with the Colony volcanic units and Tdptb. The original base of Tdpa is obscured by intrusion of the Railroad Pass pluton (Trp) and subsequent subvolcanic intrusions (Tdpai). The minimum thickness of Tdpa estimated from cross sections in the adjacent Boulder City NW quadrangle is 1000 m (Hinz et al., 2017).

Tdpap Dutchman Pass porphyritic plagioclase andesite (middle Miocene) Medium gray to purple porphyritic andesite with abundant plagioclase (8–10%), olivine (as iddingsite; 3–5%), and accessory clinopyroxene (augite) and green omphacite(?) in a fine gray groundmass. Weathers light gray to tan. Blocky plagioclase megacrysts up to 20 mm long are diagnostic of this unit, which only occurs in the southeast map area where it is depositionally overlain by both Tcd and Tdpa. The base of Tdpap is not exposed. Total thickness is >30 m.

Miocene Intrusive Rocks

Thvbai Hidden Valley basaltic andesite sills, dikes, and intrusions (middle Miocene) Medium to dark gray to blueish-gray basaltic andesite with clinopyroxene > olivine > plagioclase that intrudes the Dutchman Pass, Colony, and Hidden Valley volcanic units. These intrusions share a similar geochemistry with the extrusive lavas of Thvba (fig. 1; table 2). Thvbai is usually recessive where it intrudes andesite (Tdpa) and dacite (Tcd) lavas, and resistant where it intrudes softer tuff breccias (Tdptb). Dikes range from ~1 to 5 m thick, and generally thin toward the west and southwest. Linked networks of dikes, laterally restricted to transgressive sills, and irregular intrusions are conspicuous in upper Tdptb near the base of Thvba, and may easily be confused with extrusive lava flows, particularly in the east-central map area. Thvbai dikes are arranged in a radial pattern that strike NE–SW in the south and E–W to NW–SE in the north, which appear to converge on a point in the vicinity of the Railroad Pass pluton just east of the eastern map boundary in the adjacent Boulder City NW quadrangle (Hinz et al., 2017).

Tdpai Dutchman Pass andesitic dikes and intrusions (middle Miocene) Medium gray to pale purple-gray, porphyritic to megaporphyritic andesite typically containing abundant (up to 10–12%) plagioclase >> clinopyroxene > hornblende in an aphanitic gray groundmass. This map unit also includes a coarsely porphyritic (hornblende > plagioclase > clinopyroxene) hypabyssal andesite intrusion and closely-spaced dikes along the eastern edge of the map boundary that shows intense local propylitic alteration expressed as red, oxidized hornblende in a white, microcrystalline groundmass. Tdpai intrudes the Railroad Pass pluton (Trp) and the Dutchman Pass and Colony volcanic units with sharp contacts. The lack of olivine and the predominance of plagioclase and/or hornblende in Tdpai distinguish it from Thvbai. Dikes range from 0.5 to 5 m thick and strike primarily NW–SE and less commonly NE–SW.

Tai Undivided andesitic dikes and intrusions (middle Miocene) Dark gray to gray-purple dikes, sills, and small intrusions with variable amounts of mostly plagioclase and clinopyroxene, and less common olivine or hornblende. Tai includes undivided andesite and basaltic andesite dikes of the Dutchman Pass (Tdpai) and Hidden Valley (Thvbai) intrusions, respectively, and rare dacitic(?) dikes with plagioclase > biotite near the Colony volcanic units in the southeastern map area.

Trp Railroad Pass pluton (middle Miocene) Light gray, medium-grained, subequigranular quartz monzonite with plagioclase > quartz > hornblende ≈ biotite. Weathers tan to very pale yellow or orange. Trp is only exposed in the northeastern map area near the eastern map boundary, where it intrudes Tdpa and is crosscut and intruded by Tdpai. The Railroad Pass pluton represents the exposed part of the magmatic plumbing system that fed the McCullough stratovolcano (Smith et al., 2010) and is mapped as the Dutchman Pass volcanic unit in this and previous studies (Hinz et al., 2017). U-Pb zircon ages from Trp span a range of ca. 14.5 to 13.8 Ma (Hinz et al., 2017).

Proterozoic Metamorphic Rocks

Xgn Gneiss (Proterozoic) Orthogneiss with leucocratic pods consisting of medium-grained, sub-equigranular granodiorite to quartz monzonite (hornblende-plagioclase-quartz-biotite) or foliated granite (plagioclase-quartz-potassium feldspar). Thin (1- to 5-cm-wide) crosscutting pegmatite and aplite veins and dikes are common locally. Xgn is only exposed in one area near the eastern edge of the Sloan NE quadrangle, where it is depositionally overlain by dacite lava flows of unit Tcd. The nonconformity is marked by a red, poorly sorted, angular to subangular epiclastic sandstone that is laterally discontinuous and up to 25 cm thick.

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Table 1. Compilation of New and Published Geochronologic Data from the Sloan NE 7.5' quadrangle and Surrounding Area

Sample ID	Latitude (°N)	Longitude (°E)	7.5' Quadrangle Name	Lithology	Map Unit	Map symbol	Method	Mineral	Age (Ma)	±2σ (Ma)	Source	Notes
1229-m4	35.9705	-115.0682	Sloan NE	Ash-flow tuff	tuff of Henderson	Tht	U-Pb	zircon	**13.88**	**0.13**	This study	pumice-rich, unwelded ash-flow tuff; weighted mean of 28 dates
4/4/m4	35.9134	-115.0173	Sloan NE	Plagioclase-biotite dacite	Colony dacite	Tcd	U-Pb	zircon	**14.96**	**0.10**	This study	weighted mean of 32 dates
08CD3	35.9106	-115.0178	Sloan NE	Potassium-metasomatized biotite dacite breccia	Colony dacite	Tcd	U-Pb	zircon	**15.02**	**0.19**	This study	weighted mean of 30 dates
MD20sne-357	35.9908	-115.0849	Sloan NE	Airfall(?) tuff	Tertiary sediments	Ts	U-Pb	zircon	**-**	**-**	This study	sample submitted for anaylsis
MD20sne-188	35.8858	-115.0130	Sloan NE	Rhyodacite	Colony dacite	Tcr	U-Pb	zircon	**-**	**-**	This study	sample submitted for anaylsis
MD20sne-131	35.9155	-115.0122	Sloan NE	Orthogneiss	Gneiss	Xgn	U-Pb	zircon	**-**	**-**	This study	sample submitted for anaylsis
MD21sne-365	35.9833	-115.0382	Sloan NE	Dacite	Henderson dacite	Thd	$^{40}Ar/^{39}Ar$	TBD	**-**	**-**	This study	sample submitted for anaylsis
MD21sne-191	35.8990	-115.0825	Sloan NE	Basaltic-andesite	Hidden Valley	Thvba	$^{40}Ar/^{39}Ar$	whole rock	**-**	**-**	This study	sample submitted for anaylsis
MD20sne-206	35.8872	-115.0209	Sloan NE	Basaltic-andesite	Hidden Valley	Thvba	$^{40}Ar/^{39}Ar$	whole rock	**-**	**-**	This study	sample submitted for anaylsis
2/16/m13c	35.9739	-114.9793	Boulder City NW	Airfall tuff sourced from Snake River Plain	Tertiary sediments	Ts	U-Pb	zircon	**9.31**	**0.16**	This study	interbedded "Pipeline Ash" tuff; weighted mean of 15 dates
3/15/m1	35.8289	-115.1958	Hidden Valley	Biotite-rich dacite	Mount Sutor dacite	Tmsd	U-Pb	zircon	**12.59**	**0.17**	This study	biotite-rich dacite, western Sutor dome field; weighted mean of 14 dates
Sutor	35.8710	-115.1450	Hidden Valley	Biotite-rich dacite	Mount Sutor dacite	Tmsd	U-Pb	zircon	**13.39**	**0.24**	This study	dense, biotite-rich dacite; weighted mean of 26 dates
MSI-1	35.8799	-115.1376	Sloan	Coarse-grained biotite-rich dacite intrusion	Mount Sutor dacite	Tmsdi/Tdi_2	U-Pb	zircon	**13.32**	**0.07**	This study	Coarse-grained "intrusive" dacite, underlies Tmsd; weighted mean of 30 dates
229M1	35.9712	-114.9836	Boulder City NW	Silicified andesite hypabyssal intrusion	Dutchman Pass hypabyssal hornblende andesite	Tdphai	U-Pb	zircon	**14.92**	**0.13**	This study	weighted mean of 26 dates
517TB5	35.8387	-115.0427	Sloan SE	Plagioclase-biotite dacite dome	Colony dacite	Tcd	U-Pb	zircon	**15.11**	**0.17**	This study	weighted mean of 29 dates
3/3/m1	36.0210	-115.0153	Las Vegas SE	Biotite-plagioclase-pyroxene dacite	early(?) Henderson dacite	--	U-Pb	zircon	**14.36**	**0.15**	This study	weighted mean of 24 dates
5/19/m7	36.0132	-115.0112	Las Vegas SE	Biotite-plagioclase-pyroxene dacite	early(?) Henderson dacite	--	U-Pb	zircon	**14.03**	**0.14**	This study	basaltic enclaves present; weighted mean of 22 dates
329MP	35.9279	-114.9517	Boulder City NW	Granodiorite/quartz monzonite pluton	Railroad Pass pluton	Trp	U-Pb	zircon	**14.23**	**0.21**	Hinz et al. (2017)	southern end of Black Hills; *recalculated* for this study; weighted mean of 23 dates
RRP-1	35.9790	-114.9273	Boulder City NW	Granodiorite/quartz monzonite pluton	Railroad Pass pluton	Trp	U-Pb	zircon	**14.34**	**0.18**	Hinz et al. (2017)	northern end of Black Hills; *recalculated* for this study; weighted mean of 21 dates
NH17-660	35.9647	-114.9797	Boulder City NW	Quartz monzonite pluton	Railroad Pass pluton	Trp	U-Pb	zircon	**14.36**	**0.09**	Hinz et al. (2017)	associated with Tdphai/Tdpai; *recalculated* for this study; weighted mean of 30 dates
NH17-590	35.9496	-114.9937	Boulder City NW	Quartz monzonite pluton	Railroad Pass pluton	Trp	U-Pb	zircon	**14.66**	**0.18**	Hinz et al. (2017)	associated with Tdphai/Tdpai; *recalculated* for this study; weighted mean of 36 dates
NH17-359	35.9015	-114.9748	Boulder City NW	Andesite	Dutchman Pass andesite	Tdpa	U-Pb	zircon	**13.94**	**0.14**	Hinz et al. (2017)	Coarsely porphyritic andesite flow from upper part of section in southern McCullough stratovolcano; *recalculated* for this study; weighted mean of 15 dates
09M15	35.9609	-114.9671	Boulder City NW	Andesite	Dutchman Pass andesite	Tdpa	U-Pb	zircon	**14.49**	**0.17**	Hinz et al. (2017)	*recalculated* for this study; weighted mean of 34 dates
NH17-554	35.9582	-114.9892	Boulder City NW	Andesite (plag-hbl) hypabyssal intrusion	Dutchman Pass hypabyssal hornblende andesite	Tdphai	U-Pb	zircon	**14.72**	**0.1**	Hinz et al. (2017)	middle (relative to north-south transect) of plag-hornblende-andesite hypabyssal intrusives in western part of quadrangle; *recalculated* for this study; weighted mean of 30 dates

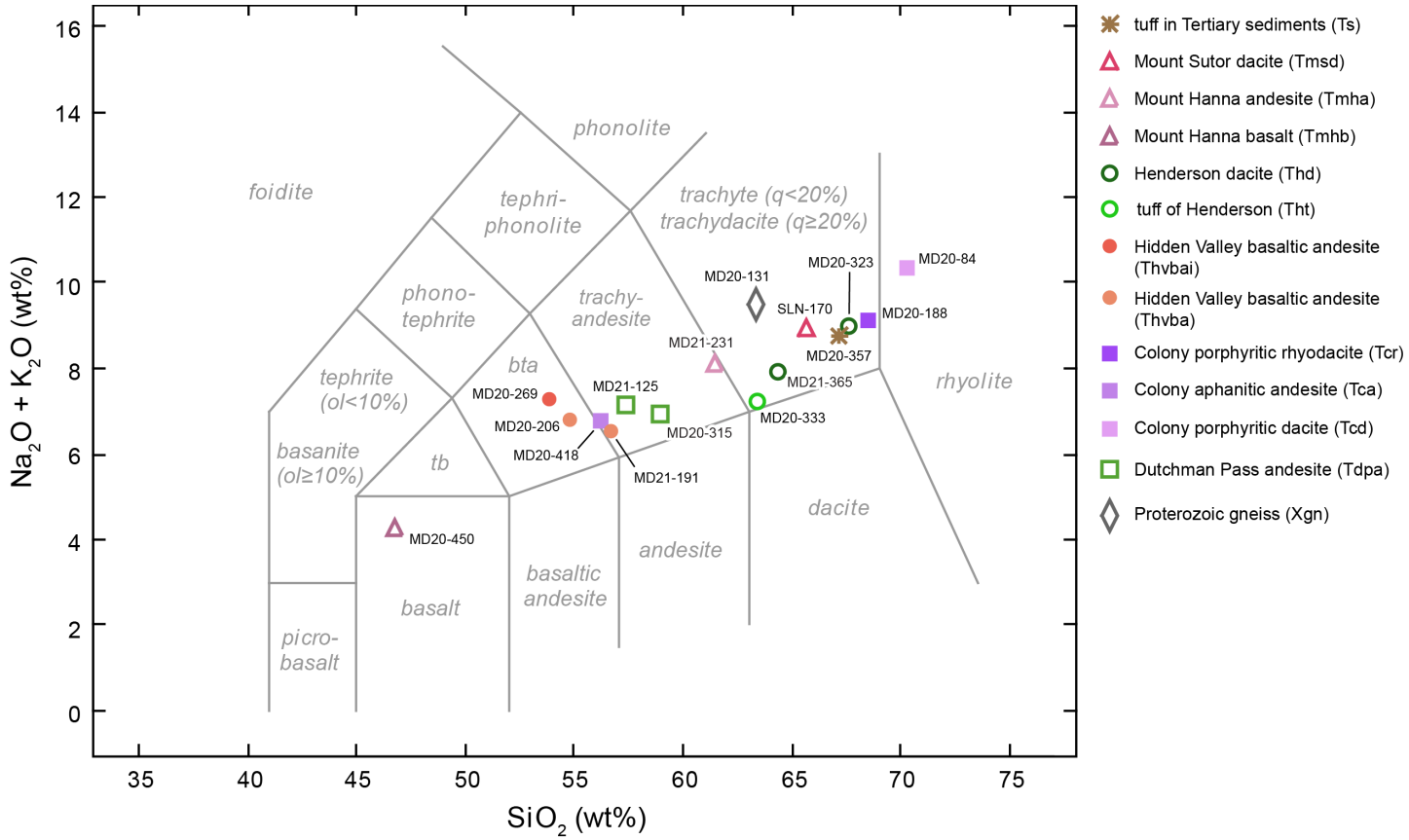

Figure 1. Total alkali versus silica diagram (LeBas et al., 1986) based on new whole-rock geochemical data from lithologic units in the Sloan NE quadrangle (see Table 2). All sample labels exclude “sne” for clarity. bta – basaltic trachyandesite; ol – olivine; q – quartz; tb – trachybasalt.

Table 2. Major and trace element geochemistry for lithologic units in the Sloan NE 7.5' quadrangle

Sample ID	MD20sne-131	MD20sne-188	MD20sne-206	MD20sne-269	MD20sne-315	MD20sne-323	MD20sne-333	MD20sne-357	MD20sne-418	MD20sne-450	MD20sne-84	MD21sne-125	MD21sne-191	MD21sne-231	MD21sne-365	SLN 170
Map Unit	Xgn	Tcr	Thvba	Thvbai	Tdpa	Thd	Tht	Ts	Tca	Tmho	Tcd	Tdpa	Thvba	Tmha	Thd	Tmsd
Major elements (wt%)																
SiO_2	63.4	68.5	54.8	53.9	58.9	67.7	63.5	67.1	56.2	46.8	70.3	57.4	56.7	61.5	64.4	65.7
Al_2O_3	16.6	15.15	15.75	15.75	15.15	14.95	16.25	11.35	16.9	14.85	15.2	17.2	16	17.45	15.75	16.6
Fe_2O_3	5.39	2.53	7.04	6.98	6.33	2.49	3.89	0.74	6.89	9.2	2.23	5.76	7.41	5.68	4.44	3.94
CaO	3.35	2.85	6.45	6.57	5.45	1.86	3.76	1.79	5.73	10.95	1.22	3.46	7.1	4.38	4.36	2.65
MgO	1.97	0.86	4.62	4.82	3.45	0.75	2.07	1.17	2.79	8.37	0.5	4.13	5.25	1.88	1.68	1.02
Na_2O	3.94	4.13	3.36	3.33	3.05	3.95	3.45	4.28	3.63	3.13	3.79	3.67	3.27	3.66	3.83	3.51
K_2O	5.57	5.01	3.42	3.94	3.91	5.03	3.76	4.46	3.16	1.16	6.53	3.49	3.23	4.46	4.07	5.43
Cr_2O_3	0.007	<0.002	0.019	0.019	0.013	0.002	0.002	<0.002	0.002	0.046	<0.002	0.004	0.027	0.002	0.003	<0.002
TiO_2	0.62	0.48	1.13	1.23	1.04	0.51	0.63	0.11	1.04	1.11	0.43	1.03	1.14	0.66	0.81	0.47
MnO	0.07	0.06	0.11	0.11	0.09	0.08	0.08	0.06	0.12	0.16	0.04	0.1	0.11	0.11	0.08	0.13
P_2O_5	0.26	0.14	0.66	0.67	0.57	0.13	0.2	0.02	0.61	1.29	0.09	0.68	0.54	0.52	0.31	0.22
SrO	0.05	0.06	0.12	0.12	0.09	0.05	0.07	0.08	0.13	0.23	0.03	0.1	0.1	0.17	0.08	0.11
BaO	0.11	0.17	0.16	0.17	0.15	0.17	0.14	0.01	0.2	0.25	0.15	0.13	0.15	0.24	0.15	0.23
LOI	0.62	1.33	2.05	2.16	2.89	3.51	3.53	10.6	1.67	4.01	1.2	4.41	0.68	1.09	1.23	1.67
Total	101.96	101.27	99.69	99.77	101.08	101.18	101.33	101.77	99.07	101.56	101.71	101.56	101.71	101.8	101.19	101.68
Trace elements (ppm)																
Ba	857	1380	1355	1435	1155	1355	1200	68.1	1575	2110	1290	1150	1245	2080	1355	2010
Ce	53.9	154.5	168	178.5	144	158.5	106.5	37	146	247	158	181.5	132.5	165	126.5	219
Cr	40	10	150	150	90	10	20	<10	20	350	10	30	210	10	20	10
Cs	0.87	2.02	1.67	2.48	1.23	3.69	3.47	11.75	1.3	3.51	2.28	0.57	1.79	1.51	1.53	1.92
Dy	3.46	3.96	6.52	6.01	5.1	4.77	3.77	4.46	5.45	8.36	3.96	5.98	5.31	5.45	4.53	8.15
Er	2.12	2.38	2.95	2.97	2.67	2.6	2.16	2.95	2.94	3.27	2.39	2.83	2.9	2.85	2.35	4.51
Eu	0.95	1.64	2.9	2.91	2.3	1.67	1.6	0.13	2.77	5.47	1.73	2.94	2.46	2.96	2.2	3.29
Ga	19	21	21	23	19.8	20	22.4	17	23.2	18.7	19.7	21.8	21.4	22.1	21.1	19
Gd	4.17	5.28	8.87	9.46	7.41	6.22	4.35	3.4	7.48	15.6	5.79	9.44	7.95	8.04	6.05	12.4
Hf	6.4	10.8	9.9	10	8.1	10	8.2	3.3	8.3	6.9	9.8	10	8.1	8.2	8	11.5
Ho	0.65	0.68	1.1	1.06	0.9	0.87	0.69	0.96	0.96	1.3	0.68	1.1	0.97	0.94	0.89	1.49
La	24	81.6	84.8	87.9	71.4	81.6	57.4	15.1	72.4	114	88.9	93.9	65.4	85	66.3	111.5
Lu	0.3	0.31	0.38	0.33	0.32	0.4	0.32	0.4	0.39	0.35	0.31	0.38	0.37	0.35	0.34	0.62
Nb	11.1	24.3	21.8	24	20.5	28.9	21.4	30.1	17.6	13.8	26.3	20.7	18.1	16.1	23	22.1
Nd	25.3	55.1	72.9	78.5	60.7	59.5	39.2	14.3	65.8	127.5	56.7	79.7	59.7	69.6	51.6	91.6
Pr	6.66	16.95	20	21.1	17.3	17.8	11.55	4.23	17.7	32	16.4	21	15.45	18.5	13.7	24.8
Rb	163	127.5	94.4	129.5	122	156.5	108	287	76.4	28.2	192	58.1	79.9	98.8	111	155
Sm	4.45	7.87	12.6	13.7	10.35	9.93	6.25	3.66	10.35	22.5	8.42	13.75	9.98	11.3	8.67	16.15
Sn	3	2	2	2	2	2	9	3	1	2	2	2	2	2	1	1
Sr	448	531	1015	1020	727	413	672	675	1105	2030	263	894	888	1450	668	917
Ta	0.6	1.4	1.2	1.2	1.1	1.7	1.4	2.4	0.9	0.6	1.6	1.1	1	0.8	1.4	1.1
Tb	0.6	0.7	1.13	1.1	0.95	0.92	0.66	0.66	0.97	1.72	0.77	1.12	0.97	1.04	0.78	1.43
Th	2.27	23.7	16.45	20.4	20.1	24.5	13.6	16.35	13.4	16.75	24.8	17.3	15.7	13.85	15.25	20.3
Tm	0.29	0.31	0.41	0.35	0.33	0.33	0.3	0.44	0.37	0.39	0.34	0.42	0.35	0.41	0.38	0.63
U	0.44	4.65	3.27	4.13	4.03	4.48	2.03	6.62	2.56	4.3	4.02	3.22	3.32	2.73	3.68	3.57
V	88	38	163	168	139	26	60	9	139	233	42	136	170	90	106	23
W	<1	2	1	2	2	3	2	3	1	2	18	1	2	1	2	2
Y	19	20.7	28.8	28.5	23.9	26.1	19.4	27.7	26.4	35.2	20.4	28.9	25.2	27.1	24	41.7
Yb	1.92	1.99	2.59	2.2	2.12	2.28	2.11	2.9	2.25	2.11	2.07	2.45	2.41	2.65	2.17	4.33
Zr	261	448	406	424	333	420	341	74	335	307	414	452	344	381	346	514