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Geologic Map of the Caliente NW Quadrangle, Lincoln County, Nevada

by

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INTRODUCTION

This geologic map is one of two geologic quadrangles of the Caliente caldera complex to be published in 2023 by the Nevada Bureau of Mines and Geology (NBMG); five more are anticipated. These result from mapping and related petrologic, geochemical, and isotopic studies by the authors that were funded by the U.S. Geological Survey (USGS) in the late 1980s and early 1990s. The mapping was part of a large project named the Basin and Range to Colorado Plateau Transition (BARCO) study in southeastern Nevada, southwestern Utah, and northwestern Arizona. Mapping was to be published at detailed (1:24,000) scale, then compiled in 1:100,000-scale quadrangles. The project ended in early 1995 during the USGS Reduction in Force (RIF).

One of the subprojects of BARCO was a study of the Caliente caldera complex and its gold deposits, led by the senior author. Mapping at 1:24,000 scale began at the western end of the caldera complex, but only three quadrangles were published (Rowley and Shroba, 1991; Rowley et al., 1994; Swadley and Rowley, 1994). Abstracts cited here and summary reports (e.g., Rowley et al., 1992, 1995, 2001; Best et al., 1993; Hudson et al., 1995, 1998; Nealey et al., 1995; Unruh et al., 1995; Scott et al., 1995a, b) also were prepared before the RIF, with some published after. The seven quadrangles we intend to complete were mapped but never published. We also intend to publish with NBMG many $^{40}Ar/^{39}Ar$ dates by L.W. Snee, most of them from rocks in the caldera complex, that were never released in final form (e.g., Snee et al., 1990; Snee and Rowley, 2000).

The physiography of the Caliente NW quadrangle consists of the northern end of the Delamar Mountains and several small ranges to the north, the Burnt Springs Range on the west and unnamed ranges east of it. In the Caliente NW quadrangle, west of these mountain clusters is the eastern edge of broad Dry Lake Valley, and east of the mountain clusters is the western part of the Antelope Canyon basin. The other map to be published in 2023, the Chokecherry Mountain quadrangle to the south (Rowley et al., 2023), contains the central to northern Delamar Mountains and the central Burnt Springs Range. East of the Caliente NW map area, the Chief Range and eastern Antelope Canyon basin were mapped by Rowley et al. (1994). Southwest of the map area, the western Dry Lake Valley, southern Burnt Springs Range, and western Delamar Mountains, including the western edge of the Delamar caldera, were mapped by Swadley and Rowley (1994).

GEOLOGY

Calderas of the Caliente Caldera Complex

The Caliente caldera complex is one of the largest caldera complexes in the U.S. The town of Caliente, Nevada, is 10 km east-southeast of the map area, within the northwestern part of the caldera complex. Noble et al. (1968) and Noble and McKee (1972) discovered the Caliente caldera complex. Ekren et al. (1977) mapped it at 1:250,000 scale and provided much of the knowledge on the complex before our project began. We later found that the caldera

complex reached into Utah, and mapping there, funded by the Utah Geological Survey (UGS), described two additional calderas within the caldera complex (Rowley et al., 2001, 2006, 2007, 2008; Biek et al., 2009). The central part of the caldera complex, just west of the Utah border, remains unmapped.

Besides being large, the Caliente caldera complex is different from most other calderas in several respects. Our previously published maps and reports documented that it was active for about 10 million years (Snee and Rowley, 2000; Rowley et al., 1995, 2001), an extraordinarily large time span for calderas. The first eruptions were probably at about 25 to 24 Ma, during the calc-alkaline episode of magmatism that produced most volcanic rocks in the Great Basin (Lipman et al., 1972). Eruptions continued into the bimodal (basalt and high-silica rhyolite) episode of magmatism that coincided with basin-and-range deformation (Christianson and Lipman, 1972). Most volcanic rocks in the Great Basin are calc-alkaline ash-flow tuffs, many of huge volume, and the early eruptions from the Caliente caldera complex were similarly large. The first of these was likely the Leach Canyon Formation (about 24 Ma), although its source from Caliente has yet to be confirmed; its caldera may underlie the unmapped part of the overall complex in Nevada, or it is buried beneath younger calderas of the complex. The caldera complex next erupted the Condor Canyon Formation, which consists of the large Bauers Tuff Member (about 23 Ma) and the smaller younger Swett Tuff Member. The Racer Canyon Tuff (about 18.7 Ma) and the Hiko Tuff (about 18.2 Ma) were the next large events. The tuff of Tepee Rocks, petrologically similar to the Racer Canyon and Hiko Tuffs, was erupted at about 17.8 Ma. The bimodal tuffs are smaller, as elsewhere in the Great Basin, and include the tuff of Acklin Canyon (about 17.1 Ma, exposed in the Caliente and Elgin NE quadrangles), tuff of Rainbow Canyon (about 15.6 Ma) and tuff of Kershaw Canyon (about 15 Ma or less, exposed in the Caliente quadrangle). The central part of the Caliente caldera complex, at the east border of Nevada, doubtless includes other calderas. In the western part of the Caliente caldera complex, the oldest rocks that unconformably overlie those of the caldera complex include the 14.6-Ma Gregerson Basin Member of the Kane Wash Tuff that was derived from the Kane Springs Wash caldera complex about 20 km to the south (Scott et al., 1995a, b, 1996).

The Caliente caldera complex is, like many in the Great Basin, elongated east-west, a result of later east-west basin-and-range extension. However, the Caliente caldera complex is unusual in that it is significantly more elongated than others, about 80 km east-west (70 of them in Nevada) and 35 km north-south. We have interpreted that the reason for its great east-west dimension is because it extended (pulled apart) east and west along east-west transverse zones, which were active during caldera magmatism. A transverse zone is a name first applied by Rowley (1998) and Rowley et al. (1998) for an east-west "lineament" as used by Ekren et al. (1976, 1977), Stewart et al. (1977), Rowley et al. (1978), and others. As recognized by Ekren et al. (1976) and emphasized by Rowley (1998) and Rowley and Dixon (2001), transverse zones are analogous to transform faults in the ocean basins, which also strike east-west, in that they separate parts of the crust north and south of them that extended at different rates or times or by different mechanisms. As noted by Ekren et al. (1976), transverse zones span the episodes of calc-alkaline volcanism and basin-and-range tectonism and likely previous parts of the Tertiary if not well into the Mesozoic. They are prominent across the Great Basin (Ekren et al., 1976; Stewart et al., 1977; Rowley, 1998; Rowley and Dixon, 2001). They bound the north and south sides of the Caliente caldera complex (Rowley, 1998; Rowley and Dixon, 2001) as the Timpahute transverse zone and the Helene transverse zone, respectively. To commemorate the unusual aspect of the Caliente caldera complex, Rowley and Anderson (1996) named this type of caldera a "syntectonic caldera." Burke and McKee (1979) called this a volcanotectonic trough. As such, it is the largest of several in the Great Basin, whereby southern and northern caldera rims are in part faults and related structures belonging to east-striking transverse zones that were active during caldera magmatism.

The Caliente NW quadrangle describes rocks that are mostly north of the Caliente caldera complex. Some of these rocks are outflow tuffs from the caldera complex. However, at its southern edge, the quadrangle includes a small part of one caldera in the caldera complex. This is the Delamar caldera (Rowley and Siders, 1988; Rowley et al., 1990), the source of the Hiko Tuff (18.2 Ma; Th, Thi), and the caldera underlies most of the quadrangle to the south, the Chokecherry Mountain quadrangle, the other map anticipated to be published now. In the southeastern part of the Caliente NW quadrangle, the northern margin of the Delamar caldera is one of the structures of the Timpahute transverse zone, specifically the west-northwest-striking Conaway Reservoir fault, named here for a small cattle reservoir southeast of the map area, in the Caliente quadrangle. This fault behaves as a partial northern caldera structural rim (called a ring fault in traditional calderas) for the Delamar caldera. On cross section B–B', we show the upper part of the caldera margin caused by this fault as a topographic margin (a contact) formed when the upper part of the over-steepened fault failed as landslides into the caldera, resulting in intracaldera megabreccia masses (Thm); the lower part of this caldera margin is the fault itself, called a structural margin (ring fault) in traditional calderas. The intrusion of Crows Nest Tank (Tci) is emplaced within the Conaway Reservoir fault, which dies out to the west-northwest within the quadrangle. Along strike to the east-southeast, the Conaway Reservoir fault passes beneath post-faulting basin-fill sediments in the Caliente quadrangle; farther east, on the southern side of Clover Creek about a kilometer east of Caliente (in the Eccles quadrangle), the northern margin of the Delamar caldera trends east-west, reflecting what is interpreted as the same fault, here inset into the older Clover Creek caldera (Rowley and Siders, 1988; Rowley et al., 1990, 2001) to the north of it, the source of the Bauers Tuff Member (Tqcb). Just to the west of the

part of the caldera rim that is the Conaway Reservoir fault, northeast- and east-northeast striking faults of the Nelson Spring fault zone, named here for a spring just south of the fault zone in the Chokecherry Mountain quadrangle, intersect the Conaway Reservoir fault and take up the deformation along the transverse zone as well as acting as the caldera rim at and just south of the map area. The northeast-striking Seven Oaks Spring fault, in the southwestern part of the map area, acts as a caldera rim on the western side of the Delamar caldera in the Pahroc Spring SE quadrangle (Swadley and Rowley, 1994) and Chokecherry Mountain quadrangle.

Faults

As the eruptions in the Caliente caldera complex began, the area was part of a relatively flat, high-elevation plateau that stretched across what is now the Great Basin. This high, relatively level plain was studded with calderas and surmounted by lesser volumes of stratovolcanoes and other types of eruptive edifices, and was likely analogous to the Andean Altiplano of South America (Vandervoot and Schmitt, 1990; Dilek and Moores, 1999; Henry, 2008; Best et al., 2009, 2013; Henry et al., 2012; Long, 2012). The high topography was smoothed over by eruption after eruption of huge ash-flow tuffs. The plateau was held up by a thick crust, perhaps a holdover from the Sevier orogenic event, as suggested by DeCelles (2004), who called it the Nevadaplano. The drainage divide trended north through central Nevada, so that the tuffs that erupted from calderas east of that divide had a greater runout down a slope to the east. The high plateau collapsed during basin-and-range extension, beginning perhaps at about 20 Ma. However, the types of faults bespeaks that the beginning of this extension (or just prior to it) was something other than east-west pulling apart (sigma three, with vertical sigma one), as we see today. In fact, to over-simplify, initiation of northwest- and northeast-striking subvertical faults argue for an initial north-south sigma one and east-west sigma three.

The Delamar Mountains and all ranges north of the Caliente caldera complex now trend north and are largely uplifted along north-striking basin-and-range faults. We use "basin-and-range fault" in the same way that Gilbert (1928a, b) and Mackin (1960) used "basin-range fault" for a fault that formed during the basin-and-range tectonic episode (generally post-20 Ma in the Great Basin) and that blocks out the north-trending basins and ranges that make up the Great Basin. These faults dominate in the map area, although slickenline data indicate that local strike-slip motion is part of the vertical offset. Some of these faults were active for considerable time, at least several million years, for some younger rock units along the faults are dipping at lesser angles than older units, indicating recurring faulting along the faults that caused the tilting. Some faults in the map area, however, are oblique-slip faults, and these are more abundant in the southern part of the map area and to the south of it. The axis of the main range-bounding normal fault zone that separates Delamar and Dry Lake valleys to the west from the central Delamar Mountains and the Burnt Springs Range to the east was shown dotted beneath basin-fill sediments by Swadley and Rowley (1994) west of the Chokecherry Mountain quadrangle, by Swadley and Simonds (1994) southwest of the map area, and in the western part of the map area. Some parts of this fault zone cut surficial deposits, as shown by Swadley and Rowley (1994) and Swadley and Simonds (1994) and in the northwestern part of the map area, and are clearly Pleistocene, if not Holocene (active). Significant northerly striking down-to-the-east normal faults include the fault that bounds the eastern side of the central Burnt Springs Range (nearly 2 km west of Rabbit and Dana springs) in the southwestern part of the map area. Another is the Porphyry Wash fault zone that bounds the eastern side of unnamed ranges extending from the northern edge of the map area southward and separate Cambrian and Ordovician rocks on the west from volcanic rocks in the western part of the northern Delamar Mountains. The Cambrian and Ordovician rocks in these ranges dip mostly west, whereas the volcanic rocks to the east of them dip mostly east. Most of these normal faults in the map area postdate the oblique-slip faults.

The mostly short east-striking cross faults that are particularly well exposed in the Burnt Springs Range and smaller ranges of Cambrian and Ordovician rocks between and north of the Burnt Springs Range and west of the northern Delamar Mountains are typical of those in many ranges in the Great Basin. For such faults in the map area, slickenline data are virtually lacking in these sedimentary rocks, so most are interpreted to be normal faults based on age of displaced rocks on either side; but these faults doubtless have some strike-slip offset, as in other east-striking transverse faults in the Great Basin (where the rocks are volcanic and slickenlines are preserved). We consider them to have formed in the same way as transverse faults, namely as boundaries separating rocks north and south of them that responded differently to the east-west extension that produced northerly striking basin-and-range faults. Some east-west faults form large crosscutting zones, as in the southern edge of the map area and in the Chokecherry Mountain quadrangle to the south, but others do not, as in the ranges of Cambrian and Ordovician rocks.

In the southern part of the quadrangle, the ranges are cut by the several mentioned large faults of the Timpahute transverse zone that strike east-northeast and west-northwest, as well as several northeast- and northwest-striking faults, all of which die out at their northern ends. Analysis of slickenline data and mapping shows that these southern faults are oblique-slip faults that reflect movement along the Timpahute transverse zone. They are longer lived than the strictly basin-and-range faults. They partly predated basin-and-range extension because they acted as caldera rims during eruption of calc-alkaline tuffs from the Caliente caldera complex. Evidence in the map area that these faults are older is also provided in the southeastern part of the Caliente NW quadrangle, where a shallow basin (Sugarloaf basin) filled with landslide and erosional debris from the Delamar caldera and subsided along the west-northwest- to

northwest-striking West Sugarloaf fault zone on the east and the northeastern part of the Seven Oaks Spring fault zone on the west; clearly these fault zones were partly contemporaneous with the magmatism of the Delamar caldera.

Movement along many oblique-slip faults in and south of the map area continued into the basin-and-range episode of magmatism and faulting. The evidence that these east-northeast, west-northwest, and northwest faults are also younger than some of the basin-and-range faults is because many crosscut some basin-and-range faults. In addition to the oblique-slip Conaway Reservoir fault zone and Nelson Spring fault zone, the map area includes the oblique-slip Seven Oaks Spring fault in the southwestern part of the map area and the oblique-slip East Sugarloaf fault in the southeastern part of the map area. In the Chokecherry Mountain quadrangle to the south, the Delamar caldera is highly deformed by many faults and fault zones, some of them large and most of which are oblique-slip and strike northeast, east-northeast, northwest, west-northwest, and east-west; many are partly contemporaneous with caldera magmatism as well as postdating it. Argon dating of ten samples from plugs and dikes, mapped as the porphyry of Meadow Valley Wash (Tpm) and discussed in detail in the Chokecherry Mountain quadrangle (only one such dike was found in the map area), emplaced along many large fault zones in and near the map area, show that these faults were active between about 20 to 16 Ma.

Mineral Deposits

We interpret that magmatism in the Caliente caldera complex resulted in several epithermal mining districts, mostly as gold mineralization. These include the small Chief mining district, with mines on the northern margin of the Cobalt Canyon stock (almost 25 Ma), emplaced just north of the Clover Creek caldera (Rowley et al., 1992, 1994, 2001; Rowley and Shroba, 1991) and presumably (the northern margin is partly covered) along the Timpahute transverse zone. The small Taylor (or Easter) mining district is within the Delamar caldera in the Chokecherry Mountain and Caliente quadrangles. The small Pennsylvania mining district is in the caldera complex in the Elgin NE quadrangle (south of the Caliente quadrangle). The large Delamar mining district, Nevada's largest gold district at the turn of the 20th century, is in the Delamar quadrangle on the western side of the Delamar caldera and southwest of the Chokecherry Mountain quadrangle. Therefore, samples were collected for metal geochemistry, including gold analyses, in all seven quadrangles; tables of these data are included with each map, as with two of the three previously published.

Surficial Deposits

Surficial deposits are mapped differently in the eastern side of the quadrangle than in the western side. Those in the east, most of which were deposited by streams draining east and north of the northern Delamar Mountains, were deposited by streams that flowed east into south-flowing, perennial Meadow Valley Wash, located east of the map area. These streams are part of through-flowing drainage, which continues through beautiful Rainbow Canyon south of Caliente and on to the Colorado River. The descriptions of the deposits therefore follow the mapping of Rowley and Shroba (1991) and Rowley et al. (1994). The surficial deposits in the western side of the quadrangle, on the other hand, were deposited by streams draining west into Dry Lake Valley and Delamar Valley, which are closed basins of the Great Basin. For these deposits, we follow the mapping of Swadley and Rowley (1994) and the discussion of Swadley et al. (1995).

DESCRIPTION OF MAP UNITS

Qal Alluvium (late Holocene) Sand, gravelly sand, and small amounts of gravel; unconsolidated, moderately well sorted to poorly sorted, massive to poorly bedded; sand is fine to coarse near mountain fronts, fine to medium at distal edges of fans; gravelly sand contains angular to subrounded pebbles and cobbles of volcanic rocks, limestone, and dolomite; large cobbles and sparse boulders as much as 1 m in diameter are locally present, chiefly near bedrock exposures; present in the west part of the map area, where unit forms channel deposits in large active intermittent washes that pass westward into low-gradient distal edges of fans in the closed basin of Dry Lake Valley (Swadley and Simonds, 1994) before grading into playa deposits; most exposures exhibit no soil development, but local areas have a thin sandy vesicular A horizon; maximum exposed thickness about 5 m.

Qac Alluvium and colluvium, undivided (Holocene and late Pleistocene) Chiefly undivided stream alluvium of intermittent side streams, as well as fan and sheetwash alluvium and hillslope colluvium; silty and pebbly sand to clast-supported, cobbly pebble gravel in a sand matrix, typically interbedded sand and pebble gravel; underlies flood plains, low terraces, and small fans; colluvium mantles adjacent hillslopes; alluvial channels commonly have incised modern drainage channels and locally have low bar-and-swale topography; soils formed in deposits of the map unit are characterized by Bk horizons that have coatings of secondary calcium carbonate on the undersides of clasts, but coatings are patchy to continuous and typically less than 0.5 mm thick; present in the east part of the map area as deposits of large intermittent washes that drain eastward; map unit locally includes main-stream alluvium and minor debris-flow deposits; maximum thickness probably about 15 m.

Qfm Fan alluvium of Meadow Valley (Holocene and latest Pleistocene?) Interbedded matrix-supported, sandy pebble gravel and pebbly sand as well as clast-supported pebble and cobble gravel in a sand matrix; slightly more silt and fine sand in the upper 30–40 cm; typically poorly sorted and crudely bedded; beds are commonly 15–75 cm thick; locally contains numerous boulders; sparsely present in the

north part of the map area, where small sidestream fans underlie surfaces that have slopes of about 7º–12º and are graded to flood plains of larger modern washes; some surfaces have well-expressed bar-and-swale topography; secondary calcium carbonate in deposits typically coats bottoms of clasts; these coatings are patchy to continuous, less than 0.5 mm thick, and occur at depths of about 20 cm to greater than 3 m; includes minor debris-flow deposits, hillslope colluvium, and talus; informally named for deposits exposed along the west side of Meadow Valley, in the Indian Cove quadrangle (Rowley and Shroba, 1991) about 11 km east of the map area, that postdated the development of through-flowing drainage and canyon cutting of Meadow Valley Wash to the Colorado River; maximum thickness about 15 m.

Qc Colluvium (Holocene and late Pleistocene) Pebble gravel and minor amounts of interbedded pebbly sand, deposited by mass-movement processes, that form thin mantles overlying and obscuring bedrock; as mapped, includes small areas of fan and sheet wash deposits; maximum thickness about 5 m.

Qae Alluvium (early Holocene and late Pleistocene) Sand, gravelly sand, and small amounts of gravel; unconsolidated to weakly consolidated, poorly to moderately well sorted and poorly bedded; sand is fine to coarse grained near the mountain front and fine to medium grained on more distal parts of fans; gravelly sand contains angular to subrounded pebbles, cobbles, and boulders of volcanic rocks, limestone, and dolomite that are generally less than 0.3 m in diameter; gravel is commonly angular to subangular, has a sand matrix, and occurs chiefly near bedrock exposures; exposed in the west part of the map area, where unit forms large low-gradient fans, small steep fans adjacent to mountain fronts, and small terrace remnants and inset fans along the larger washes; deposits of unit stand 1–2 m above active washes (unit Qal); surface of deposit is smooth on lower fans and terraces; bar-and-swale topography is locally preserved near the heads of some steeper fans; soil developed in the unit consists of a sandy vesicular A horizon that locally overlies a thin weakly developed textural B horizon that overlies a Bk horizon with stage I carbonate about 25 cm thick; no color change in the textural B horizon with respect to the parent material was observed; the Bk horizon is only weakly developed where the unit consists entirely of sand; maximum thickness about 4 m.

Qlb Lacustrine beach deposits (late Pleistocene) Gravelly sand, unconsolidated to weakly consolidated, moderately well sorted, calcareous; sand is chiefly fine to medium; gravel clasts (mostly less than 3 cm across) comprise about 10 percent of deposit and consist of volcanic rocks, limestone, and dolomite; exposed only in the northwest corner of the map area, where here and to the west (Swadley and Simonds, 1994) forms as many as four discontinuous parallel ridges that mark former shorelines of a late Pleistocene pluvial lake called Lake Bristol by Mifflin and Wheat (1979); the ridges have been dissected and form a line of low elongate mounds about 1 m or less in height that are covered by a sparse gravel lag; the higher of the two more prominent ridges stands at an elevation of about 1407 m and probably marks the highest sustained level of the lake, which had a water depth of about 14 m (Swadley and Simonds, 1994); the only soil development consists of a 3- to 4-cm-thick sandy vesicular A horizon; maximum exposed thickness 1 m.

Qta Terrace alluvium (late Pleistocene) Stream alluvium underlying small terrace remnants; clast-supported and matrix-supported pebble gravel and local beds of cobble gravel in a sand matrix interbedded with minor pebble sand; poorly to moderately well sorted and poorly to well bedded; upper part of unit weakly to locally strongly indurated by secondary calcium carbonate; clasts are subangular to subrounded volcanic rocks, limestone, and dolomite; present in the east part of the map area as terrace remnants at several levels from about 3 to 10 m above present stream level along large intermittent washes that drain eastward; locally includes thin deposits of Holocene colluvium; exposed thickness 3 to 5 m.

Qfr Fan alluvium of 1001 Ranch (late Pleistocene) Clast-supported pebble and cobble gravel in a sand matrix; poorly sorted and locally contains numerous small boulders; sparsely present in the northeast part of the map area, where several sidestream fans underlie surfaces graded to a level about 5 m above floor of modern washes and has a slightly dissected surface; upper part of unit consists of a lag of gravel and lacks bar-and-swale topography; soil formed in unit has a thin (30 cm) K horizon having weak stage III carbonate that overlies a Bk horizon (more than 20 cm thick) having stage II carbonate; includes deposits of Holocene alluvium on floors of modern washes; informally named for deposits exposed along the west side of Meadow Valley, in the Indian Cove quadrangle (Rowley and Shroba, 1991) about 11 km east of the map area, that postdated through-flowing drainage and canyon cutting of Meadow Valley Wash to the Colorado River; locally includes minor debris-flow deposits; exposed thickness 2 m.

Qaj Alluvium of Jumbo Wash (middle Pleistocene) Sand, gravelly sand, and small amounts of gravel; weakly consolidated, moderately well sorted to poorly sorted, poorly to moderately well bedded; sand is medium- to coarse-grained near the mountain front and medium on more distal parts; gravel and the clasts in the gravelly sand are angular to subrounded pebbles, cobbles, and boulders of volcanic rocks, limestone, and dolomite that are generally less than 0.5 m in diameter; present in the west part of the map area, where unit forms fan remnants that extend from mountain fronts and smaller fans inset into deposits of middle Pleistocene age; deposits of unit stand 2–4 m above active washes (Qal); surface of deposit is smooth to slightly dissected; a loosely to tightly packed stone pavement is sparsely developed; a dull-brown rock varnish is locally present on a few clasts of the pavement; soil consists of a 3- to 5-cm-thick fine sand and silt vesicular A-horizon, a 30–35 cm dark yellowish-orange B horizon, and a 0.5- to 0.7-

m-thick Bk horizon that typically has stage II carbonate in the upper part and stage I carbonate in the lower part; the carbonate zone of the C horizon is commonly thinner and less well developed where unit is composed mostly of sand; unit informally named for deposits along and near Jumbo Wash in the Gregerson Basin quadrangle (Scott et al., 1990) about 30 km south-southwest of the map area; maximum thickness at least 5 m.

Qfms Fan alluvium of Miller Spring Wash (middle Pleistocene) Clast-supported and matrix-supported pebble and cobble gravel and local minor beds of small-boulder gravel in a sand matrix, interbedded with pebbly sand; poorly to moderately sorted; unit mostly in the east part of the map area, where fan surfaces are graded to a level about 25–30 m above Meadow Valley Wash (Rowley and Shroba, 1991); upper part of unit consists of a lag of gravel; locally may contain stream terrace deposits; soils formed in unit commonly consist of the following top-to-bottom sequence of horizons: a silt-enriched vesicular A horizon 5 cm thick, a cambic B horizon or locally a weakly developed argillic B horizon 25–50 cm thick (both with stage I carbonate), a K horizon 50–100 cm thick having stage III carbonate, and a Bk horizon more than 50 cm thick having stage I–II carbonate; locally includes deposits too small to be mapped, including Holocene alluvium in modern washes, locally derived Holocene colluvium on steep slopes, terrace alluvium of late Pleistocene age, and pediment alluvium; informally named for deposits exposed along the west side of Meadow Valley, in the Indian Cove quadrangle (Rowley and Shroba, 1991) about 11 km east of the map area, that postdated through-flowing drainage and canyon cutting of Meadow Valley Wash to the Colorado River; exposed thickness 2–3 m.

Qaw Alluvium of Willow Spring (middle Pleistocene) Interbedded gravelly sand, sand, and gravel; weakly to moderately well consolidated; moderately well sorted to poorly sorted and poorly bedded; gravel consists of angular to subrounded clasts of volcanic rocks, limestone, and dolomite that are generally less than 1 m in diameter; present in the west part of the map area, where unit forms gravelly sand and sand remnants along larger washes and small steep gravel and gravelly sand fans adjacent to mountain fronts; the more distal remnants of larger fans are locally veneered by thin deposits of alluvium Qae; these partly covered remnants commonly stand less than 1 m above adjacent deposits of unit Qae and have sparse to common clasts of pedogenic carbonate at the surface; depositional surface of unit is mainly intact but is moderately dissected by V-shaped washes; surface of unit typically stands 2–5 m above active washes (Qal); a tightly packed stone pavement is locally developed, in which surface clasts have a weakly to moderately well-developed rock varnish; sand is fine to coarse, poorly sorted, and generally poorly bedded, with local cross-bedding; gravel consists of subangular to rounded clasts of volcanic rocks, limestone, and dolomite, and is mostly pebble and cobble sized, with sparse boulders as much as 1 m in diameter; soil includes a 4- to 6-cm-thick, silty sand vesicular A horizon, a dark-yellowish-orange to light-brown B horizon that is rarely preserved, and a 1- to 1.5-m-thick zone of carbonate accumulation that commonly has a stage III horizon in the upper part and a stage II Bk horizon in the lower part; unit named for deposits near Willow Spring in the Delamar 3 SE quadrangle (Swadley et al., 1990) about 60 km south-southwest of the map area; maximum thickness at least 8 m.

Qfo Fan alluvium of Oxborrow Ranch (early Pleistocene) Clast-supported, cobbly pebble gravel, and local minor beds of boulder gravel in which clasts are as long as 60 cm, in a sand matrix, interbedded with matrix-supported pebble gravel and pebbly sand; unit exposed on the north side of the upper reaches of Antelope Canyon, in the east part of the map; upper part of unit consists of a lag of gravel and numerous calcium-carbonate-coated clasts and small, tabular, calcium-carbonate-cemented fragments derived from an underlying indurated soil K horizon that is poorly exposed; unit includes minor deposits of pediment alluvium; informally named for deposits exposed along the west side of Meadow Valley, in the Indian Cove quadrangle (Rowley and Shroba, 1991) about 11 km east of the map area, that postdated through-flowing drainage and canyon cutting of Meadow Valley Wash to the Colorado River; maximum thickness about 10 m.

QTa Alluvium (early Pleistocene and Pliocene?) Gravel and gravelly sand; moderately well consolidated, poorly sorted, and poorly bedded; weakly to moderately well cemented with calcite; gravel clasts consist of angular to subrounded volcanic rocks, limestone, and dolomite as pebbles, cobbles, and boulders with a maximum size of 2 m; occurs as small dissected fan remnants in scattered places in the west part of the map area, mostly adjacent to the Burnt Springs Range; distinguished from unit Qaw by deeper dissection, more abundant pedogenic carbonate fragments on the eroded surface, and greater content of boulders; the surfaces of the unit commonly stand 4 to 8 m above active washes and are typically littered with boulders and common to abundant fragments of pedogenic carbonate; a tightly packed stone pavement is locally developed on gently sloping surfaces; soil development in unit typically consists of a 1- to 1.5-m-thick zone of carbonate accumulation that has a stage III K horizon in the upper part and a stage II Bk horizon in the lower part; the K horizon is overlain by a 4- to 6-cm-thick clayey, silty sand vesicular A horizon; soil developed in this unit conforms to an erosional surface and likely is significantly younger than the deposit; maximum exposed thickness is about 10 m.

QTu Alluvium, undivided (Holocene to Pliocene?) Units Qal, Qac, Qae, Qta, Qaj, Qaw, and QTa; shown in cross section A–A' only.

QTfc Fan alluvium of Chief Mountain (early Pleistocene or late Pliocene) Clast-supported, cobbly pebble gravel and local minor beds of small-boulder gravel in a sand matrix, interbedded with matrix-supported pebble gravel and pebbly sand; unit forms large to small fan

remnants in Antelope Canyon basin, including along the east side of the map area; upper part of unit consists of a lag of gravel, numerous calcium-carbonate-cemented clasts, and small tabular calcium-carbonate-cemented fragments derived from an underlying indurated soil K horizon that is poorly exposed; unit includes local deposits of pediment alluvium and thin lag gravels; informally named for deposits exposed along the west side of Meadow Valley, in the Indian Cove quadrangle (Rowley and Shroba, 1991) about 11 km east of the map area, that postdated through-flowing drainage and canyon cutting of Meadow Valley Wash to the Colorado River; maximum thickness probably about 10 m.

Tfa Fan alluvium of Antelope Canyon (Pliocene) Basin-fill sequence of light-gray and tan, locally light-pink, poorly to moderately consolidated, mostly clast-supported but locally matrix-supported, poorly sorted, subangular to subrounded, boulder to pebble conglomerate and pebbly sandstone; mostly medium bedded (0.2–0.5 m) to thick planar bedded (> 0.5 m) and locally cross-bedded; boulders are mostly volcanic rocks, most notably basalt (Tb), with clasts as large as 1 meter in diameter, although a 2-meter-diameter clast of Hiko Tuff (Th) was found; mostly stream alluvium but includes debris-flow deposits; has lower dips (generally less than 15 degrees) and unconformably overlies the sedimentary rocks of Newman Canyon (Tn); in the Chief Mountain quadrangle to the east (Rowley et al., 1994), this contact is gradational and poorly exposed; as mapped, locally includes younger fan and stream terrace alluvium as well as colluvium, and may include deposits of late Miocene or early Pleistocene; informally named for deposits exposed along the west side of Meadow Valley, in the Indian Cove quadrangle (Rowley and Shroba, 1991) about 11 km east of the map area, that postdated through-flowing drainage and canyon cutting of Meadow Valley Wash to the Colorado River; this unit represents the oldest of these fan deposits that postdate drainage integration and represent erosion of basin-fill deposits in Antelope Canyon basin and adjacent basins; minimum thickness in Antelope Canyon basin about 250 m.

Tb Basalt (Pliocene) Thin resistant lava flows of dark-gray, crystal-poor basalt containing generally less than 5 percent of antigorite altered after olivine; flows locally interbedded with the fan alluvium of Antelope Canyon (Tfa); exposed only in the northeast corner of the map area; maximum thickness about 40 m.

Tn Sedimentary rocks of Newman Canyon (Miocene) Tuffaceous basin-fill sequence of poorly to moderately consolidated, light- to medium-gray, poorly sorted, subangular to subrounded, boulder to pebble conglomerate and lesser pebbly sandstone; boulders are mostly volcanic rocks, including clasts as long as 3 m of the Bauers Tuff Member of the Condor Canyon Formation (Tqcb), as long as 2 m of basalt, as long as 2 m of Hiko Tuff (Th, Thi), as well as boulders of the Harmony Hills Tuff (Tqh) and the rhyolite of Antelope Canyon (Tra); basalt (Tb) clasts become more common higher in the section; mostly stream alluvium but includes debris-flow deposits; aerial photos show the unit to be planar bedded, yet on the ground there are few exposures; aerial photos also show it to be darker, more resistant, coarser grained, and dipping more steeply than the unconformably overlying fan alluvium of Antelope Canyon (Tfa); map unit overlies the rhyolite of Antelope Canyon (Tra) and is intertongued with the Ox Valley Tuff (To); tentatively correlated with the sedimentary rocks of Newman Canyon in the Chief Mountain quadrangle (Rowley et al., 1994) to the east, but there it is finer grained, assumed thicker (the base is not exposed), and better exposed, and it is made up in greater volume by sedimentary clasts derived from erosion of the Chief Range, on the east side of the basin; in fact, the main similarity is that the sedimentary rocks of Newman Canyon in the Chief Mountain quadrangle also intertongues with the Ox Valley Tuff (To), which then was called the tuff of Etna; in the Caliente NW quadrangle, we assume that the lithologic difference between the rocks in the Chief Mountain quadrangle reflects the volcanic dominance on the west side of the basin; in the Chief Mountain quadrangle, a water-laid pumice bed within the upper part of the unit (above the Ox Valley Tuff, which is about 14.0 Ma) yielded a K-Ar date on sanidine of 13.8 ± 0.9 Ma (Snee et al., 1990; Rowley et al., 1992, 1994); L.W. Snee determined an $^{40}Ar/^{39}Ar$ date of 14.09 ± 0.05 Ma (biotite) from a bed of ash-fall tuff (sample 91-985) in these sediments from the southeast part of The Bluffs quadrangle, about 7 km north-northeast of Porphyry Spring; maximum thickness roughly 300 m (dip angle could only be estimated).

To Ox Valley Tuff (Miocene) Moderately resistant, light- to medium-gray and pink, mostly densely welded, generally crystal-poor, high-silica rhyolite ash-flow tuff; has a dense, brick-like consistency; contains 10–20 percent, but locally increasing upward to as much as 40 percent, phenocrysts of mostly sanidine (some of which is adularescent), subordinate quartz (commonly embayed and locally large and conspicuous), and minor plagioclase, Fe-Ti oxides, pyroxene, hornblende, and olivine, and traces of biotite; contains abundant pumice, generally several percent but more than 15 percent in some rocks; contains lithic fragments (volcanic rock fragments, or VRFs) as long as 2 cm, generally making up 0.5 to several percent of rock volume; a young outflow tuff especially conspicuous capping mesas south of Caliente in the northern Caliente caldera complex, where Bowman (1985) mapped it as unit C4; during mapping of the caldera complex, Rowley et al. (1994) called it the tuff of Etna after a railroad stop in Rainbow Canyon 7 km south-southwest of Caliente; although Rowley et al. (1994, 1995) recognized that it had many similarities in lithology and petrography with the Ox Valley Tuff, which is exposed in the Enterprise area of the Bull Valley Mountains of Utah about 100 km east-northeast of the map area, it was not until the mapping of the Goldstrike 7.5-minute quadrangle in Utah (Rowley et al., 2007) and its compilation in the St. George 30-minute x 60-minute quadrangle (Biek et al., 2009) that additional work, notably additional isotopic ages, confirmed that the two units are the same; furthermore, the source of the tuff is a

high-silica granite porphyry laccolith, the Mineral Mountain intrusion (the southern and youngest pluton of the Iron Axis, a northeast-trending belt of intrusions partly controlled by thrust faults and characterized by iron occurrences; Mackin, 1960; Tobey, 1976; Hacker, 1998; Hacker et al., 2002), about 65 km east-northeast of the map area, in the Goldstrike quadrangle, that is distinctive in that it is made up mostly of fine-grained orthoclase with large quartz "eyes" (Rowley et al., 2007); the tuff of Etna was considered to have an age of about 14 Ma because stratigraphically it is above the 14.4-Ma upper unit of the Gregerson Basin Member of the Kane Wash Tuff and below the 13.8-Ma age of a water-laid tuff in the sedimentary rocks of Newman Canyon (Tn), whereas several K-Ar dates on the Ox Valley Tuff indicated that its age was 12.6 to 12.3 Ma (Rowley et al., 1995), leading us to doubt that the tuff of Etna correlated with the Ox Valley Tuff; as the Goldstrike quadrangle was being mapped, Snee and Rowley (2000) reported $^{40}Ar/^{39}Ar$ dates of 13.46 ± 0.05 Ma from the lowest of four cooling units in the type area of Ox Valley, 14.10 ± 0.03 Ma from just west of Beaver Dam State Park, Nevada, and 12.19 ± 0.08 Ma from a rhyolite flow that rests on Ox Valley at Docs Pass, Nevada, and the UGS and New Mexico Geochronology Research Laboratory (2007) reported a date of 13.93 ± 0.08 Ma from southwest of Enterprise; an outflow tuff about 11 km south-southwest of Mineral Mountain has a thickness of 1200 m, prompting Anderson and Hintze (1993) and Hintze et al. (1994) to suggest that this was its caldera source, but Rowley et al. (2007) found that these deposits rest on andesite flows and mudflows, thus interpreted the deposits to be outflow occupying canyons or basins at the base of the rapidly rising laccolith of Mineral Mountain, similar to outflow from other laccoliths of the Iron Axis (Hacker et al., 2002, 2017); thickness in the map area generally about 25 m.

Tra Rhyolite of Antelope Canyon (Miocene) Resistant, light-gray and reddish-brown, flow-foliated, crystal-poor high-silica rhyolite lava flows and volcanic domes; contains 10–15 percent phenocrysts of quartz, subordinate sanidine and plagioclase, and minor but conspicuous biotite; includes a black basal vitrophyrye, beneath which is a light-red flow breccia, beneath which is a thin tuff containing clasts of gray glass; exposed only about 3 km north of the upper headwaters of Antelope Canyon, in the northeast part of the map area; thickness about 300 m.

Trc Tuff of Rainbow Canyon (Miocene) Nonresistant, light-yellow, tan, pink, and pinkish-tan, nonwelded to poorly welded, crystal-poor, high-silica rhyolite ash-flow tuff; contains about 10 percent phenocrysts of quartz and sanidine, subordinate to minor plagioclase, and minor biotite and Fe-Ti oxides; contains abundant (as much as 20 percent) volcanic rock fragments of cogenetic light-yellow, rhyolite flow rock as large as 1 meter in diameter; contains as much as 20 percent partly compacted pumice; exposed only in the northeast part of the map area, where it rests on the tuff of Tepee Rocks about 3 km northwest of the upper headwaters of Antelope Canyon; where the tuff of Tepee Rocks is missing, rests on the outflow Hiko Tuff (Th) about 1.5 km west of these upper headwaters; map unit is an outflow tuff derived from the Buckboard Canyon caldera (Rowley and Siders, 1988; Rowley et al., 1990, 1995), which is exposed south and southeast of the map area; analyses of sanidine from separate samples of intracaldera tuff collected from the mouth of Buckboard Canyon, about 8 km southeast of the map area, resulted in a K-Ar date of 15.2 ± 0.6 Ma (Mehnert et al., 1989) and a preliminary $^{40}Ar/^{39}Ar$ date of 15.64± 0.18 Ma (Rowley et al., 1995; Snee and Rowley, 2000); of these two dates, the Ar date is more likely and corresponds better to a date on a genetically related rhyolite dome that overlies the tuff of Rainbow Canyon in the Chokecherry Mountain quadrangle; maximum thickness about 90 m.

Tpm Porphyry of Meadow Valley Wash (Miocene) Dikes, sheared intrusive lenses, and intrusive plugs of resistant, mostly light- to dark-gray, reddish-brown, and khaki, commonly glassy, locally sheared and brecciated, crystal-poor to crystal-rich, hypabyssal dacitic to rhyolite porphyry occurring along or within large fault zones mostly within calderas of the Caliente caldera complex in nearby quadrangles but also outside of the calderas, as in the map area; intrusive bodies contain miarolitic cavities and local flow foliation; distinctive because phenocrysts of sanidine and plagioclase may be as long as 2 cm, and quartz crystals also may be large; first mapped (Rowley and Shroba, 1991) as a dike containing about 35 percent phenocrysts of plagioclase, much subordinate sanidine, quartz, hornblende, biotite, and Fe-Ti oxides, and minor pyroxene and sphene in a glass groundmass that was intruded into the large, northwest-striking right-lateral oblique-slip Chief Mountain fault zone north of Caliente, where the fault cuts the Clover Creek caldera; the dike continues westward into the Chief Mountain quadrangle (Snee et al., 1990; Rowley et al., 1994), where other dikes and plugs of the map unit as much as 0.25 km in width/diameter occur in the northeast-striking, left-lateral oblique-slip Gravel Pit fault zone (named for a gravel pit shown on the map) and in the north-striking oblique-slip Meadow Valley Wash fault zone that contains both left-lateral and right-lateral components; exposed in only one place in the map area as a 3-m-wide east-striking dike in lower Porphyry Wash 3.5 km west-northwest of Porphyry Spring in the northwest part of the map area, as a rhyolite glass containing 10 percent phenocrysts of sanidine, lesser quartz and plagioclase, and trace amounts of biotite, hornblende, Fe-Ti oxides, and sphene; a sample (91-382, table 2) yielded a date of 16.26 ± 0.08 Ma (sanidine); the map unit is discussed in greater detail in the text of the Chokecherry Mountain quadrangle.

Ttr Tuff of Tepee Rocks (Miocene) Moderately resistant, gray and tan, poorly welded, generally crystal-poor, low-silica rhyolite ash-flow tuff; contains 10–25 percent phenocrysts of quartz, sanidine, and plagioclase, subordinate to minor biotite, and minor hornblende, Fe-Ti oxides, and sphene; resembles the Hiko Tuff (Th) and Racer Canyon Tuff but distinguished by lower biotite and hornblende (Rowley et al., 1995); contains as much as 6 percent volcanic rock fragments and as much as 40 percent

white pumice; identified in only one place in the map area, located beneath the tuff of Rainbow Canyon (Trc) and 3.7 km north-northwest of the upper headwaters of Antelope Canyon; outflow tuff derived from the Caliente caldera complex, and doubtless the same magma chamber as Hiko and Racer Canyon Tuffs, but the main outcrops at Tepee Rocks, about 100 m thick and eroded to prominent hoodoos within the caldera complex about 6 km east-southeast of Caliente, in the Eccles quadrangle, could be either outflow or intracaldera deposits; L.W. Snee determined a $^{40}Ar/^{39}Ar$ date on biotite of 17.77 ± 0.07 Ma from a sample collected at Tepee Rocks (Rowley et al., 1995; Snee and Rowley, 2000); maximum thickness in the map area about 6 m (base not exposed).

Rocks of the Delamar caldera (Miocene)

Parts of the Delamar caldera, one of the younger calderas of the Caliente caldera complex, are exposed at the south edge of the map area; in addition, the Sugarloaf basin and its associated deposits (unit Tbs), in the southeast part of the map area and extending into the north edge of the Chokecherry Mountain map area, appears to be tangentially related to the Delamar caldera inasmuch as the basin subsided at about the same time as the caldera but along northwest- and north-northwest-striking right-lateral oblique-slip faults that connect with the faults of the Timpahute transverse zone that created the Delamar caldera; other features of the Delamar caldera are post-subsidence but cogenetic rhyolite flows and tuffs deposited as volcanic domes on the caldera's north side (unit Tci), as is common in other calderas (e.g., Rowley et al., 2002) and even after significant ash-flow eruptions (e.g., Rowley et al., 1981).

Tci Intrusion of Crows Nest Tank (Miocene) Thin fragments of a resistant thick dike of light-gray, cream, and yellowish-green, flow-foliated, vesicular, crystal-rich, low-silica rhyolite at the south edge of the map area and about a half kilometer south and southeast of Crows Nest Tank, a cattle tank in the southeast part of the map area; contains about 35 percent phenocrysts of plagioclase, subordinate but subequal amounts of sanidine and quartz, much subordinate biotite, minor hornblende and Fe-Ti oxides, and trace amounts of sphene; intruded along the west-northwest-striking, oblique-slip (right-lateral and down to the south) Conaway Reservoir fault zone, which here forms the north rim of both the Delamar caldera and here the Caliente caldera complex; the dike may be the upper part of an intracaldera (resurgent) pluton of the Delamar caldera, and it probably fed a rhyolite dome perched on the caldera margin; it is a similar lithology to, and was probably derived from the same magma chamber as, the Hiko Tuff and intruded along the fault zone that forms the north caldera rim; L.W. Snee determined $^{40}Ar/^{39}Ar$ dates (Rowley et al., 1995) from the dike just south of the map area of 18.08 ± 0.19 Ma (sanidine), the preferred age, and 18.33 ± 0.12 Ma (hornblende); the map unit is similar in age, lithology, and position as a volcanic dome on the north edge of the Delamar caldera at two other places, (1) the volcanic dome of Barnes Canyon, in the Eccles quadrangle 7 km east of Caliente, for which L.W. Snee determined $^{40}Ar/^{39}Ar$ dates of 18.17 ± 0.08 Ma (sanidine) and 18.23 ± 0.17 Na (biotite), and (2) the volcanic dome of Islen, north of Islen in the Islen quadrangle and 19 km east-southeast of Caliente, for which L.W. Snee determined two (analyzed twice as two separates) sanidine $^{40}Ar/^{39}Ar$ dates of 18.22 ± 0.05 Ma and 18.26 ± 0.03 Ma; only the edge of the dike, less than 60 m across, is exposed at the south edge of the map area, but just to the south it is 300 to 600 m thick.

Tbs Basin sediments of Sugarloaf (Miocene) Moderately consolidated, tan, cream, and gray, well-bedded, locally cross-bedded, locally thin-bedded and laminated, tuffaceous sandstone, siltstone, conglomeratic sandstone, shoestring beds of conglomerate, volcanic mudflow breccia, and subordinate crystal-poor, pumiceous, rhyolite ash-fall tuff, water-laid tuff, and poorly welded ash-flow tuff; the sandstone and mudflow breccia in many places contain megabreccia blocks of house-size and larger of dark or tan older volcanic rocks, notably of the Hiko Tuff, Bauers Tuff Member, and Isom Formation; the poorly welded tuffs interbedded with the sediments appear to be of Hiko eruptions, with the same minerals, from 5–20 percent of quartz, subequal to slightly subordinate amounts of sanidine and plagioclase and minor biotite, hornblende, pyroxene, and Fe-Ti oxides; the deposits occupy a sag basin west of a ridge of Cambrian rocks and south of the ridge's highest part, a 200-m-high hill of Cambrian limestone named Sugarloaf (called Grey Dome on later editions of the topographic quadrangle and on the Caliente, Nevada-Utah 1:100,000 quadrangle); the basin continues south to the north margin of the Delamar caldera at the south edge of the map area; some sediments are lacustrine in origin and the rest were deposited by streams draining into the basin, into which landslides composed of older volcanic rocks were deposited; sediments locally folded and in places hydrothermally altered, with carbonate and silica hot-spring sinter, including red agate in several places at the south end of the basin; the basin resembles a caldera moat along the outer margins of traditional calderas that formed during emplacement of the intracaldera (resurgent) pluton in the interior of the caldera fill, but here the basin is floored by rocks from outside the caldera margin, including lava flows and volcanic mudflow breccia of a local andesitic sequence (Tad) that is intertongued with ash-flow tuffs of the Isom Formation and exposed on the west side of the basin; the basin is tilted east and northeast against the basin's bounding fault, called the West Sugarloaf fault zone, on the east and northeast side of the basin; the pre-basin volcanic rocks, which may include the stratovolcano vent, are about 180 m thick about 1.1 km west-southwest of the Sugarloaf, thinning southward to about 60 m thick and unconformably overlying Cambrian rocks, represent a mystery in that it appears that post-Isom, pre-Hiko volcanic rocks were not deposited on the edifice of the andesite stratovolcano, although some may have landslid or were eroded and transported southward into the caldera; the sediments in the

basin thicken northeastward to at least 60 m, but the base here is not exposed.

Hiko Tuff (Miocene)

Named by Dolgoff (1963) for a widespread outflow sheet in Nevada that was suggested by Noble et al. (1968) and Noble and McKee (1972) to be derived from the Caliente caldera complex; Ekren et al. (1977) confirmed this interpretation, adding that it came from the "western lobe" of the complex; the Chokecherry Mountain quadrangle contains the northwest part of this west lobe; it was named the Delamar caldera by Rowley and Siders (1988) and Rowley et al. (1990), although some Hiko deposits were derived from a 2-km-diameter vent west of the caldera and south of the ghost town of Delamar that was named the Cedar Wash vent (Rowley et al., 1995); Cook (1965) correlated the Hiko Tuff with the lithologically and petrologically similar Racer Canyon Tuff, which is widespread in Utah, but the two have different ages and paleomagnetic signatures (Grommé et al., 1997) and petrographically are slightly different (Siders et al., 1990; Rowley et al., 1995); Grommé et al. (1997) published three sanidine single-crystal $^{40}Ar/^{39}Ar$ dates on the Racer Canyon Tuff of 18.33 ± 0.02 Ma from the top of the unit (it has multiple cooling units here) just south of Upper Enterprise Reservoir in Utah, 18.61 ± 0.02 Ma from the base of the unit from the same place, and 18.65 ± 0.05 Ma from a roadcut on U.S. Highway 56 near Uvada, Utah; later mapping of the east end of the Caliente caldera complex, in Utah, revealed that the Racer Canyon Tuff was derived from the Telegraph Draw caldera there, and that an unpublished $^{40}Ar/^{39}Ar$ date by L.W. Snee from a sample (89-314e) of the tuff just south of Upper Enterprise Reservoir in Utah is 18.70 ± 0.11 Ma (sanidine, Rowley et al., 2008); the similarities between Racer Canyon and Hiko Tuffs indicate that they were probably derived from the same connected magma chamber, presumably compositionally layered; Taylor et al. (1989) suggested an age of the Hiko Tuff of 18.6 Ma based on an average of several $^{40}Ar/^{39}Ar$ dates determined by D.R. Lux (University of Maine at Orono); Grommé et al. (1997) published sanidine single-crystal $^{40}Ar/^{39}Ar$ dates on the Hiko of 18.23 ± 0.02 Ma from Condor Canyon, Nevada, and 18.32 ± 0.02 Ma from the south end of the North Pahroc Range, Nevada; many, mostly unpublished $^{40}Ar/^{39}Ar$ dates by L.W. Snee, using a standard from Lux and sent to Snee, also give ages of about 18.3–18.2 Ma (Snee and Rowley, 2000; Rowley et al., 1995), and this number is supported by the same or slightly younger dates by Snee on the intrusion of Crows Nest Tank (Tci), the volcanic dome of Barnes Canyon, and the volcanic dome of Islen, all on the north margin of the Delamar caldera; one of the Snee dates on the intracaldera Hiko Tuff is 18.19 ± 0.14 Ma (sanidine) given by Scott et al. (1995b) and collected by Lux, but the only location they provided for the sample (RC8) is that it came from Rainbow Canyon (in the Delamar caldera) about 10 km south of Caliente; eight previously unpublished $^{40}Ar/^{39}Ar$ sanidine dates by L.W. Snee on the Hiko Tuff are the following: (1) 18.26 ± 0.03 Ma from a sample (92-489) of intracaldera Hiko Tuff from the south side of Buckboard Canyon 0.7 km southwest of Buckboard Spring in the Chokecherry Mountain quadrangle; (2) 18.23 ± 0.09 Ma from a sample (92-482b) of intracaldera Hiko Tuff from 1.8 km south of the railroad tracks in Clover Creek canyon and 0.2 km east of the west edge of the Eccles quadrangle; (3) 18.30 ± 0.04 Ma from a sample (92-484) of intracaldera Hiko Tuff from the north side of Buckboard Canyon 3.2 km southwest of Conaway Reservoir in the Caliente quadrangle; (4) 18.22 ± 0.04 Ma from a sample (92-519i) of intracaldera Hiko Tuff from 2.2 km west-northwest of the railroad stop of Islen, which is 20 km east-southeast of Caliente; (5) 18.28 ± 0.05 Ma from a sample (92-595a) of intracaldera Hiko Tuff from the north wall of Rock Springs Canyon and 1 km northeast of the site of Finlay in the northeast part of the Slidy Mountain quadrangle; and (6–8) 18.24 ± 0.06 Ma, 18.25 ± 0.07 Ma, and 18.31 ± 0.03 Ma from three samples (92-549c, f, and i) from progressively higher subhorizontal cooling units (#2, #3, and #4 in this section) of outflow Hiko Tuff (neither base nor top exposed, but the total thickness of Hiko estimated to be 370 m) in a prominent 250-m-high ridge 7 km northwest of Delamar Lake in the southwest part of the Delamar NW quadrangle (Swadley and Scott, 1990), southern South Pahroc Range and 33 km southwest of the map area.

Th Outflow deposits Moderately resistant but upper part crumbly, tan, pink, light-gray, and white (in the upper part), moderately welded, low-silica rhyolite ash-flow tuff; several cooling units, some with black basal vitrophyres; shows considerable variation in modal amounts and ratios, but generally contains 15–40 percent phenocrysts of plagioclase and lesser but subequal amounts of quartz (conspicuous, locally light purple) and sanidine, much subordinate biotite, and minor hornblende, pyroxene, Fe-Ti oxides, and sphene (Rowley et al., 1995); contains lenticules (fiamme) as long as 12 cm and 2 cm across; contains abundant (commonly 10 percent) white pumice and volcanic rock fragments (commonly 5 percent); basal parts of the unit are particularly pumice-rich, and the base is laminated and cross-bedded unwelded tuff, locally resting on tuffaceous pebbly sandstone; maximum thickness about 180 m.

Thi Intracaldera deposits Shown only on cross section B–B′, beneath megabreccia deposits (Thm) just south of the west-northwest-striking, oblique-slip (right-lateral and down to the south) Conaway Reservoir fault, which here forms the north rim of the Delamar caldera, but extensively exposed in the Chokecherry Mountain quadrangle; lithology that of the outflow deposits; interbedded with megabreccia deposits and, where it overlies lenses of these deposits and locally elsewhere, commonly includes a basal vitrophyre, indicative of eruption after a cooling break (represented by the megabreccia).

Thm Intracaldera megabreccia deposits Small, poorly exposed area at the south edge of the map area, just south of the Conaway Reservoir fault, which forms the rim of the Delamar caldera; consists of poorly resistant, dark (mostly reddish-brown and medium-gray) breccia masses of pre-caldera rocks derived from landsliding off the caldera margin as well as volcanic mudflow breccia, debris-flow deposits, conglomerate, and sandstone; most deposits derived from the distinctive Bauers Tuff Member (Tqcb) but includes rocks mapped here in the Isom Formation (Tih, Tib); thickness here at least 100 m but considerably more extensive and thicker to the south.

Tlf Lava flows (Miocene) Nonresistant, dark-gray, black, and red, light-gray weathering sequence of poorly exposed, crystal-poor, aphanitic, andesitic to dacitic lava flows and volcanic mudflow breccia between the Harmony Hills Tuff and Hiko Tuff; exposed southeast, east, and northeast of Porphyry Spring, which is north of the center of the map area; also exposed but of lesser thickness about 2 km west-northwest of Sugarloaf, where the Pahranagat Formation and the Harmony Hills Tuff are not present, therefore the map unit rests on the Bauers Tuff Member; contains about 5 percent small phenocrysts of plagioclase, olivine (commonly weathered to red antigorite), Fe-Ti oxides, biotite, and pyroxene; high in small vesicles; also mapped in the northwest part of the Chief Mountain quadrangle (Rowley et al., 1994), where it is about 120 m thick; maximum thickness in the map area about 90 m.

Quichapa Group (Miocene and Oligocene)

Proposed as Quichapa Group by Cook (1957) for a sequence of informally named regional ash-flow tuffs in southwestern Utah; Mackin (1960) reduced the unit rank to the Quichapa Formation; Williams (1967a, b) renamed it to group rank, described the units within it, and provided isopachs that indicated their caldera sources; Anderson and Rowley (1975) formalized the designation as well as the formations (Harmony Hills Tuff, Condor Canyon Formation, and Leach Canyon Formation) and their members listed below.

Tqh Harmony Hills Tuff (Miocene) Moderately resistant, pink, tan, light-greenish-gray, and gray, crystal-rich, moderately welded, dacitic to andesitic ash-flow tuff; contains 25–60 percent phenocrysts of plagioclase and subordinate biotite, hornblende, and quartz, and minor sanidine, pyroxene, and Fe-Ti oxides; although there is some evidence that the unit came from the Caliente caldera complex, isopach- and distribution-data and detailed mapping suggests that the source is one of the plutons of the Iron Axis in the eastern Bull Valley Mountains (Williams, 1967a, Blank, 1959; Blank et al., 1992; Rowley et al., 1995); many isotopic dates give conflicting ages but based on underlying and overlying units, our favored age is from a $^{40}Ar/^{39}Ar$ plateau date of 22.03 ± 0.15 Ma (Cornell et al., 2001); maximum thickness about 60 m, pinching out on underlying topography.

Condor Canyon Formation (Miocene and Oligocene?)

Proposed by Cook (1965) for two reddish-brown, densely-welded ash-flow tuffs that commonly occur together in western Utah and eastern Nevada, including in Condor Canyon just north of Panaca, Nevada; the Bauers Tuff Member, however, is much larger and more widespread.

Tqcb Bauers Tuff Member (Miocene) Resistant, reddish-brown, red, gray, and light-purple, densely welded, crystal-poor, rhyodacitic ash-flow tuff containing a black basal vitrophyre and an upper gray or light-purple vapor-phase zone characterized by bronzy biotites; contains 10–20 percent phenocrysts of plagioclase, subordinate but conspicuous sanidine, and minor biotite, pyroxene, and Fe-Ti oxides; contains conspicuous lenticles of drawn-out gas cavities; two cooling units in places, the lower with lenticules and the upper red; top locally flow-foliated due to fusing to a liquid in the final few meters before coming to rest; Williams (1967a) predicted that the unit came from the Caliente caldera complex, and this hypothesis was confirmed by Rowley and Siders (1988) and Rowley et al. (1990), who named the source the Clover Creek caldera of the caldera complex, with well-exposed faulted pieces of the caldera in Clover Creek just east of Caliente (Rowley and Shroba, 1991; Rowley et al., 1992, 1994); two $^{40}Ar/^{39}A$ dates by Best et al. (1989b) give a preferred (average) age of 22.78 Ma, and this is supported by a $^{40}Ar/^{39}Ar$ date by L.W. Snee of 22.81 ± 0.1 Ma (sanidine) on a dike-like mass (sample 89-530) of the Bauers intracaldera pluton collected just north of Caliente (Rowley et al., 1994; Snee and Rowley, 2000); another $^{40}Ar/^{39}Ar$ date by L.W. Snee is 22.56 ± 0.06 Ma (sanidine) from a sample (91-1097) from the White River Narrows but appears to be too young; maximum thickness about 120 m.

Tqcs Swett Tuff Member (Miocene or Oligocene) Resistant, reddish-brown and brown, densely welded, crystal-poor rhyodacitic ash-flow tuff exhibiting in most places a black basal vitrophyre as much as 2 m thick; contains about 10 percent small phenocrysts of plagioclase and minor biotite and Fe-Ti oxides; has small red lithic fragments and conspicuous half-cm or locally larger gas cavities, some lined with yellow vapor-phase minerals; probably derived from the Caliente caldera complex based on its distribution similarity with the Bauers Tuff Member and Leach Canyon Formation (Williams, 1967a); L.W. Snee determined $^{40}Ar/^{39}Ar$ dates of 24.38 ± 0.06 Ma and 23.87 ± 0.04 Ma on biotite from two samples, respectively, from the White River Narrows (sample 91-1096) and Condor Canyon (sample 94-1), but both are too old with respect to the accepted age of the Leach

Canyon, although the one from Condor Canyon is not far off; maximum thickness 60 m.

Tql Leach Canyon Formation (Oligocene) Pinkish-tan and light-gray, poorly to moderately welded, low-silica rhyolite ash-flow tuff; contains 10–20 percent phenocrysts of plagioclase, quartz, and sanidine, and minor biotite, hornblende, pyroxene, and Fe-Ti oxides, as much as 15 percent noncompacted white pumice as long as 15 cm, as many as 5 percent lithic fragments including some distinctively red, and small vesicles that may be lined with yellow vapor-phase crystals; commonly includes a black basal vitrophyre as thick as 3 m; may have two or more cooling units; source caldera unknown but likely to be the Caliente caldera complex based on isopachs and distribution, both of which are nearly identical to those of the Bauers Tuff Member, and both with the center of the isopach bullseye just east of the town of Caliente (Williams, 1967a); age about 23.8 Ma (Rowley et al., 1995); maximum thickness about 110 m.

Tpa Pahranagat Formation (Miocene) Generally poorly resistant, pink and pinkish-tan, poorly welded, moderately crystal-rich, low-silica rhyolite ash-flow tuff characterized by 5–10 percent white, partly collapsed pumice fragments as much as 8 cm long and 3 cm wide; contains rare lithic fragments; contains about 20 percent phenocrysts of subequal amounts of quartz (commonly with a blue adularescence), sanidine, and plagioclase, minor biotite, and trace amounts of hornblende, pyroxene, and Fe-Ti oxides; named the Pahranagat Lakes Tuff by Williams (1967a, b) and included in his Quichapa Group between the Bauers Tuff Member and the Harmony Hills Tuff; Williams' designation in the Quichapa Group was not accepted by Anderson and Rowley (1975), perhaps because the unit was then unknown in Utah, nor by the current map; Deino and Best (1988), Best et al. (1989b), and Best et al. (1995) applied additional field work, paleomagnetism, and single-crystal $^{40}Ar/^{39}Ar$ geochronology to correlate the unit with other named tuffs and therefore to expand the depositional area in Nevada beyond that of Williams (1967a, b); Best et al. (1989b) proposed that the Kawich caldera, about 130 km west-northwest of the map area, is the source; map unit recently found in the southwest part of the Black Mountains of Utah, specifically resting on the Bauers Tuff Member 1.6 km west to southwest of Lost Spring (Rowley, 1975) and continuing northward interbedded with volcanic mudflow breccias between the Harmony Hills Tuff and the Bauers Tuff Member 0.8 km east of Jako Wash (Rowley, 1978); the Black Mountains was much later found to be entirely within the Black Mountains gravity slide (Biek et al., 2019, 2020, 2022), so it is likely that after about 19 Ma the Pahranagat Formation there was displaced about 15 to 30 km southward from where it was originally deposited; within the map area, exposed only in the north-central part, east and northeast of Porphyry Spring and continuing to the north edge of the map area and into the northwest part of the Chief Mountain quadrangle (Rowley et al., 1994); $^{40}Ar/^{39}Ar$ age given as an average of 22.65 Ma, based on four sanidine dates (Deino and Best, 1988), then updated based on single-crystal (sanidine) chronology at 22.639 ± 0.009 Ma (Best et al., 1995); Scott et al. (1995a) summarized data on the unit and renamed it the Pahranagat Formation; maximum thickness about 20 m, thinning and pinching out southward.

Tad Andesite of the northern Delamar Mountains (Oligocene) A local volcanic field of poorly to moderately resistant, mostly light- to dark-gray, red, and reddish-brown andesitic volcanic mudflow breccia and lava flows, and minor ash-flow tuff and conglomerate derived from clustered stratovolcanoes in the northern Delamar Mountains, in the south-central part of the map area; regional ash-flow tuffs are intertongued with this field consisting of, from youngest to oldest, the Hole-in-the-Wall Tuff Member of the Isom Formation, the Shingle Pass Tuff, and the Baldhills Tuff Member of the Isom Formation; the sequence consists of three main units: (1) the most extensive and youngest unit is a poorly resistant, gray, pink, or red (in the upper part) or light-tan and light-green (6 km north-northwest of Sugarloaf, where it is poorly exposed) volcanic mudflow breccia, with interlayered lava flow segments, that underlies the Leach Canyon Formation and both overlies and underlies the Hole-in-the-Wall Tuff Member; in several places in the central part of the map area, the top bed exposed beneath the Leach Canyon Formation is a tan boulder conglomerate about 10 feet thick; the upper red part includes conglomerate and sandstone in the southeast part of the map area; clasts in the mudflow part of this unit are as much as 4 m in diameter and flow segments average 10 m in length along strike and several meters thick; flow segments and clasts in mudflows are mostly fine-grained aphanitic to glassy matrix (clasts in some mudflows are black glass) in which small to absent phenocrysts are of plagioclase, subordinate pyroxene, and generally minor hornblende and Fe-Ti oxides; (2) an underlying unit of mostly resistant, red and reddish-brown trachyte lava flows and flow breccia that locally overlie and underlie the Shingle Pass Tuff and contain variable (as much as 30 percent) amounts of large plagioclase and pyroxene phenocrysts; and (3) a series of moderately resistant, gray and reddish-brown, flow-foliated "chippy-weathering" (rocks are commonly cracked so that they weather into small chips) lava flows and flow breccia that in some places directly underlies the mostly gray mudflows, as in the southeast part of the map area, but in other places intertongue with the red trachyte flows; some flows of this part of the sequence resemble the Baldhills Tuff Member and probably include that tuff, but based on limited petrographic study, the flows seem to contain more pyroxene and whole phenocrysts of plagioclase and pyroxene, instead of the broken crystals that ash-flow tuffs have; the volcano source for all subunits is interpreted to be located about a kilometer southwest of the top of Sugarloaf to about 2 km west of this same top, where the map unit is thickest, at about 180 m and where exposures of all lithologies are found; also, dikes (fissure vents) of some of the crystal-rich trachyte lava flows were noted 2–3 miles north-northwest of the top of Sugarloaf; L.W. Snee determined $^{40}Ar/^{39}Ar$ dates of 25.12 ± 0.26 Ma (hornblende)

and 24.33 ± 0.12 Ma (biotite) on a tan north-striking andesite dike (sample 91-580, table 2, probably unit #2, dike not separated in the mapping) containing about 20 percent plagioclase, 3 percent hornblende, and minor Fe-Ti oxides, biotite, and altered pyroxene, and located 4 km west-southwest of Sugarloaf, in the southwest part of the map area; overall maximum aggregate thickness (not all in one place) of map unit at least 300 m.

Isom Formation (Oligocene)

Formation and members proposed and described by Mackin (1960) and Williams (1960), who first recognized that these units represented a series of densely welded ash-flow tuffs that they first mapped in the Iron Springs mining district of southwest Utah, then correlated over a broad area of western Utah and eastern Nevada; units described also by Anderson and Rowley (1975); of these, the Baldhills Tuff Member is significantly larger in volume and area of deposition, representing several cooling units at Iron Springs and extending eastward into the High Plateaus of Utah, whereas the Hole-in-the-Wall Tuff Member makes up one cooling unit at Iron Springs and does not get into the High Plateaus; the Hole-in-the-Wall and Baldhills Tuff Members have been mapped in many parts of Nevada, including the Chief Mountain quadrangle (Rowley et al., 1994), and the Baldhills Tuff Member was mapped in the Pahroc Spring SE quadrangle (Swadley and Rowley, 1994); the Hole-in-the-Wall Tuff Member postdates the Shingle Pass Tuff (Tsp), whereas the Baldhills Tuff Member predates the Shingle Pass Tuff.

Tih Hole-in-the-Wall Tuff Member Resistant red, reddish-brown, and purplish-red, densely welded, crystal-poor, trachytic ash-flow tuff; contains 5–10 percent phenocrysts of plagioclase and minor pyroxene and Fe-Ti oxides; contains conspicuous light- or dark-gray "lenticules," a term applied by Mackin (1960) and interpreted to be gas-rich zones drawn out in the plane of bedding and thus not likely to be fiamme (flattened pumice), that in the map area are as much as 2 m long and 2 cm thick; contains abundant pinhead-sized vesicles, at times giving the tuff a brick-like appearance; contains sparse dark-brown lithic fragments; at least two and as many as four cooling units, the upper of which is the thickest (maximum of 20 m), has the most conspicuous lenticules, and locally includes a thin (half meter) black basal glass; intertongued with or overlying the upper part of the andesite of the northern Delamar Mountains (Tad); source unknown but, based on their similar lithology and chemistry, probably the same as the Baldhills Tuff Member; maximum thickness about 25 m in the map area.

Tib Baldhills Tuff Member Resistant red, reddish-brown, and light-purple, densely welded, crystal-poor, trachytic ash-flow tuff; upper part is flow foliated due to apparent congealing of shards in the last several meters of travel; contains thin lenticules, although these are generally seen as partings; contains 5–15 percent phenocrysts of plagioclase and minor pyroxene and Fe-Ti oxides; best exposed in the southwest part of the quadrangle, where two cooling units underlie the lowest (olivine-bearing) cooling unit of the Shingle Pass Tuff (Tsp) and are in turn underlain by red, crystal-rich trachyte lava flows of the andesite of the northern Delamar Mountains (Tad); in some places weathers to chips of devitrified glass (that is, chippy weathering, as in some lava flows of the andesite of northern Delamar Mountains, Tad); source considered by Best et al. (1989a) to be the Indian Peak caldera complex, specifically near where the Isom Formation is thickest, along the southwest edge of the Escalante Valley of Utah, perhaps centered near the town of Modena; most likely the magma source of such exceptionally hot ash-flow tuffs is deep in the crust and thus never expressed as a typical collapse caldera (Ekren et al., 1984); old K-Ar dates (recalculated for modern decay constants, Dalrymple, 1979) on plagioclase from the Baldhills Tuff Member were calculated at 25.7 ± 0.5 Ma from a sample collected in the Iron Springs mining district by Armstrong (1970) and 25.7 ± 0.4 Ma from a sample collected in the Markagunt Plateau of Utah by Fleck et al. (1975), but these are too young because the Baldhills underlies the Shingle Pass Tuff, so a $^{40}Ar/^{39}Ar$ date of about 27 Ma (Best et al., 1989b, fig. R1; analytical data not given) is more reasonable; about 15 m thick.

Tsp Shingle Pass Tuff (Oligocene) Resistant, red, light-purplish-gray, light-brown, and pink, densely welded, crystal-poor, low-silica rhyolite ash-flow tuff; two or more cooling units in the map area, some including a half-meter thick crumbly black basal vitrophyre; contains about 5 percent white pumice fragments about 15 cm long and 2 cm thick, and medium-gray pumiceous lenticules as much as 0.3 m long and 2 cm thick; locally hydrothermally altered; cooling units contain wildly different percentages (5 to 20) and modes of phenocrysts of sanidine and plagioclase (either can be dominant), generally either subordinate or nearly absent quartz, and subordinate biotite and minor hornblende, pyroxene, and Fe-Ti oxides; the lowest cooling unit in the map area and elsewhere contains minor olivine in the mode, identified in the field by orange spots of antigorite; named by Cook (1965) with a type section at Shingle Pass in the Egan Range; caldera source considered to be in the Quinn Canyon Range (Best et al., 1989b), but it took detailed mapping by E.B. Ekren to confirm that hypothesis and to map and define the caldera, which he called the Monotony Valley caldron complex (here called a caldera complex) (Ekren et al., 2012); this caldera complex also was the caldera source for the Monotony Tuff (Tm), which underlies the map unit; the caldera complex is about 80 km west-northwest of the map area, near the center of distribution of this large tuff (diameter of its distribution is about 225 km, slightly greater than and overlapping the distribution of the slightly less voluminous Monotony Tuff, with its eastern boundary just west of the Nevada-Utah state line (Best et al., 1989b; Ekren et al., 2012); the caldera complex is 100 km across north-south and 90 km east-west, extending from the

Quinn Canyon Range westward across Monotony Valley and southern Railroad Valley to include the Reveille Range and southern Pancake Range, then farther west across Reveille Valley to the Kawich Range; Ekren et al. (2012) counted "as many as 10 cooling units" of outflow tuffs, with significant differences in relative modal amounts of phenocrysts between cooling units (and within some cooling units) from top to bottom, although all cooling units are rhyolite and all modes contain quartz, sanidine, plagioclase, and biotite, and trace amounts of hornblende, pyroxene, and for some olivine; with such a high-volume tuff, each worker in various places has mapped several different cooling units but the correlation of each unit between these places is not clear; for example, Cook (1965) gave a single mode (7 percent total phenocrysts) for Shingle Pass in which sanidine is dominant (more than that of plagioclase and quartz combined), with subordinate plagioclase, lesser quartz, and minor biotite, and at the type section measured the tuff at 125 feet thick, yet Ekren et al. (2012) noted that the type section has five cooling units, the one at the top and the one at the base similar to the single mode that Cook gave, but the three between are free or nearly free of quartz, and the basal unit has olivine; in a regional study, Best et al. (1989b; 1993, table 1) described an upper unit (5–10 percent total phenocrysts) that yielded a $^{40}Ar/^{39}Ar$ date of 26.00 ± 0.03 Ma and contains plagioclase, subordinate sanidine, and lesser biotite, and a trace of quartz, hornblende, and pyroxene; they also distinguished several "intermediate" cooling units (5–15 percent phenocrysts) dated at between 26.4 and 26.5 Ma and contain modes similar to his upper cooling unit, as well as a lower unit (10–20 percent phenocrysts) that yielded a $^{40}Ar/^{39}Ar$ date of 26.68 ± 0.03 Ma and contains sanidine, subordinate plagioclase, lesser quartz, and traces of biotite, hornblende, pyroxene, and olivine; in their regional study, Page and Dixon (1994) identified two parts to the formation, an upper part (as with Best et al.) that was quartz-poor and a lower part that was relatively rich in strongly resorbed quartz; Scott et al. (1995a) had a similar interpretation of the type section, of two units, the lower of which had olivine and the upper of which had little quartz, but elsewhere (the southern Delamar Mountains) defined an intermediate unit between the other two that resembled his upper unit in modal amounts but had normal polarity; in their detailed regional study, Ekren et al. (2012) concluded that the upper outflow cooling unit, which he named the tuff of Sawmill Canyon, has abundant quartz, although sanidine exceeds plagioclase (ratio increases as go downward in the tuff) or quartz, as well as lesser but significant biotite, and minor hornblende, pyroxene, and Fe-Ti oxides, and that the lowest regional cooling unit, which he named the tuff of Stairstep Mountain, has abundant, highly resorbed quartz, although it also is subordinate to sanidine and generally subordinate plagioclase (without internal differences in modal ratios), and minor ferromagnesian minerals, including olivine; between these two petrographically similar tuffs, Ekren et al. (2012) correlated from place to place a series of many other cooling units in which quartz is absent or minor in abundance; he concluded that the upper tuff of Best et al. (1989b, 1993) and Page and Dixon (1994) is one of his intermediate-age quartz-poor units, whereas their lowest unit was his tuff of Stairstep Mountain; maximum thickness in the map area about 25 m.

Tm Monotony Tuff (Oligocene) Moderately resistant, light-gray and light-green, moderately welded, crystal-rich, rhyodacite ash-flow tuff characterized by abundant biotite and quartz and sparse red volcanic rock fragments; contains 20–35 percent phenocrysts of plagioclase, subordinate quartz, biotite, and sanidine, and lesser Fe-Ti oxides and hornblende; named by Ekren et al. (1971); much later, E.B. Ekren found the caldera source, which he called the Monotony Valley caldron complex (name modified here to call it a caldera complex), about 80 km west-northwest of the map area and near the center of distribution of this large tuff (diameter of its distribution is about 225 km, with its eastern boundary just west of Caliente) (Best et al., 1989b; Ekren et al., 2012); the caldera complex, which includes the caldera source of the Shingle Pass Tuff (Tsp), is 100 km across north-south and 90 km east-west, with its eastern end in the Quinn Canyon Range; three $^{40}Ar/^{39}Ar$ dates are available: 27.31 ± 0.03 Ma by Best et al. (1989b), and both a plateau age on biotite of 27.1 Ma and a plateau age on hornblende of 26.7 M from the same sample (Taylor et al., 1989); maximum thickness in the map area about 15 m.

Tc Conglomerate (Oligocene, Eocene, or Paleocene) Well-rounded clasts of limestone, with lesser white quartzite and volcanic rocks (including a dark Isom-like flow rock) in a reddish-tan silty matrix at the base of the volcanic section below the Monotony Tuff; seen at several outcrops north and south of Porphyry Wash and between 1 and 2 km north-northwest of Porphyry Spring, in the northern part of the map area; the presence of volcanic clasts argues for an Oligocene age; maximum thickness about 2 m.

Op Pogonip Group (Middle and Lower Ordovician) The upper part of what Westgate and Knopf (1932) called the Mendha Formation, and what Lewis (1987) correlated with the Pogonip; symbol used only in the cross sections.

> **Opu Upper part** Mostly resistant, mostly dark-gray, well-bedded limestone and dolomite that forms 3- to 4-m-high, rounded ledges; includes interbeds of red and light- to medium-gray laminated limestone; contains white, brown, and orange chert, as well as red silty partings and mottles; lower half of the upper part is exposed in the northern Burnt Springs Range of the map area but not the upper half, although the rocks above a horizontal fault are interpreted to be part of this upper half; the rocks above this fault are gently folded and consist of dark-gray limestone containing masses of orange and dark-brown chert; below the fault, from top to bottom, the map unit is thin-bedded and laminated light- to medium-gray limestone with dark-gray oncoids, medium-gray dolomite, a poorly exposed pink limestone, a light-gray and a light-yellow intraformational limestone conglomerate, and light- to

dark-gray dolomite that contains white chert; thickness about 100 m.

Opl Lower part Slope-forming unit of interbedded moderately resistant, rounded 1- to 2-m-high ledges of limestone and covered areas of pink and purple shale; the limestone is medium gray containing distinctive orange- and red-weathering zones and is planar bedded, separated by unbedded limestone; contains fossil hash and intraformational conglomerate; thickness about 40 m.

Ꞓndh Nopah Formation, Dunderberg Shale, and Highland Peak Formation, undivided (Upper and Middle Cambrian) Only on cross section A–A′.

Ꞓn Nopah Formation (Upper Cambrian) The middle part of what Westgate and Knopf (1932) called the Mendha Formation, now correlated with the Nopah Formation of the Mormon Mountains (Lewis, 1987); Lewis (1987) broke the unit into three units, given below; symbol used only on cross sections.

Ꞓnu Upper member Resistant, mostly dark-gray, lesser light-gray, and locally pink limestone that forms 2- to 3-m-high, massive cliffs, locally interbedded with light- and medium-gray, locally light-yellow, hackly weathering, sugary dolomite; limestone contains abundant black oncoids, common sparry calcite including possible white oolites, pink and white mottles, local pink silty partings and orange-brown or white chert in masses parallel to bedding; includes a red 10-m-thick covered interval containing red siltstone float, above which are well-bedded heads of stromatolites; uppermost 15 m is medium-gray limestone containing black and white chert and gradational in lithology with the interbedded black limestone beds and soft shale of the Pogonip Group; lower part gradational with middle member as a resistant, black, poorly to well-bedded dolomite section at least 10 m thick that passes upward into a thick limestone section; thickness at least 170 m.

Ꞓnm Middle member A distinctive resistant, medium-gray and lesser light-gray ("silver"), massive and homogeneous, coarse-grained dolomite exposed as rounded, poorly continuous, 1- to 3-m-high ledges (stairsteps), passing downward into medium-gray, coarse-grained sugary (crystalline) dolomite; contains brown and orange chert and some stromatolites; thickness at least 60 m.

Ꞓnl Lower member Mostly resistant, medium-gray, poorly bedded limestone and lesser interbedded dark-gray limestone containing red tinges, orange, tan, and red mottles and partings, and some brown chert, occurring as 1- to 5-m-high rounded ledges (steps), with one medium-gray, well-bedded, 10-m-high rounded cliff of limestone containing pink, green, and tan silty partings, all separated by slopes of tan, orange, pink, yellow, and light-gray siltstone and soft limestone, and yellow and pink platy shale, resulting in an overall purple color, with yellow and red tinges; commonly the limestone is detrital in origin, containing abundant sand-sized fossil debris, consisting of oolites, dark-gray, tan, red, and orange oncolites, and sparry fossil hash generally less than 0.5 cm in diameter; a few stromatolites were seen in the slope-forming beds; includes cross-beds and one or more 5-cm-thick intraformational limestone breccia beds; includes light-red laminated limestone as lenses; upper part consists of mostly dark-gray limestone containing dark-orange silty partings; lower part gradational with the underlying Dunderberg Shale, with yellow dolomite and black oncoids at the base; thickness at least 100 m.

Ꞓd Dunderberg Shale (Upper Cambrian) A distinctive formation exposed as an orange slope, out of which are poking thin beds of resistant, gray, brown, and orange shaly limestone and interbedded dolomitic limestone; poorly exposed or unexposed shale and siltstone are subordinate, commonly at a spacing of about 1 m; the limestone is dominantly dark gray but locally medium gray, pink, light green, and purplish pink; limestone is poorly bedded and contains pink, red, and yellow splotches and mottles as much as 0.3 m in diameter; the poorly exposed rocks weather to form distinctive dark-brown (desert varnish), reddish-brown, and light-green laminated siltstone chips in the soil; includes a distinctive, 10-m-thick mostly covered interval with beds of brown laminated siltstone and light-green intraformational limestone conglomerate; Lewis (1987) noted that fossil hash is abundant, as pieces of trilobites, brachiopods, gastropods, oolites, and oncolites; Westgate and Knopf (1932) formerly called this the lower part of the Mendha Formation, but A.R. Palmer, in oral communication with Lewis (1987), identified fossils that correlate the rocks in the map area with the Dunderberg Shale of southern Nevada; thickness about 100 m.

Ꞓh Highland Peak Formation (Upper and Middle Cambrian) Mostly resistant, light- to dark-gray, well-bedded, laminated (less than 0.5 cm) to thick-bedded (more than 0.5 m), marine limestone and dolomite; originally named the Highland Peak Limestone by Westgate and Knopf (1932); later renamed the Highland Peak Formation by Wheeler and Lemmon (1939; see also Merriam, 1964); maximum thickness about 1500 m in the Pioche mining district, where it was described in detail and members assigned by Merriam (1964); in and near the mapped area, mapped and described in detail by Lewis (1987), Sleeper (1989) and Burke (1991); symbol used in cross sections and for several small outcrops of limestone that could not be assigned member names.

Ꞓh$_{13}$ Unit 13 (Upper Cambrian) Distinctive in that it is the upper unit of Highland Peak carbonates, contrasting with the shale-bearing overlying Dunderberg Shale; of variable lithology and moderately resistant, mostly dark in appearance, consisting of alternating light-gray laminated limestone and dark-gray mottled limestone that form 0.5- to 2-m-high

massive beds and rounded cliffs; includes light-yellow and light-gray sugary dolomite; limestone contains bright- to light-yellow chert and apparent worm burrows; basal contact placed where lithographic limestone below gives way to tan-weathering laminated dolomite (Lewis, 1987); thickness as much as 130 m.

Ꞓh$_{12}$ Unit 12 (Upper Cambrian) Identified by the return in time to limestone, this unit being a moderately resistant, mostly light-gray, thick-bedded, fine-grained lithographic limestone, some with brown chert, that is interbedded with tan, greenish-gray, and locally pink, laminated limestone; upper 10 m of the unit is a tan, white, and pink, laminated limestone in which covered parts contain red silt; lower part gradational with unit 11 and includes minor dolomite; thickness as much as 100 m.

Ꞓh$_{11}$ Unit 11 (Upper Cambrian) Moderately resistant, mostly light-gray, lacy, sugary, homogeneous dolomite with dark-brown chert in 1- to 3-m-thick beds; unit locally contains 0.5-m-thick, dark-gray ledges containing red tinges; upper part light-gray, thick-bedded sugary dolomite; lower part dark-gray mottled, mostly sugary, thick-bedded dolomite; thickness about 75 m in the southwest part of the map area, but in the northwest part is about 15 m and was mapped, following Lewis (1987), with unit 10.

Ꞓh$_{10}$ Unit 10 (Upper Cambrian) A distinctive cliff of dark-gray, thick-bedded massive mottled, fine- to medium-grained limestone; includes some limestone that is medium gray and contains abundant sparry calcite and some limestone that is light gray and heavily mottled; upper part of unit consists of 15 m of dark-gray limestone that occurs as ledges, underlain by pink and light-gray laminated limestone; underlain by the dark-gray main part of the unit, forming a 20- to 30-m cliff of well-bedded limestone with pink mottles and some wavy bedding (stromatolites) in one place; gradational with the top of unit 9, with the basal contact placed above the uppermost light-gray beds; thickness about 70 m.

Ꞓh$_{9}$ Unit 9 (Middle Cambrian) Characterized by alternating resistant, dark-gray, well-bedded, mottled limestone and less resistant, light-gray, thin-bedded and laminated dolomite, by its great thickness, and by its abundant large (generally a third- or half-meter in diameter), concentrically-laminated stromatolites; the alternating dark- and light-gray beds are on a scale of 2–3 m, with the dark-gray limestone forming ledges and low cliffs and more abundant than the light-gray dolomite; the upper 20 or 30 m of the unit is less resistant than the rocks below and contains somewhat more light-gray (with some yellow, tan, and pink) laminated dolomite and stromatolites than in the lower part, as well as yellow siltstone and a 0.5-m-thick intraformational limestone conglomerate bed; the dark-gray limestone contains pink and tan mottles, abundant sparry (birds-eye or bluebird structure) calcite, and black and orange-brown chert; the stromatolites commonly are dark-gray or black chert that weather brown; Lewis (1987) mapped a 1-m-thick marker bed of tan, cherty stromatolites about 60 above the base; the light-gray laminated dolomite in the lower part of the unit includes some beds with red or brown chert and chips of orange-brown siltstone; the basal contact of the unit is placed where light-gray laminated dolomite becomes significant above the distinctive dark-gray cliffs that make up unit 8 and about 15 m below a brownish-orange-weathering chert bed that is 1 m thick; Lewis (1987) found the thickness of the unit in the northwest part of the map area to be at least 290 m thick, but a section in the southeast part of the map area where the top is not exposed is at least 300 m thick.

Ꞓh$_{8}$ Unit 8 (Middle Cambrian) Characterized by dark-gray massive cliffs that are 2- to 10-m-high and consist of thick-bedded, mottled limestone that contains polka dots of white sparry calcite, brownish-black chert, and local dark-tan silty partings; mottles are abundant and pink and greenish gray; upper part more thinly bedded and includes some light-gray dolomite and, at the top, float of orange chert from unit 9 (Ꞓh$_{9}$); middle part contains some zebra-striped beds with brown and orange chert; calcite spar blebs ("bluebird") stand out in the lower part; thickness about 150 m.

Ꞓh$_{7}$ Unit 7 (Middle Cambrian) Unit largely poorly to moderately resistant and light-colored, which contrasts sharply with the dark rocks of the member below and the unit above; mostly light-gray laminated dolomite containing red and brown chert alternating with subordinate dark-gray, well-bedded mottled limestone with dark-brown chert and silt partings, especially in the upper part; at top, thin beds of red siltstone and pink limestone, below which is a light-gray laminated dolomite bed that weathers tan; main body consists of thin slopes of light-gray dolomite, above which are steps of dark-gray limestone; lower part mostly poorly resistant, light-gray laminated dolomite; basal contact is marked by the first light-gray laminated dolomite; thickness as much as 80 m.

Ꞓhm Meadow Valley Member (Middle Cambrian) Characterized by a resistant upper part of rounded, 2- to 10-m-high ledges and cliffs of dark-gray and black, brown-weathering, well-bedded limestone with red chert, calcite spar (birds-eye), orange mottles, and abundant dark-tan silty partings; basal 5 m is a moderately resistant, light-gray, platy limestone, with red mottles, and laminated at base; thickness about 100 m.

Ꞓhc Condor Member (Middle Cambrian) A distinctive marker unit because of its orange siltstone and aphanitic dolomite, much of it appearing as extensive chips in the float from mostly covered parts of the unit between exposed light- to dark-gray and

pink, laminated and thin-bedded limestone, the latter lithology especially in the upper part of the unit; the distinctive but poorly exposed parts consist of reddish-tan, orange-tan, orange, yellow-orange, and brown, thin-bedded and laminated siltstone, fine-grained quartzite, and sugary dolomite; maximum thickness about 15 m.

Ꞓhs Step Ridge Member (Middle Cambrian) Characterized by resistant limestone and lesser dolomite exposed as a dominant middle part made up of medium-bluish-gray limestone that erodes to slightly rounded "stair step" ledges and cliffs 1–5 m high, and thinner upper and lower parts that are mostly light- to dark-gray limestone and light-gray laminated sugary dolomite that form 10-m-high jagged cliffs; from his work near Pioche, Merriam (1964) broke these three parts into units a, b, and c from base to top; the upper part includes a dark-gray, thin-bedded, mottled limestone cliff that overlies light-to dark-gray, locally cross-bedded, mottled limestone that has pink and gray silty partings; the middle part is well-bedded mottled fine-grained lithographic limestone and black- and white-striped (zebra striped) oolitic limestone commonly with sparry calcite chips (birds eye) and commonly containing resistant wavy silty partings; the lower part of the member consists of light- to dark-gray, aphanitic limestone and dolomite with birds-eye structure and more rounded ledges; at the base is a mostly light-gray, cliff-forming limestone; Merriam (1964) concluded that the member in the Pioche Hills is 225 m thick; no complete sections exist in or near the map area owing to faults and the great thickness of the unit, but probably about 300 m thick.

Ꞓhbc Burnt Canyon Member (Middle Cambrian) Characterized by being relatively poorly resistant compared to beds in the overlying and underlying units; mostly medium- to dark-gray, blue-gray, and black, well-bedded, thin-bedded, dense, fine-grained limestone, with some dolomite; unit generally erodes to 1- to 3-m-high ledges; contains local red silty partings, red splotches, and in lower part of member red and black oncoids; includes local black and white (zebra-striped) oolite beds, resistant wavy silty partings, and birds-eye structure; beds in upper part are light gray and gradational with those of the Step Ridge Member, but beds in the lower part of the member include black, slag-like beds; Merriam (1964) proposed Burnt Canyon Member, reducing it from formational rank (Burnt Canyon Limestone of Wheeler, 1948); thickness about 40 m.

Ꞓhb Burrows Member (Middle Cambrian) Characterized by having resistant cliffs at the top and base of the unit and by many zebra-striped limestone beds; consists of light-gray, white, and light-yellow, well-bedded, mostly medium- to thick-bedded, crystalline ("saccharoidal"), blocky weathering, mottled dolomite and lesser dense, light- to medium-gray and black (zebra striped), locally cross-bedded, lithographic, oolitic, mottled and birds-eye limestone containing small brown chert nodules; upper part is a rounded cliff or several cliffs of alternating white and light- to dark-gray (zebra striped), locally cross-bedded oolitic mottled limestone beds contains sparry chips (bluebird) and silty partings, underlain by a slope formed on the same rock types; middle part of the unit is a less resistant, light-gray sugary dolomite; lower part is a distinctive high (nearly 20 m), dark-gray and black, rounded cliff of limestone containing resistant, wavy silty partings and distinctive beds of measles-like oncoids generally less than 1.5 cm in diameter; Merriam (1964) proposed Burrows Member, reducing it from formational rank (Burrows Dolomite of Wheeler, 1948); thickness about 100 m.

Ꞓhp Peasley Member (Middle Cambrian) Identified as the lowest limestone cliff of the Highland Peak Formation, overlying the Chisholm Shale; resistant, bluish-gray and medium- to dark-gray, medium-bedded to thick-bedded, fine- to medium-grained, locally mottled, dense, detrital, oolitic, algal limestone; upper part generally forms a slope, whereas the main body of the member forms several slightly rounded ledges; contains orange-brown, gray, and tan silty partings and splotches, dark-gray, orange, and red oncoids, abundant orange chert, and scattered shell fragments; upper soft part includes a lumpy, nodular limestone bed that is thin-bedded, well-bedded, dark-gray limestone and dark-gray, black- and white-striped oolite beds; base commonly consists of a dark-gray, 20-m-thick limestone cliff containing reddish-brown mottles and sparry calcite chips; Merriam (1964) proposed Peasley Member, reducing it from formational rank (Peasley Limestone of Wheeler, 1948); thickness about 30 m.

Ꞓc Chisholm Shale (Middle Cambrian) Distinctive poorly resistant, khaki, pinkish-brown, green, and brown (generally weathering red and purplish-red), locally fossiliferous, nonmicaceous marine shale and subordinate thin (1 m or less) lenses of thin-bedded, medium-gray, greenish-gray, tan, and dark-green limestone and siltstone; limestone is well bedded and wavy bedded, with orange splotches and partings and local small dark-gray oncoids; named by Walcott (1916; see also Westgate and Knopf, 1932) for exposures in the Pioche area; thickness about 30 m.

Ꞓl Lyndon Limestone (Middle Cambrian) Distinctive, resistant, medium- and dark-gray, black, greenish-gray, and locally light-gray, dense, thin- to thick-bedded, hackly weathering, fine-grained marine limestone; a detrital limestone that commonly includes oolites; has conspicuous silty orange and tan partings and mottles and orange and red chert; upper part weathers to a light-gray, rounded, thick-bedded ledge capped by yellow sugary dolomite, whereas lower part weathers to dark-gray, ledgy, locally mottled, locally black- and white-striped, well-

bedded limestone that locally contains red oncoids and birds-eye (sparry calcite) structure; includes sugary dolomite; named by Westgate and Knopf (1932) for exposures in the Pioche area, where the formation is a massive cliff-forming unit 115 m thick; in the map area, forms two cliffs that total 40 m thick.

Ꞓp Pioche Shale (Middle and Lower Cambrian) Distinctive, poorly resistant, green (locally weathering brown and khaki), locally fossiliferous, micaceous marine shale and lesser amounts of siltstone and sandstone and scattered thin lenses of resistant, tan, grayish-green, and gray, oncoid-bearing, locally fossiliferous (small trilobites are common) limestone; upper part contains brown, fine-grained sandstone; named by Walcott (1908) for exposures in the Pioche area, where unit is about 250 m thick; only the upper part, about 20 m thick, is exposed at the south edge of the map area, but a complete section is exposed just south of the map area, where it is about 230 m thick.

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Table 1. Chemical analyses of grab samples of hydrothermally altered and silicified rocks from the Caliente NW quadrangle, Nevada.

Sample	**87-757**	**87-762**	**87-887**	**87-897**	**87-904**	**90-608**
Lithology	Quartz mass	Jasperoid	Altered rocks	Silica mass, altered rocks at an adit	Silica mass	Calcite veins, altered rocks along fault zone
Map Unit	Tbs	Tbs	Tbs	Tbs	Tbs	Fault zone
Latitude	37.625739	37.626884	37.639699	37.629319	37.625676	37.675626
Longitude	-114.657143	-114.659659	-114.676995	-114.693375	-114.689983	-114.726985
Tl (.05)	0.05	0.1	N	0.15	N	<
Au (.05)	N	N	N	N	N	N
Ca (.05)	10	1	0.5	1.5	20	>20
Fe (.05)	0.15	0.7	0.2	1	0.05	0.07
Mg (.02)	0.1	0.07	0.1	0.7	7	0.3
Na (.2)	<	<	<	1	<	N
P (.2)	<	<	<	<	N	N
Ti (.002)	0.015	0.03	0.03	0.15	0.005	0.015
Ag (.5)	<	N	N	N	N	N
As (200)	N	<	1000	<	N	N
B (10)	50	300	100	200	10	N
Ba (20)	50	70	300	300	200	30
Be (1)	<	N	<	<	<	<
Co (10)	N	N	N	<	N	N
Cr (10)	N	N	N	<	N	15
Cu (5)	<	<	<	5	<	<
Ga (5)	<	N	<	15	N	N
La (50)	<	N	N	N	<	N
Mn (10)	70	150	100	500	15	300
Mo (5)	N	20	15	N	N	N
Nb (20)	N	<	N	N	N	N
Ni (5)	5	5	5	5	<	N
Pb (10)	N	N	N	N	<	15
Sb (100)	N	N	N	N	N	N
Sc (5)	N	<	N	5	N	N
Sr (100)	200	100	N	200	3000	300
V (10)	<	100	70	50	20	15
Y (10)	N	<	N	10	N	<
Zr (10)	15	20	20	100	<	<

Table 1. Chemical analyses of grab samples of hydrothermally altered and silicified rocks from the Caliente NW quadrangle, Nevada (continued).

Sample	**90-611**	**90-BS86**	**91-515**	**91-563**	**91-594**
Lithology	Calcite veins, altered rocks along fault zone	Mn, silica boxwork in a prospect along fault	Hydrothermally altered andesite	Quartz and calcite veins	Quartz and calcite veins
Map Unit	Fault zone	Tih	Tad	Ꞓh	Tbs
Latitude	37.672008	37.660142	37.68743	37.631341	37.625416
Longitude	-114.734185	-114.706733	-114.691014	-114.698501	-114.677241
Tl (.05)	0.2	2.9	0.1	N	0.05
Au (.05)	N	N	<	0.012	0.002
Ca (.05)	>20	20	7	>20	15
Fe (.05)	0.15	0.7	3	0.07	0.07
Mg (.02)	0.3	0.2	1	1.5	5
Na (.2)	N	<	3	N	<
P (.2)	N	N	0.2	N	<
Ti (.002)	0.002	0.007	>1	<	0.003
Ag (.5)	N	N	N	<	N
As (200)	N	N	N	N	N
B (10)	N	20	15	N	50
Ba (20)	<	>5000	1000	20	100
Be (1)	<	1.5	1.5	2	N
Co (10)	N	N	<	N	N
Cr (10)	10	N	70	10	<
Cu (5)	5	10	20	7	7
Ga (5)	N	<	70	N	N
La (50)	N	N	50	N	N
Mn (10)	500	>5000	200	150	500
Mo (5)	N	<	N	N	N
Nb (20)	N	20	20	N	N
Ni (5)	<	N	10	N	<
Pb (10)	10	20	50	20	<
Sb (100)	N	N	N	N	N
Sc (5)	N	N	15	N	<
Sr (100)	N	500	1000	700	700
V (10)	20	50	300	15	<
Y (10)	<	N	70	N	15
Zr (10)	<	10	300	N	<

Flame atomic absorption analyses of Te, Tl, and Au by F. Tippitt, C.A. Motooka, R.H. Hill, B.H. Roushey, L.A. Bradley, and Norma Rait, USGS. Direct-current arc atomic emission spectroscopy analyses of other elements by B.M. Adrian and R.T. Hopkins, USGS. Ca, Fe, Mg, Na, and Ti given in percent; all other values reported in parts per million (ppm). On left, lower limit of determination for each element given in percent or in ppm in parentheses. N, not detected at lower limit of determination; <, detected but below lower limit of determination; >, greater than; Te, Bi, Cd, Ge, Sn, Th, W (except in sample 90-BS86, for which W is 200 ppm), and Zn not detected.

Table 2. $^{40}Ar/^{39}Ar$ geochronology data for samples from the Caliente NW map area.

Sample	Map Unit	Latitude	Longitude	Mineral	Age (Ma)	±2σ (Ma)
91-382	Tpm	37.730999	-114.722695	sanidine	16.26	0.08
91-580	Tad	37.640256	-114.712434	biotite	24.33	0.12
91-580	Tad	37.640256	-114.712434	hornblende	25.12	0.26