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Geologic Map of the South Half of the Boulder Canyon Quadrangle, Clark County, Nevada

by

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DESCRIPTION OF MAP UNITS

Quaternary Deposits

Qa Alluvium (Holocene) Locally derived gravel, sand and silt in active drainages and young alluvial-fan deposits. Generally poorly sorted, variably rounded, and unconsolidated. Thickness is generally less than 3 m.

Qc Colluvium (Holocene) Poorly sorted, angular, and generally unconsolidated gravelly colluvium. Locally derived and confined to rockfall-prone slopes. Weakly consolidated locally where active drainages have incised through thick accumulations at the base of slopes. Thickness generally less than 3 m.

Qoa Older alluvium (early Holocene to Pleistocene) Gravel, sand, and silt present on inactive alluvial fans and elevated terraces above active drainages. Generally distinguished from modern alluvium by color on aerial imagery due to rock varnish and/or development of desert pavement. Generally poorly sorted, variably rounded, unconsolidated to well cemented by caliche. Usually preserved as sidewash in canyons or as abandoned alluvial-fan or piedmont-slope surfaces. Thickness typically ranges from 3 to 15 m.

Tertiary Sedimentary Rocks

Red sandstone unit (late Miocene)

Informal rock unit in the Lake Mead area defined by Bohannon (1983) and Duebendorfer and Wallin (1991) that includes basin-fill strata primarily consisting of rhythmically interbedded sandstone, siltstone, conglomerate and gypsum of highly variable lithology and locally containing input from coeval volcanic sources. Interbedding with the volcanic rocks of Callville Mesa (ca. 10.5–8.5 Ma) and geochronologic data from numerous interbedded tuffs tightly constrain the age of the red sandstone unit to ca. 11.7–10 Ma (e.g., Duebendorfer and Wallin, 1991; Castor et al., 2000; Beard et al., 2007). In the Boulder Canyon quadrangle, rocks are mapped as the red sandstone unit if they meet either of these criteria: (1) they unconformably overlie the ~13.5–12.5-Ma volcanic rocks of Boulder Wash (Tbwd, Tbwt) and are interbedded with the ~13.0–10.7-Ma lavas of Hamblin-Cleopatra volcano (Thcb, Thca); or (2) they overlie the 13.8–12-Ma Lovell Wash Member of the Horse Spring Formation (Thl) and are overlain by lavas dated between 11.1 ± 1.1 and 9.4 ± 0.6 Ma in the adjacent Petroglyph Wash quadrangle (Barker et al., 2012).

Trsc Conglomerate lithofacies Reddish-brown, thin- to medium-bedded volcaniclastic conglomerate and subordinate pebbly sandstone. Mostly matrix-supported. Locally displays normal grading and wavy or ripple lamination in sandier beds. Granule- to cobble-sized clasts are typically angular to very angular. The clast assemblage is distinctly monolithologic and composed of porphyritic dacite lava and tuff containing biotite and plagioclase phenocrysts; groundmass colors are variably light gray or pale purple and less commonly cyan, pink, yellow, or red. The monomict clast assemblage suggests that the volcanic rocks of Boulder Wash (Tbwd, Tbwt) are the primary source for this unit in the map area. Outsize clasts up to 50 cm are rare. Maximum thickness is 220 m.

Trss Sandstone lithofacies Reddish-brown to maroon, unsorted to poorly sorted, matrix-supported volcaniclastic sandstone and pebbly sandstone, with uncommon pebble-cobble conglomerate and rare gypsiferous sandstone. Sandstone is typically well cemented, gray to reddish-purple and composed almost entirely of fine- to medium-grained volcanic lithic fragments. Bedding is generally thin and planar, but

locally discontinuous and wavy; normal grading is common. Clasts are distinctly monolithologic dacite identical to that of the conglomerate lithofacies (Trsc). Thickness varies from 10 to 100 m.

Trsg Gypsum lithofacies Mostly white to gray, thinly bedded and laminated gypsum with subordinate tan to brown gypsiferous mudstone, sandstone, and tuff. Individual laminae are planar to wavy or crinkly and commonly red, maroon, or dark gray, and less commonly yellowish-gray or pale blue-green. Locally displays 0.5- to 2-m-thick red, oxidized breccia reflecting subaerial exposure and karstification. Intercalated cyan or greenish-blue tuffs 0.5- to 4-m-thick are conspicuous and composed of fine ash with rare sub-mm biotite phenocrysts; the upper parts of some tuffs are reworked and ripple laminated. Maximum thickness is 280 m.

Trsl Landslide blocks and breccia Pale brown weathered, brecciated limestone blocks and debris flow breccia near the base of this unit. Basal contact is locally a sharp, undulatory slip surface or glide plane. Source of clasts is uncertain. Thickness is up to 10 to 15 m.

Thl Horse Spring Formation, Lovell Wash Member (middle Miocene) Gray pale yellowish-gray and pale orange mudstone, limestone, sandstone, tuffaceous sandstone, and gypsum. Bedding is thin to medium (~3–20-cm thick), even, and laterally continuous. Where mapped between strands of the Hamblin Bay fault, these strata are intruded by hypabyssal igneous rocks of the Hamblin-Cleopatra volcano (Thci). Geochronologic data from outside of the Boulder Canyon quadrangle indicate an age span of ca. 13.2–12.0 Ma for this unit (Bohannon, 1983; Harlan et al., 1998; Castor et al., 2000).

Trg Rainbow Gardens formation (early Miocene to late Oligocene) Conglomerate, sandstone, limestone, and mudstone representing the basal Tertiary section that unconformably overlies Mesozoic and Paleozoic units throughout the Lake Mead domain (Lamb et al. 2015, 2018). Although undivided on the map, this unit may be broken out into three members, including in ascending order: (1) a reddish-gray basal conglomerate member consisting of resistant, carbonate-cemented, clast-supported conglomerate that weathers to a conspicuous dark brown and is composed exclusively of subrounded to rounded Paleozoic carbonate and Mesozoic sandstone clasts; (2) relatively recessive red to tan sandstone, mudstone, tuff, limestone and minor gypsum; and (3) pale gray to yellow, resistant, thin- to thick-bedded, algal-laminated limestone with subordinate sandstone, mudstone and gypsum intercalations. Thickness is highly variable due to faulting, ranging from 20 to 120 m.

Mesozoic Sedimentary Rocks

Ja Aztec Sandstone (Early Jurassic) Light tan to pale pink eolian sandstone with characteristic large-scale trough cross-bedding. Composed of fine- to medium-grained, well-rounded and well-sorted quartz arenite. Weathers tan to reddish-orange. Moderately indurated with minor hematitic cement, although locally friable and uncemented. Thickness is uncertain due to faulting but is more than 400 m in the quadrangle.

Chinle Formation (Late Triassic)

TRcu Upper part Mostly poorly exposed rusty red to light reddish-brown mudstone and gypsiferous mudstone with subordinate sandstone and limestone. Sandstone is weathered red, gray on fresh surfaces and consists of very fine-grained, well-sorted, well-rounded, quartz-rich sand with subtle ripple laminations and conspicuous burrow textures along some bedding planes. Bedding is very thin to thin, typically wavy and discontinuous, and only expressed by sandstone and limestone interbeds. Mostly equivalent to Petrified Forest Member. Thickness is 150 to 200 m.

TRcs Shinarump Member Pale gray to yellowish-gray or tan sandstone, pebbly sandstone and conglomerate. Weathers gray to pale brown. Sandstone consists of moderately sorted, subrounded, medium- to very-coarse-grained quartz arenite with minor (<5%) chert fragments. Pebbles up to 3 cm wide occur as thin stringers or are concentrated at the base of sandstone beds, are very well rounded and composed of dominantly orange, brown, dark gray and pale maroon chert with subordinate white vein quartz. Generally thick to very thick bedded, commonly displays trough or planar tabular crossbedding. Thickness is 20 to 30 m.

TRm Moenkopi Formation (Early Triassic) Mostly tan to pale reddish-brown, ripple-laminated siltstone interbedded with subordinate yellowish-gray sandstone and gypsiferous mudstone. Bedding is typically very thin to thin and continuous, although locally discontinuous to lenticular. Thickness is uncertain due to poor exposure in the map area, but is estimated to be up to 400 m in the adjacent Callville Bay quadrangle (Anderson, 2003). Thickness is >150 m.

Ꞓm Muav Limestone (Cambrian) Cliff-forming, rusty yellow-orange to tan weathering, medium-grained crystalline dolomite tentatively correlated with the Muav Formation and Bonanza King Formation (Beard et al., 2007). West of Boulder Point, this unit is locally brecciated and apparently interbedded with breccias composed of angular crystalline basement and yellow dolomite clasts of Thtb-h. The basal contact of Ꞓm was previously interpreted as a low-angle detachment fault separating Precambrian crystalline basement in the lower plate from Cambrian and younger strata in the upper plate (Naumann, 1987; Eschner, 1989; Duebendorfer et al., 1990). In Flamingo Cove, however, the basal contact with Tw is clearly intrusive as indicated by its undulatory, nonplanar geometry and the occurrence of dolomite blocks up to 2 m wide that are entrained within Tw along the contact. Variable thickness up to about 40 m.

Tertiary Volcanic and Intrusive Rocks

Hamblin-Cleopatra volcano (late to middle Miocene)

Dissected stratovolcano emplaced during, and offset by, middle to late Miocene sinistral slip along the Hamblin Bay fault (Anderson, 1973; Weber and Smith, 1987). Mafic and intermediate lavas and autobreccias dominate, while tuffs and other pyroclastic rocks are conspicuously sparse. Lavas are subalkaline and geochemically classified as basalt, hawaiite, trachybasalt, shoshonite, and trachyte (Barker et al., 2012). Eruptive activity occurred from ~13.0 to 10.7 Ma (Thompson, 1985; Barker et al., 2012) and overlapped in time and in space with deposition of the Lovell Wash Member of the Horse Spring Formation (Thl), the volcanic units of Boulder Wash (Tbwd, Tbwt), and the red sandstone unit (Trsc, Trss, Trsg, Trsl).

Thcb Basaltic lavas Basaltic andesite to shoshonite lava flows and breccias occurring in the east part of the map area and generally correlated with the Cleopatra lobe of the Hamblin-Cleopatra volcano. Weathers reddish-brown, brown, burgundy, or grayish-purple. Textures vary between flows from aphanitic to porphyritic. Most lavas are finely porphyritic with minor (2–4%) plagioclase, clinopyroxene and/or olivine (as iddingsite) phenocrysts in a dense, microlitic, gray groundmass. A distinctive flow contains ~5% euhedral plagioclase crystals up to 12-mm long and accessory olivine in a medium-gray groundmass. Lavas commonly display a reddish-gray basal autobreccia consisting of slightly vesicular basalt clasts. Thickness of individual flows varies from approximately 2 to 15 m.

Thca Andesitic lavas Andesitic to trachyte lava flows and massive breccias occurring in the west part of the map area and generally correlated with the Hamblin lobe of the Hamblin-Cleopatra volcano. Highly weathered to reddish-purple or brown. Most lavas are porphyritic with ~8–12% mm-scale phenocrysts of plagioclase and clinopyroxene and accessory amphibole(?) set in a very fine grained gray groundmass. Thickness uncertain due to faulting, but probably exceeds 200 m.

Thci Hypabyssal rocks Homogenous, gray porphyritic andesite with abundant plagioclase up to 8 mm long in a dense groundmass. Angular xenoliths composed of porphyritic basaltic andesite or andesite are locally abundant. Absence of autobreccias and flow foliation is conspicuous and suggests these rocks are shallow intrusive equivalents of the andesite extrusions (Thca). Commonly intruded by andesite and dacite dikes. This unit is interpreted as the hypabyssal intrusions representing the subvolcanic plumbing system of the Hamblin-Cleopatra volcano.

Volcanic units of Boulder Wash (middle Miocene)

Interbedded dacite lavas, tuffs, and breccias referred to as the "Boulder Wash volcanics" by Naumann (1987). Subdivision of these units is done for the purpose of showing structure and dividing lava-dominant (Tbwd) from pyroclastic-dominant facies, which are interstratified throughout the map area. Barker et al. (2012) reported an age of 14.2 ± 0.5 Ma [K-Ar] on plagioclase from a dacite lava within Tbwt, and Beard et al. (2007) reported a whole rock age of 12.52 ± 0.04 Ma [$^{40}Ar/^{39}Ar$] from a dacite lava in Tbwd. Naumann (1987) interpreted the Boulder Wash lavas to represent a structurally disrupted stratovolcano and noted that geochemical and textural data indicate they are volcanic equivalents of the Wilson Ridge pluton (Tw). Total thickness is >600 m although variable and uncertain due to faulting.

Tbwt Dacitic tuffs and breccias Pale greenish-blue to cyan or white tuffs and tuff breccias with subordinate dacite lava flows (Tbwd). Pumice-lithic tuffs commonly contain white, biotite-phyric pumice and/or angular biotite-plagioclase dacite clasts that are generally <5 cm wide. Tuffs vary from homogeneous ash to pumice- and/or lithic-rich with small dark gray to purple angular volcanic-lithic fragments. Tuff breccias are matrix-supported. Mostly recessive, slope-forming unit, although may form relatively resistant cliffs locally.

Tbwd Dacitic lavas and tuffs Variably colored pale pink, purple, gray, or grayish-green dacite lava flows with subordinate dacitic tuffs and breccias (Tbwt). Weathered tan-orange, brown or black. Lavas are porphyritic (10–15% phenocrysts) and contain a disequilibrium assemblage of biotite >= rounded sodic plagioclase >> embayed quartz and rare olivine in a dense pink or gray groundmass. Basal and carapace autobreccias are common and reach up ~40 m thick. Lava flow interiors typically display well-developed and tightly spaced (1–3 cm) pink-gray flow foliations. Uncommon flows also contain dark purple, subrounded to subangular porphyritic plagioclase-biotite dacite or aphanitic basalt(?) inclusions typically up to 8–10 cm wide, which may represent chilled enclaves of mafic magma (Naumann, 1987).

Wilson Ridge pluton (middle Miocene)

Compositionally and texturally diverse composite pluton composed of fine-grained quartz monzonite to quartz diorite (Eschner, 1989; Larsen and Smith, 1990; Anderson et al., 1994); however, in the Boulder Canyon quadrangle it mostly consists of abundant light to dark-gray dikes of granite porphyry, basalt, and rhyodacite commonly arranged in parallel or dike-on-dike array (Naumann, 1987; Anderson, 2003). Pervasive fractures are commonly coated with riebeckite, and secondary hematite and barite are common. The unusual chemical and textural diversity in both the Wilson Ridge pluton and correlative volcanic units of Boulder Wash (Tbwd) probably record intimate mixing

and comingling of mafic and granite magmas (Naumann, 1987). Age is accepted to be ~13.5–12.5 Ma based on K-Ar ages of 13.4–13.5 Ma south of the Boulder Canyon quadrangle (Larsen and Smith, 1990) and $^{40}Ar/^{39}Ar$ ages of ~12.5–12.6 Ma at the northern end of the pluton just west of the map boundary in the Callville Bay quadrangle (Anderson et al., 1994; Anderson, 2003); the younger ages are thought to reflect alteration history and/or cooling to <300°C rather than emplacement age.

Twa Hydrothermally altered quartz monzonite Reddish-orange to brown or yellow, fine-grained, hypabyssal quartz monzonite or rhyolite showing extensive hydrothermal alteration. Mineralized by hematite, malachite, manganese, barite, and gypsum.

Tw Hypabyssal quartz monzonite Mostly medium to dark gray, fine-grained, hypabyssal quartz monzonite and and rhyodacite containing abundant (up to 25%) and large (up to 5 mm) euhedral plagioclase, with less common and smaller biotite and embayed quartz in a dense aphanitic groundmass. Aphanitic to weakly porphyritic basalt dikes are subordinate. Weathers black to reddish-brown. Extensively fractured and typically showing minor to moderate deuteric or hematitic alteration.

Metamorphic Rocks

Hornfelsed screens of Horse Spring Formation within Wilson Ridge pluton (middle Miocene)

Blocks and screens >1 km long of stratified rocks displaying common hornfels and deuteric alteration that are mapped entirely within the Wilson Ridge pluton (Tw). These screens are tentatively correlated with sedimentary strata of the Thumb Member of the Horse Spring Formation based on (1) similar lithofacies consisting of interbedded conglomerate, sandstone, mudstone, tuff, angular breccia and megabreccia composed of crystalline-basement clasts, and mafic lavas (Castor et al., 2000; Duebendorfer, 2003; Fryxell and Duebendorfer, 2005), and (2) the requirement that these were deposited prior to emplacement of Tw (i.e, pre–13.5 Ma), which is compatible with deposition of the Thumb Member from 17.2 to 14.5 Ma (Castor et al., 2000; Beard et al., 2007).

Thtv-h Thumb Member(?), mafic lavas Weathered grayish-purple to green porphyritic mafic lava with abundant plagioclase and variable amounts of clinopyroxene and Fe-Ti oxides as phenocrysts up to 5 mm long. Pervasively fractured with variable deuteric and chloritic(?) alteration. Thickness is 50 to 80 m.

Thtf-h Thumb Member, sandstone, shale, and tuff Mostly tan to reddish-brown, well-sorted sandstone with lesser-gray limestone, weathered brownish-yellow, thinly laminated greenish-gray shale, and uncommon conglomerate and tuff. Beds are medium thickness, planar, laterally extensive, and well indurated. Sandstones display plane bed and subtle low-angle and trough cross-stratification. Many are normally graded and contain a basal layer of granules or small pebbles composed predominantly of gneiss or granite, although chert and limestone clasts are locally abundant as well. Pale cyan tuffs are aphanitic, weathered light tan, and mostly occur near the base of the unit near the contact with underlying Thtb-h. Thickness is 40 to 60 m.

Thtb-h Thumb Member, granite- and gneiss-clast breccia and conglomerate Mapped in two locations at Bearing Peak and Guardian Peak. Poorly sorted, matrix-supported conglomerate, breccia and megabreccia consisting of angular clasts of crystalline basement including primarily megacrystic granite and gneiss, with less common garnet gneiss, amphibolite, and schist. Clasts are mostly pebble to cobble size, and rarely blocks up to 2 m wide. Beds are amalgamated and massive or thick to very thick where bedding is discernible. In the Guardian Peak screen, this unit contains beds with up to 70% clasts of rusty-brown dolomite (Ꞓm). This unit was previously interpreted by Naumann (1987) as a hydro-magmatic breccia formed either by hydrofracturing or decompression-driven volatile exsolution during emplacement of the Wilson Ridge pluton (Tw). However, compelling evidence supports a sedimentary origin for this unit that is unrelated to pluton emplacement, including: (1) preserved bedding and bed-perpendicular grading in many outcrops; (2) polymict clast assemblages of diverse crystalline basement lithologies not exposed in or near the map area; and (3) the conspicuous absence of hypabyssal quartz monzonite clasts that characterize Tw. Thickness is highly variable and ranges from at least 150 to 350 m.

Ꝑg Orthogneiss (Proterozoic) Banded to strongly foliated quartzofeldspathic and amphibolitic gneiss. Locally migmatitic and showing irregular ptygmatic folding of quartz-rich leucosome. Exposed only on the southeast side of Guardian Peak. This unit likely correlates with similar Paleoproterozoic crystalline basement exposed at Gold Butte and throughout the eastern Lake Mead region (e.g., Beard et al., 2007).

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