Text and references accompanying Nevada Bureau of Mines and Geology Open-File Report 16-4

Preliminary Geologic Map of the Boulder City Quadrangle, Clark County, Nevada

by

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DESCRIPTION OF MAP UNITS

Anthropogenic Features and Deposits

Qx Anthropogenic modifications (Anthropocene to Holocene) Areas of extensive anthropogenic disturbance and modification, including urban development and major transportation corridors.

Quaternary Deposits

Age estimates shown are based on the criteria described in House et al. (2010) for mapping geomorphic surfaces and related sedimentary deposits in the Ivanpah Valley area.

Qc Colluvium (Holocene) Unconsolidated, angular to slightly rounded boulders to pebbles of bedrock in a variably sandy matrix.

Qa Young alluvium (Historic to late Holocene) Coarse-grained alluvial deposits in recently active washes; typically sandy with pebble- to cobble-sized gravel. Fresh bar-and-channel morphology with minimal soil development.

Qfy Young alluvial-fan deposits, undivided (late Holocene to late Pleistocene) Coarse-grained alluvial deposits in intermittently active alluvial fans; typically sandy pebble- to cobble-sized gravel with boulders. Clasts are subrounded to subangular. Surface morphology ranges from fresh bar-and-channel forms to slightly smoothed surfaces, commonly forming low terraces adjacent to Qa. Typical soils have cambic development with Stage I to weak Stage II $CaCO_3$.

Qfy_1 Youngest alluvial-fan deposits (late to middle Holocene) Coarse-grained alluvial deposits in intermittently active alluvial fans; typically sandy pebble- to cobble-sized gravel with boulders. Clasts are subrounded to subangular. Surface morphology ranges from fresh bar-and-channel forms to slightly smoothed surfaces, commonly forming low terraces adjacent to Qa. Typical soils have cambic development with Stage I $CaCO_3$.

Qfy_2 Young alluvial-fan deposits (early Holocene to late Pleistocene) Coarse-grained alluvial deposits in generally inactive alluvial fans; typically sandy pebble- to cobble-sized gravel with boulders. Clasts are subrounded to subangular. Surface morphology ranges from subdued bar-and-channel forms to fully smoothed surfaces with moderately- to well-developed gravel pavement; forms terraces 1–2 m above active washes. Typical soils have cambic to juvenile argillic development with weak Stage II $CaCO_3$.

Qfi Intermediate-aged alluvial-fan deposits (late to middle Pleistocene) Coarse-grained alluvial deposits in mostly inactive alluvial fans; typically sandy pebble- to cobble-sized gravel. Clasts are subrounded to subangular. Fully smoothed surfaces with erosionally rounded margins and well developed gravel pavement; surfaces are 2–4 m above active washes. Argillic soil horizons typically erosionally stripped, with Stage II–III $CaCO_3$ horizons up to 1.5 m thick.

Qfo Older alluvial-fan deposits (middle to early Pleistocene) Coarse-grained alluvial deposits; typically sandy pebble- to cobble-sized gravel with boulders. Clasts are subrounded to subangular. Fully smoothed surfaces with erosionally rounded margins, locally mantled with

angular clasts of pedogenic carbonate and/or eolian silt. Surfaces are 2–4 m above active washes. Upper soil horizons erosionally stripped; Stage IV $CaCO_3$ horizons up to 2.5 meters thick.

QTf Early Pleistocene to late Pliocene alluvial-fan deposits (early Pleistocene to late Pliocene) Coarse-grained alluvial deposits; typically sandy pebble- to cobble-sized gravel with boulders. Clasts are subrounded to subangular. Fully smoothed to erosionally rounded surfaces commonly mantled with angular clasts of pedogenic carbonate and/or lag deposits of desert varnished basalt boulders. Variable separation from younger surfaces but locally 10+ m above active washes. Upper soil horizons erosionally stripped; Stage V $CaCO_3$ horizons up to several meters thick. Extensive deposits of QTf at the mouth of Quail Wash have granite clasts of an unknown provenance, which suggest hydraulic conductivity with a much larger drainage area prior to stream capture associated with incision of the Colorado River.

Tertiary Volcanic and Sedimentary Rocks

Mount Davis volcanics (middle Miocene)

Tdur Upper rhyolite and dacite lavas of Mount Davis (middle Miocene) Light tan-pink, porphyritic rhyolite and dacite lavas. This unit is limited to the northeast quarter of the quadrangle where it largely rests on cogenetic tuffs (Tduts), and locally rests on Tbc. The age of Tdur has been dated at 13.1 Ma from exposures located outside of this quadrangle (Gans and Bohrson, 1998; Faulds et al., 1999). A single analysis from a sample collected in this quadrangle yielded SiO_2 content of 68.9 wt.% (figure 1). Thickness is generally 30 to 60 m and locally reaches >150 m thick.

Tduts Upper sediments of Mount Davis (middle Miocene) Light tan to white, coarse, angular tuffaceous sediments, lapilli-rich with abundant rhyolite and dacite lithic clasts and minor Tdmb and Tbc clasts in the lower 10 m. This unit is directly overlain by Tdur and probably represents erupted breccia, tuff, and reworked sediments deposited prior to the eruption of the Tdur lavas. Age is between ~13.27 (Tdmb) and 13.1 Ma (Tdur) and may match that of Tdur. Up to 120 m thick.

Tdmb Middle basalt lavas of Mount Davis (middle Miocene) Dark gray to black, commonly vesicular, aphanitic to porphyritic basalt lavas. Porphyritic lavas contain plagioclase, pyroxene, and olivine. Tdmb locally underlies Tduts, overlies Tds, Tdmr, and Tbc, and is locally interbedded with Tds. One age date has been previously obtained on Tdmb in the north central part of the quadrangle and is 13.27±0.03 Ma (Felger et al., 2014). Previous geochronologic studies outside of this quadrangle have distinguished a lower part of Tdmb with an age range of 14.2 to 14.1 Ma and an upper part with an age range of 13.77 to 13.27 Ma (Gans and Bohrson, 1998; Faulds et al., 1999). Based on contact relationships with Tdmr, the Tdmb in the Boulder City quadrangle is probably entirely the upper 13.77 to 13.27 Ma part. SiO_2 content ranges from 44.6–50.6 wt.% based on six samples from this quadrangle (figure 1). Thickness ranges from 10 to 250 m thick.

Tdmd Middle dacite and rhyolite lavas of Mount Davis(?) (middle Miocene) Medium gray, abundantly and coarsely porphyritic dacite and rhyolite lavas exposed between Tdmh and Tdmb on the southeast flank of the River Mountains. Possibly correlative or related to the Tdmr lavas exposed in the Eldorado Mountains. Alternatively Tdmd lavas may correlate with the Bootleg Wash dacite (Tbd). On the southwest flank of the River Mountains the Tdmb/Tdmd/Tdmh stratigraphic sequence rests on an angular unconformity above Trm. All three of these units, Tdmb, Tdmd, and Tdmh are unaltered and contrast the underlying altered Trm. A single analysis from a sample collected in this quadrangle yielded SiO_2 content of 68.6 wt.% (figure 1). Age is unknown, but may correlate with the 14.1 Ma Tdmr. Thickness is 10–15 m thick

Tdmh Middle hornblende dacite lavas of Mount Davis(?) (middle Miocene) Light gray to tan-brown, flow foliated, hornblende-plagioclase-biotite dacite. More finely porphyritic then the overlying Tdmd. Tdmh may be correlative or related to the Tdmr lavas exposed in the Eldorado Mountains. Alternatively, Tdmh lavas may correlate with the Bootleg Wash dacite (Tba). This unit rests under Tdmd and Tdmb and rests on an angular unconformity with the locally highly altered Trm. SiO_2 content ranges from 62.9–65.5 wt.% based on two samples from this quadrangle (figure 1). Age is unknown, but may correlate with the 14.1 Ma Tdmr. Thickness is 10 to 25 m thick.

Tdmr Middle dacite and andesite lavas of Mount Davis (middle Miocene) Medium gray porphyritic dacite and andesite lavas that underlie Tdmb in this quadrangle. South of the Boulder City quadrangle, Tdmr is interbedded with both Tdmb and Tds (Felger et al., 2014). The base of Tdmr is only exposed along the east edge of this quadrangle where it rests on Tpl. A single analysis from a sample collected in this quadrangle yielded 58.6 wt.% SiO_2 (figure 1). One age date has been obtained for this unit regionally, 14.1 Ma (Gans and Bohrson, 1998), placing it between the lower and middle parts of Tdmb. Thickness is 40–60 m thick.

Tds Undivided sediments of Mount Davis (middle Miocene) Tan to brownish gray sandstone, pebble conglomerate, and breccia with local interbedded thin non-welded tuffs, reworked tuffs, siltstone, claystone and coarse grained manganiferous gypsum beds. Clasts are subrounded to subangular with variable lithologies

sourced from proximal bedrock units. Unit is primarily comprised of alluvial fan and fluvial deposits with local lacustrine interbeds. This unit is interbedded with the entire section of Mount Davis volcanics. Thickness is 10–60+ m thick.

Bootleg Wash volcanics (middle Miocene)

The Bootleg Wash volcanics are exposed at the head of Bootleg Wash, in the northwest part of the map area, and extend into the adjacent Henderson and Boulder Beach quadrangles (Bell and Smith, 1980; Smith, 1982). Structurally, the Bootleg Wash volcanics fill the axial part of a north-plunging syncline, bound by Trm. The origin of this relatively minor syncline has not yet been identified.

Tbd Bootleg Wash dacite and rhyolite (middle Miocene) Medium-light gray to pinkish, abundantly porphyritic, locally flow-banded dacite and rhyolite lavas, tuffaceous sediments, and breccia. This unit rests in depositional contact with Tba. Distinguished from Trm using stratigraphic position, abundance of phenocrysts, and absence of hydrothermal alteration. SiO_2 content ranges from 66.1–70.4 wt.% based on three samples from this quadrangle (figure 1). Age is 13.42±0.26 based on new U-Pb zircon analyses from one sample (this study). Up to 30 m thick.

Tba Bootleg Wash andesite (middle Miocene) Medium to dark gray, porphyritic andesite lavas and breccia interlayered with Tbd. Includes poorly exposed tuffaceous sediments at the base of the unit. Interpreted as depositional along an unconformity with underlying Trm. However, previous mapping by Smith (1982) and Bell and Smith (1980) interpreted that the Bootleg Wash volcanics were entirely in fault contact with older Trm. It is possible that the Bootleg Wash volcanics (Tba and Tbd) may represent the youngest and least altered part of the greater Red Mountain volcanics. SiO_2 content ranges from 53.0–53.7 wt.% based on two samples from this quadrangle (figure 1). Distinguished from the underlying Trm by less alteration and consistent porphyritic texture. Distinguished from Tbd by darker color and sparser phenocryst content. Up to 90 m thick.

Red Mountain volcanics (middle Miocene)

Trm Red Mountain volcanics (middle Miocene) A mixed dacite and andesite composition complex of lavas, volcaniclastic sediments, and hypabyssal intrusions. Generally steeply north dipping, but attitudes are scarce due to alteration and the high volume of intrusive rocks. Total thickness is unknown. Areas of hydrothermal alteration (red stipple pattern) are commonly brecciated, silicified and sericitized. The alteration boundary is sharp against the granitic stock of the southeast River Mountains (Tg) and also against low and high-angle faults; however, it is otherwise generally gradational up stratigraphic section to the northwest. Previously published maps and research papers have distinguished this section of volcanics from the andesitic "volcanic Rocks of River Mountains" to the north on the basis of alteration (Bell and Smith, 1980; Smith, 1982, 1984). The Red Mountain volcanics are overlain by the 13.42 Ma Bootleg Wash volcanics and are intruded by the 13.65 Ma granite stock (Tg). Based on contact patterns, ages, and possible correlation between Tbc and Tg, the Red Mountain volcanics are interpreted to be part of the volcanic pile erupted from the Boulder City pluton and displaced laterally along the Hemenway Wash fault.

Patsy Mine volcanics (middle to early Miocene)

Tpm Middle Patsy Mine volcanics (middle Miocene) Porphyritic, locally flow-banded, hydrothermally altered dacite in contact with Tbc, southeast of Hemenway Wash. Estimated local thickness ranges from 10 to 50 m thick. Provisionally interpreted to correlate with the altered dacite, Teda of the Boulder Beach quadrangle (Smith, 1984), and Tpma of Felger et al. (2014). Based on regional age dates, this unit is 15.5 to 15.2 Ma (Gans and Bohrson, 1998; Faulds et al., 1999; Felger et al., 2014). However, this unit (Tpm) may also correlate with the Red Mountain volcanics (Trm) exposed in the southern River Mountains and be younger than the primary middle Patsy Mine volcanic sequence. SiO_2 content ranges from 66.8–67.3 wt.% based on two samples from this quadrangle (figure 1).

Tpl Lower Patsy Mine volcanics (early Miocene) Andesite lavas exposed in a single outcrop about 90 m thick along the east-central margin of this quadrangle underlying Tdmr. The base of Tpl is not exposed in this quadrangle and thus the total thickness of about 200 m shown in the cross section is based on thicknesses of exposed Tpl to the south and southeast (Anderson, 1977; Felger et al., 2014). Age of lower Patsy Mine volcanics ranges ~18.5 to 16 Ma (Gans and Bohrson, 1998; Faulds et al., 1999). This outcrop may correspond with the upper part of Tpl and be closer to the 16 Ma age range.

Tertiary Intrusive Rocks

Tdri Rhyolite and dacite intrusions, correlative with Tdur (middle Miocene) Medium tan-brown porphyritic rhyolite to dacite intrusions that may correspond to the Tdur lavas. Tdri is exposed along Boy Scout Canyon in the northeast part of this quadrangle. Tdri consists of one dike that intruded a north-northwest-striking normal fault and multiple other amorphous hypabyssal intrusions. SiO_2 content ranges from 68.7–68.9 wt.% based on two samples from this quadrangle (figure 1).

Tdmbi Basalt dike, correlative with Tdmb (middle Miocene) Dark gray, sparsely and finely porphyritic basalt

dike intruding Tds in the north-central part of the quadrangle. Probably correlative with Tdmb. Consists of a single, steeply dipping dike, ~1 m wide, offset across multiple dextral fault strands. Contains phenocrysts of plagioclase, pyroxene, and olivine.

Trdi Rhyolite and dacite dikes (middle Miocene) Light gray, porphyritic rhyolite and dacite dikes that intrude Trm and contain feldspar and biotite phenocrysts. These dikes were not observed in the Bootleg Wash volcanics and may relate to the Bootleg Wash dacite and rhyolite lavas (Tbd). SiO_2 content ranges from 67.3–67.7 wt.% based on two samples from this quadrangle (figure 1).

Tdi Dacite and rhyolite dikes (middle Miocene) Light to medium gray, porphyritic dacite and rhyolite dikes that contain ~25–30% phenocrysts of feldspar (20–25%, 1–5 mm), biotite (3–4%, 1–2 mm), and hornblende (1–2%, 2–3 mm). Intrudes Tbc along the north central margin of the quadrangle. May include some Tpai dikes where the lithology was difficult to distinguish. SiO_2 content of 69.1 wt.% based on one samples from this quadrangle (figure 1).

Tpai Porphyritic andesite dikes (middle Miocene) Medium gray, porphyritic andesite dikes that contain ~20–25% phenocrysts of feldspar (15–20%, 1–3 mm), hornblende (2-4%, 2–3mm), pyroxene (2–3%, 1–2 mm), and biotite (1%, 1–2 mm). Intrudes Tbc and Tbcm along the northern and northeastern parts of the quadrangle. May include some Tdi dikes where the lithology was difficult to distinguish Tpai and Tdi dikes predate the numerous steeply dipping faults mapped through the north-central part of this quadrangle. SiO_2 content ranges from 53.7–53.8 wt.% based on two samples from this quadrangle (figure 1).

Tgi Granite dikes (middle Miocene) Light gray, slightly porphyritic, granite(?) composition dikes that intrude Tbc in the northern part of the quadrangle. Predate the numerous steeply dipping faults mapped through this part of the quadrangle.

Tertiary Plutonic Rocks

Boulder City pluton (middle Miocene)

Tbcp Boulder City pluton, porphyritic younger phase (middle Miocene) Light pinkish-gray, fine grained, porphyritic granite(?) that intrudes Tbc and Tbcm in the north-central part of the map area. Composed of orthoclase, plagioclase, hornblende, biotite, and sparse fine-grained quartz. Contacts with Tbcm are sharp and are locally sharp to gradational with Tbc. Probably one of the youngest phases of the Boulder City pluton.

Tbc Boulder City pluton, main phases (middle Miocene) Light gray, fine- to medium-grained quartz syenite and granite with equigranular and porphyritic phases. Composed primarily of orthoclase, plagioclase, hornblende, biotite, with interstitial quartz. Tbc intrudes Xgn, Tpm, and Tbcm, and is intruded by Tdi, Tpai, Tgi, and Tdri dikes. Tbc includes unmapped bodies of Tbcm. The middle and upper Mount Davis volcanics rest nonconformably on Tbc and are not hydrothermally altered. In contrast, the Patsy Mine volcanics (Tpm) are intensely hydrothermally altered adjacent to the Boulder City pluton. The largely concealed trace of the sinistral shear zone in Hemenway Wash bounds the pluton on the northwest side. In the northeastern part of the quadrangle, Tbc is cut by numerous down-to-east and down-to-west normal faults. In the north-central part of the quadrangle, Tbc is cut by numerous tightly spaced dextral and dextral-oblique faults with strikes that curve from ~N-S, to NW, to E-W, to WSW as they approach the sinistral shear zone in Hemenway Wash. These curving faults probably accommodated oroclinal flexure associated with the sinistral shear zone. Tbc is also pervasively brecciated within a 1 to 1.5 km-wide zone abutting the shear zone in Hemenway Wash. Below 710 to 730 m elevation much of Tbc and Tbcm are oxidized and stained dark red brown with iron and manganese oxides This oxidation alteration probably reflects a paleo-groundwater horizon associated with the late Miocene Lake Las Vegas (e.g., Faulds et al., 2016) and overprints the faulting and brecciation associated with the sinistral shear zone in Hemenway Wash. Goundwater oxidation was mapped as an overprint on the Boulder City pluton (blue stipple pattern). Two age dates have previously been obtained on the Boulder City pluton and include 12.48±0.48 (Honn, 2012) and 13.96±0.25 (Felger et al., 2014). Three new U-Pb zircon dates were acquired in this study with ages of 13.50±0.21 13.99±0.28, and 14.45±0.09 Ma. SiO_2 content ranges from 53.7–71.6 wt.% based on eight samples from this quadrangle (figure 1).

Tbcm Boulder City pluton, older mafic phases (middle Miocene) Medium gray and gray-brown, porphyritic diorite and aphanitic andesite(?) intruded by the Boulder City pluton. This unit is distributed as amorphous bodies in the central and eastern parts of the Boulder City pluton. The Tbcm exposures in the north-central part of the map area are variably hydrothermally altered, ranging from areas of low, moderate, and high intensity alteration. In areas of high intensity alteration the rock is pervasively altered with fine-grained actinolite throughout the groundmass. In areas of low to moderate intensity alteration, actinolite distribution is generally limited to veins 1–3 mm thick, and locally up to 10 mm thick. Tbcm exposures in the Boy Scout Canyon area are locally weakly hydrothermally altered. The Tbcm unit probably represents an older, early phase of the Boulder City pluton and may in part include altered Patsy Mine volcanics as roof pendants. Age of Tbcm probably overlaps at least in part with the main

phases of Tbc. SiO_2 content ranges from 51.8–67 wt.% based on eight samples from this quadrangle (figure 1).

Tg Granite stock of the River Mountains (middle Miocene) Medium to dark gray, fine-grained, equigranular granite stock exposed along the southeast flank of the River Mountains both southwest and northeast of Bootleg Canyon. Dominantly composed of orthoclase, plagioclase, quartz, and hornblende with minor fine-grained biotite. Intrudes Trm. Outcrops typically weather in low relief relative to the surrounding altered volcanics. SiO_2 content ranges from 60–66 wt.% based on two samples from this quadrangle (figure 1). Age is 13.65±0.2 based on new U-Pb zircon analyses from one sample (this study). Based on ages and contact patterns with the volcanic rocks, authors in this study infer that this unit may correlate with part of the Boulder City pluton that has been displaced along the Hemenway Wash fault.

Paleozoic Sedimentary Rocks

Pzu Undivided sedimentary rocks (Paleozoic) Tabular bodies of thinly bedded, unfossiliferous, gray carbonate with interbedded sandstone and chert of probable Paleozoic or possibly Mesozoic affinity. Interpreted as screens associated with hypabyssal intrusions within Trm. Blocks of Pzu are cross-cut by Trdi dikes.

Paleoproterozoic Metamorphic Rocks

Xgn Gneiss (Paleoproterozoic) Predominantely garnet-bearing orthogneiss and schist with minor amphibolite. Xgn is exposed in two areas in the Boulder City quadrangle, including the north-central and along the northeast edge of the map. In the north-central part of the map Xgn is intruded by Tbc and Tbcm, and it is not clear if the Xgn exposures are screens within the Boulder City pluton or if they represent in-situ paleotopographic highs. Along the northeastern edge of the quadrangle, previous mapping by Anderson (1977) depicted that all Tertiary units were in fault contact with the exposed Xgn. In producing this map, some contacts were reinterpreted as depositional between Tduts, Tdmb, and Xgn. The new interpretation would support that this area may have been a paleotopographic high during eruption of the Mount Davis volcanics; however, further work is needed to assess the contact relationships around the exposure of Xgn in this area.

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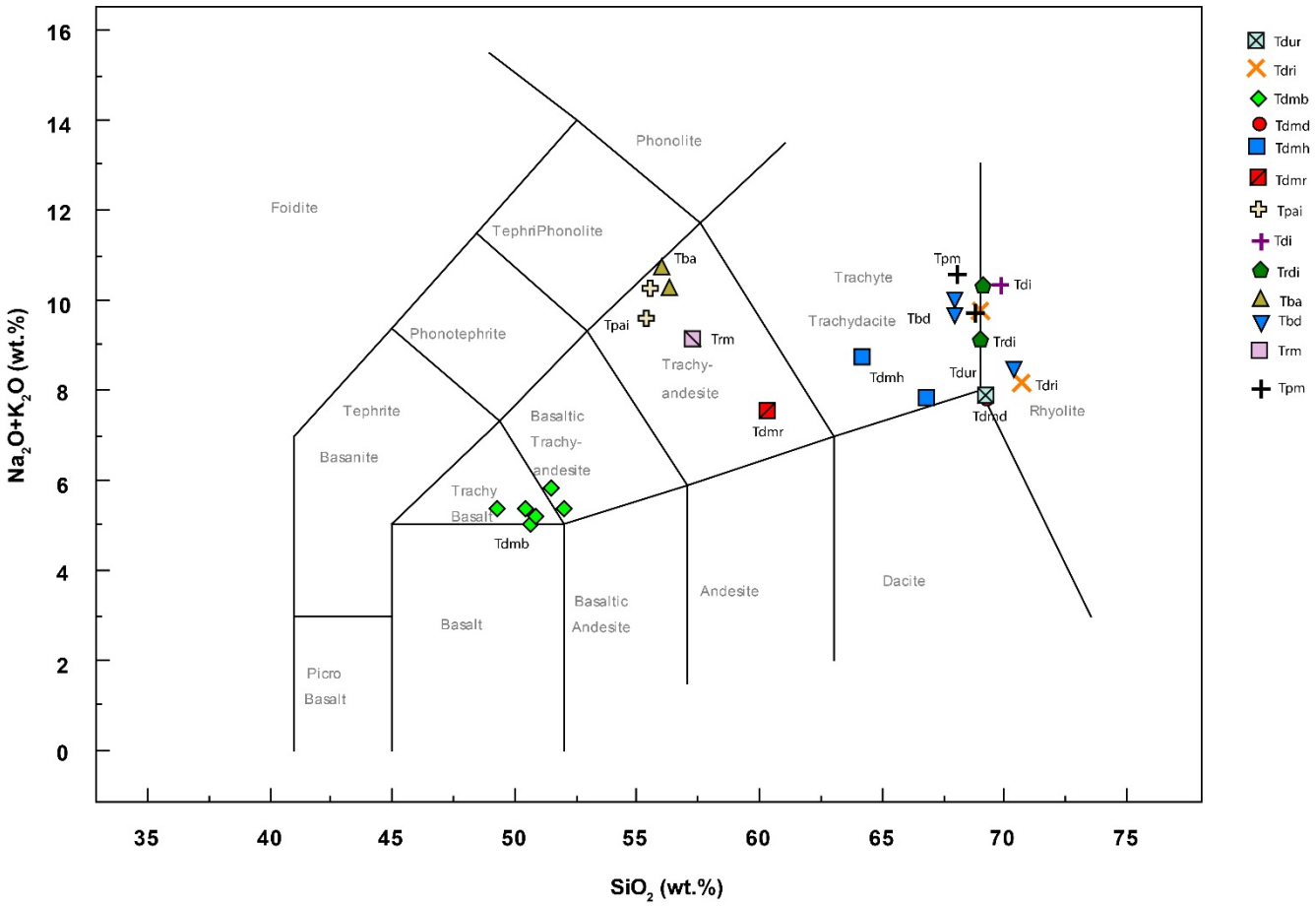

Figure 1. Total alakalis-silica (Le Bas et al., 1986) plot of samples from the Boulder City quadrangle. Unit abbreviations correlate to the text and to the legend on the map sheet.