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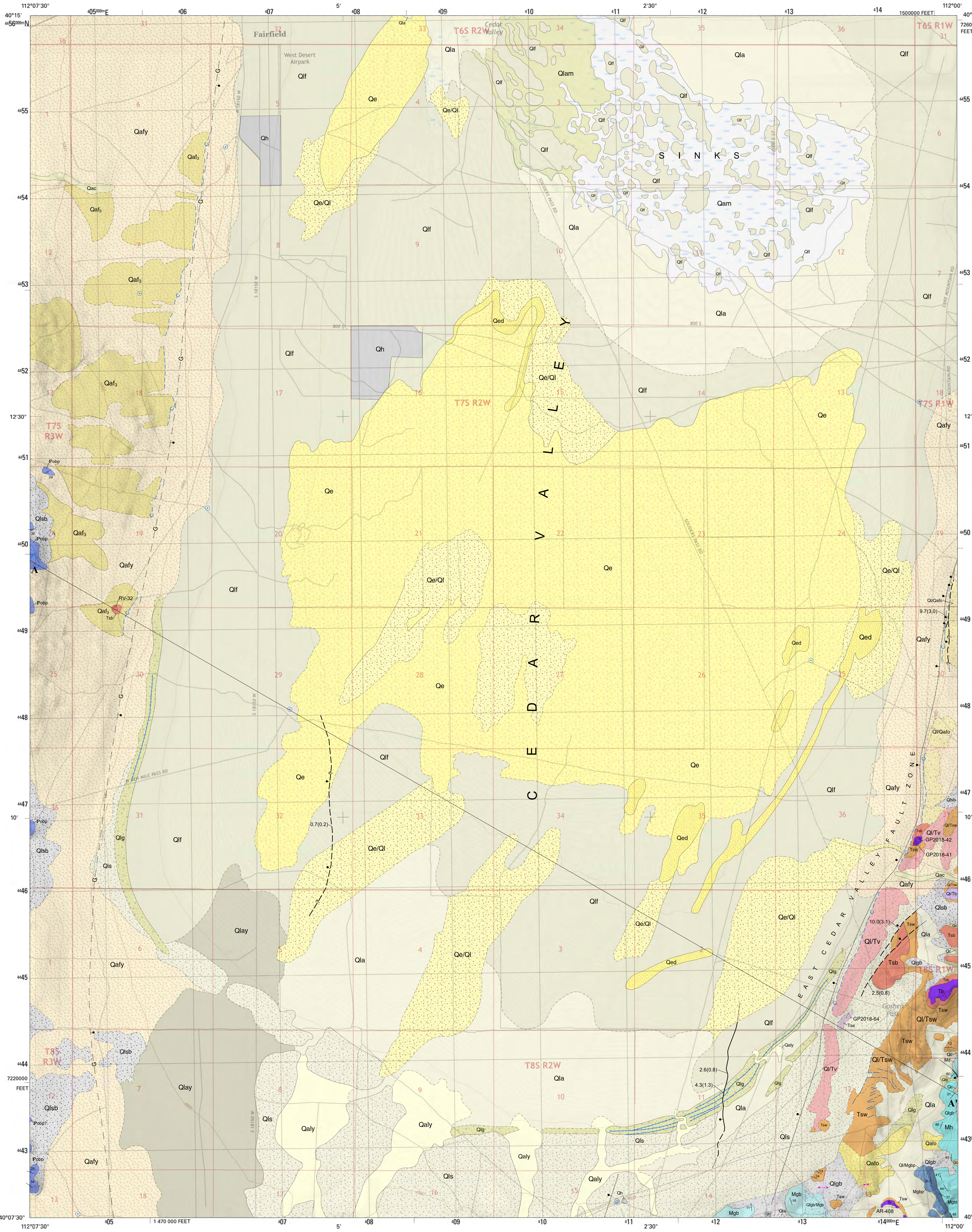

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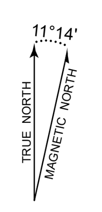


APPROXIMATE MEAN DECLINATION, 2020

SCALE 1:24,000

1 0.5 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 0.5 0 1 KILOMETER

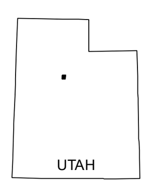
CONTOUR INTERVAL 20 FEET

GEOLOGIC MAP OF THE GOSHEN PASS QUADRANGLE, UTAH COUNTY, UTAH

by

Adam P. McKean

2020



QUADRANGLE LOCATION

Base from USGS US Topo Goshen Pass 7.5' Quadrangle (2017). Projection and datum for base map and GIS data are UTM NAD83. To conform to adjoining geologic maps, the geology is mapped to the 7.5' boundary of older UTM NAD27 base maps to the west and newer UTM NAD83 base maps to the east. The geology is accurately shown relative to cultural and topographic features on the US Topo base map.

Project Manager: Donald L. Clark
Geology mapped in 2018–19
GIS and Cartography: Adam P. McKean and Rosemary I. Fasselin

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1	2	3
4		5
6	7	8

1. Mercur
2. Cedar Fort
3. Saratoga Springs
4. Fivemile Pass
5. Soldiers Pass
6. Boulter Peak
7. Allens Ranch
8. Goshen Valley North

ADJOINING 7.5' QUADRANGLE NAMES

MAP UNITS

Qaly	Young stream deposits, undivided
Qafy	Younger alluvial-fan deposits, undivided
Qaf_3	Alluvial-fan deposits related to the transgressive and regressive phase of Lake Bonneville
Qafo	Older alluvial-fan deposits, pre-Lake Bonneville
Qc	Colluvial deposits
Qe	Eolian deposits, undivided
Qed	Eolian dune deposits
Qh	Fill and disturbed land
Qlg	Lacustrine gravel and sand related to Lake Bonneville and Cedar Valley Lake
Qls	Lacustrine sand and silt related to Lake Bonneville and Cedar Valley Lake
Qlf	Lacustrine fine-grained deposits related to Lake Bonneville and Cedar Valley Lake
Ql	Lacustrine deposits, undifferentiated related to Lake Bonneville and Cedar Valley Lake
Qlgb	Lacustrine gravel and sand related to the Bonneville shoreline and transgressive phase of Lake Bonneville
Qlsb	Lacustrine sand and silt related to the Bonneville shoreline and transgressive phase of Lake Bonneville
Qac	Alluvial and colluvial deposits, undivided
Qam	Alluvial mud-flat and marsh deposits, undivided
Qla	Lacustrine and alluvial deposits, undivided
Qlam	Lacustrine, alluvial, and marsh deposits, undivided
Qlay	Lacustrine and younger alluvial-fan deposits, undivided
Qe/Ql	Eolian deposits over lacustrine deposits related to Lake Bonneville and Cedar Valley Lake
Ql/Tb	Lacustrine deposits, undifferentiated over Mosida Basalt
Ql/ETs	Lacustrine deposits, undifferentiated over Soldiers Pass Formation, White Knoll Member
Ql/Tv	Lacustrine deposits, undifferentiated over Tertiary volcanic and sedimentary rocks, undifferentiated
Ql/Qafo	Lacustrine deposits, undifferentiated over older alluvial-fan deposits, pre-Lake Bonneville
Ql/Mgb	Lacustrine deposits, undifferentiated over Great Blue Limestone, Paymaster Member
Qlgb/Mgb	Lacustrine gravel and sand related to the Bonneville shoreline and transgressive phase of Lake Bonneville over Great Blue Limestone, undifferentiated
Tb	Mosida Basalt
Tsb	Soldiers Pass Formation, breccia member
Tsw	Soldiers Pass Formation, White Knoll Member
Tsa	Soldiers Pass Formation, andesite member
Tv	Tertiary volcanic and sedimentary rocks, undifferentiated
Pobp	Oquirrh Group, Butterfield Peaks Formation
Mgb	Great Blue Limestone, undivided
Mgbp	Great Blue Limestone, Paymaster Member
Mgbt	Great Blue Limestone, Topliff Member
Mh	Humbug Formation
Md	Deseret Limestone

GEOLOGIC SYMBOLS

Contact – Dashed where approximately located; queried where uncertain on cross section

4.3(1.3) Normal fault – Dashed where approximately located, dotted where concealed; queried where uncertain; bar and ball on downthrown side; arrows on cross section indicate direction of relative movement; vertical surface offset of fault shown in feet and (meters)

G Normal fault, geophysical – Inferred from gravity data; dotted where concealed and very approximately located; bar and ball on downthrown side

Lacustrine shorelines – Major shorelines of Lake Bonneville and Cedar Valley Lake; mapped at the top of wave-cut bench for erosional shorelines and at the top of constructional bars and barrier beaches; may coincide with geologic contacts

B Bonneville shoreline (highstand) – Dashed where approximately located (located in one place near the western end of cross section A-A')

t Transgressive shorelines (present above the Provo shoreline [not present in the quadrangle] and below the Bonneville shoreline) – Dashed where approximately located

C Cedar Valley Lake shoreline – Dashed where approximately located

Crest of lacustrine barrier bar related to Cedar Valley Lake

Potential scour marks at the southern threshold of Cedar Valley from Bonneville floodwaters leaving the valley (near Goshen Pass)

Axial trace of anticline – Dotted where concealed

Axial trace of syncline – Dotted where concealed

A——A' Line of cross section

65 Strike and dip of inclined bedding

Water well (selected)

RV-32 Rock sample location and number, see McKean and others (2013), McKean (2019), and Clark and others (in preparation) for geochemical data

Qe/Ql Stacked unit – Denotes thin cover of first unit overlying second unit

See booklet for introductory text, map unit descriptions, acknowledgments, and references.

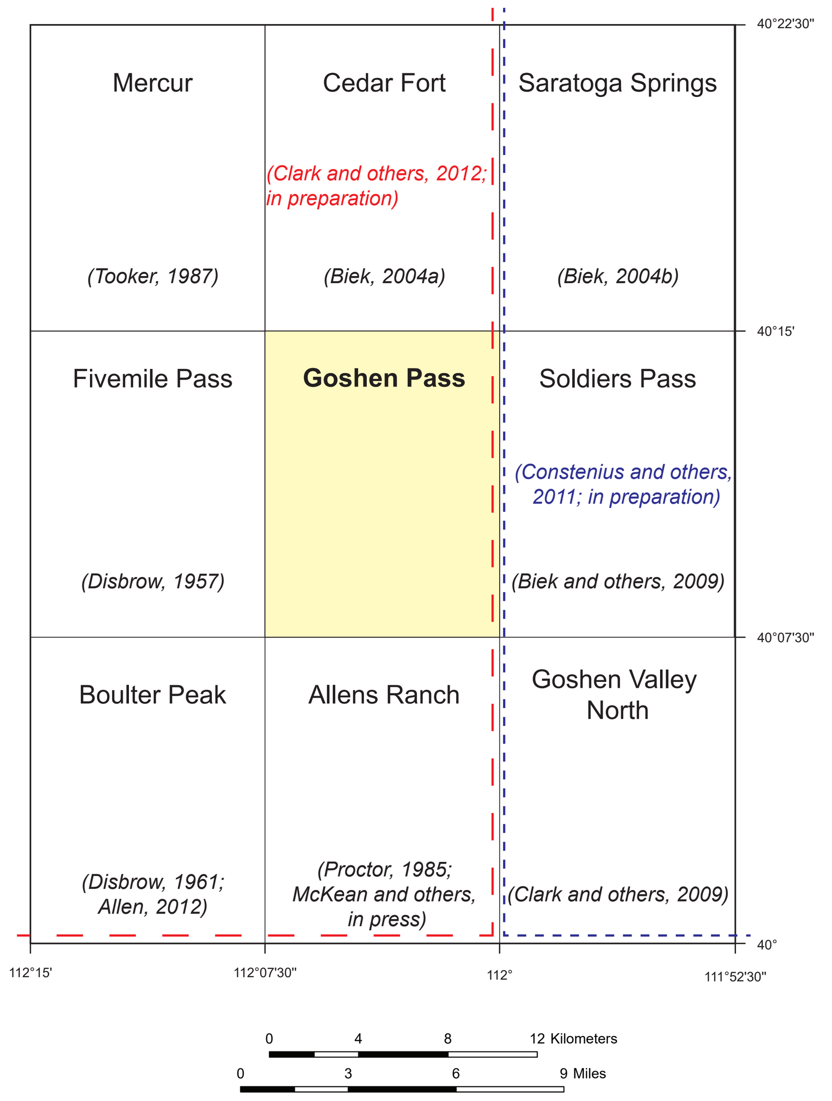


Figure 1. Index map showing selected geologic maps available for the Goshen Pass and surrounding 7.5' quadrangles.

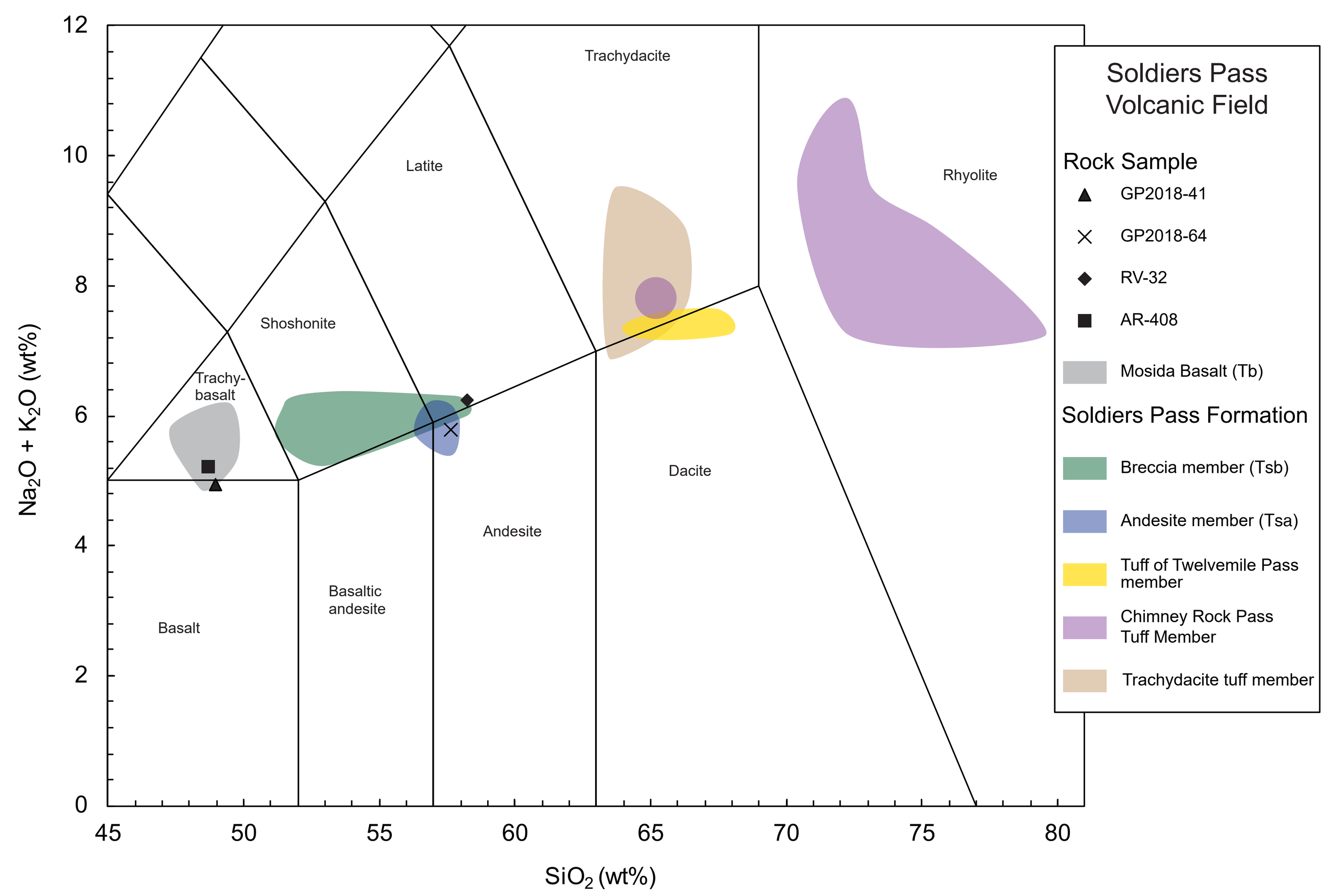
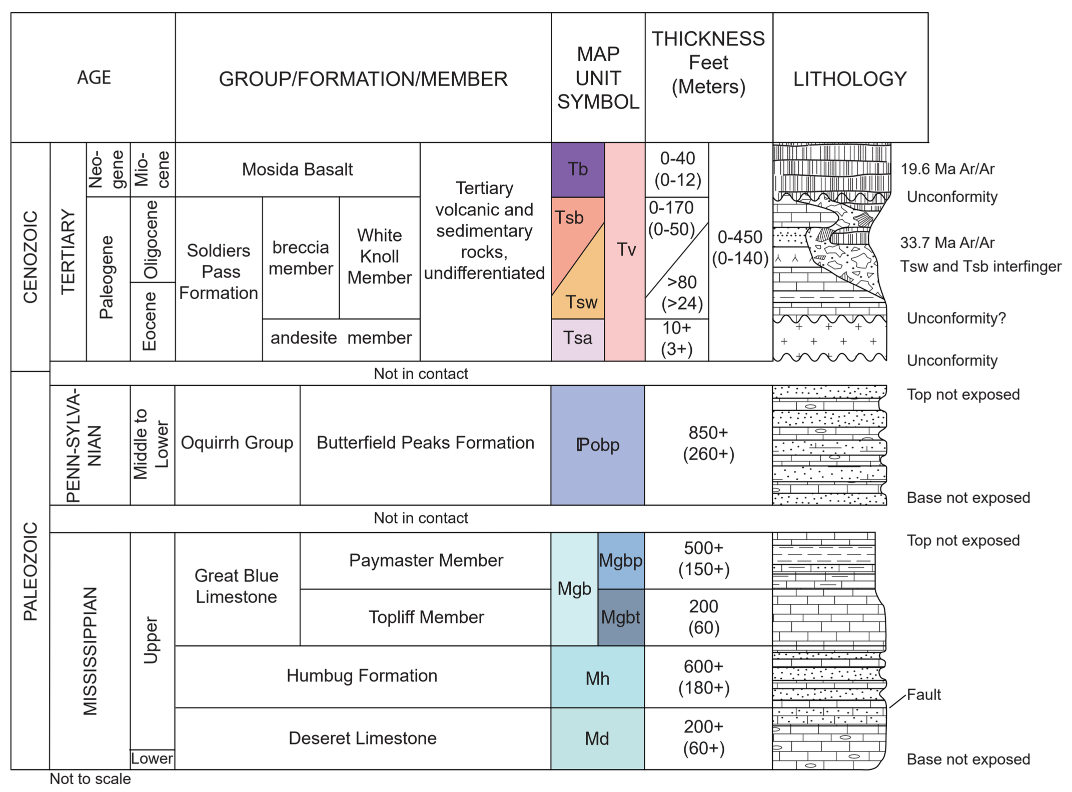
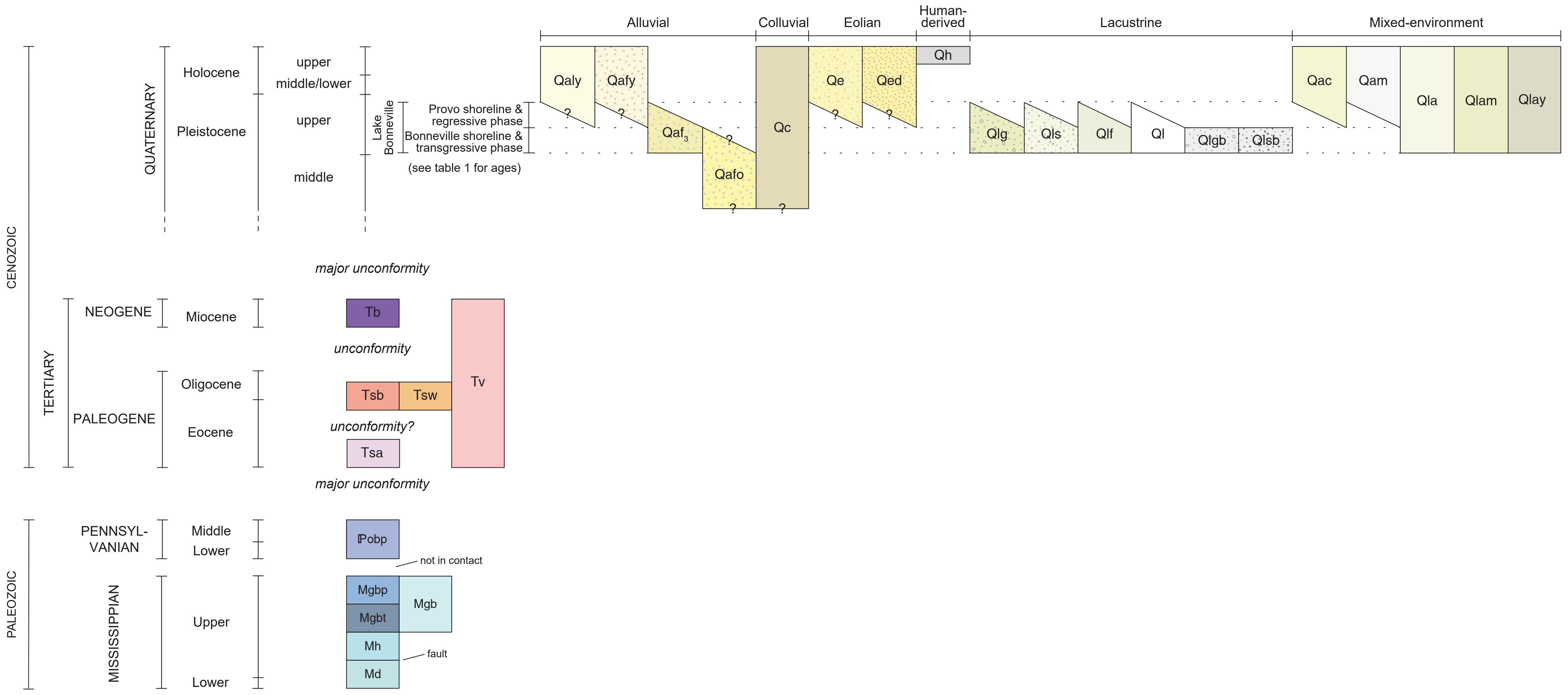


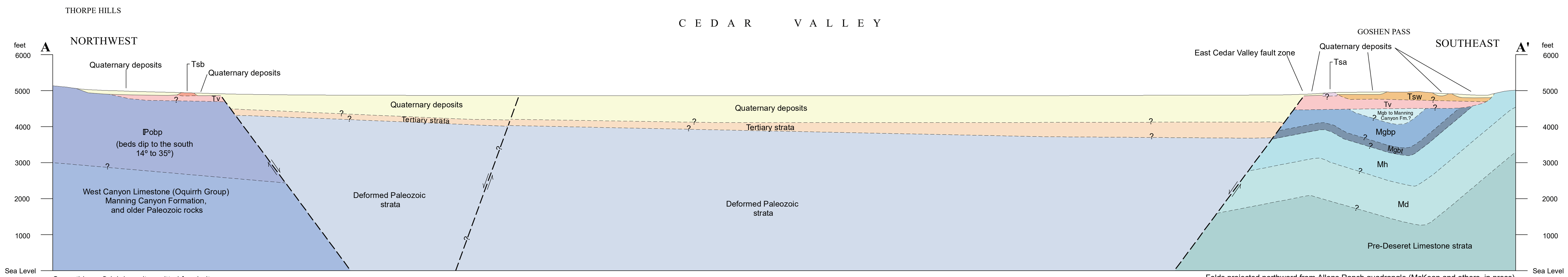
Figure 2. Total alkali-silica classification for igneous rocks of the Goshen Pass quadrangle (values have been normalized to 100% on a volatile-free basis). Classification diagram from Le Bas and others (1986); see McKean and others (2013), Clark and others (in preparation), and McKean (2019) for whole-rock geochemical data. Geochemical compositions for igneous units in the Soldiers Pass volcanic field (shown as fields) are available in Christiansen and others (2007), Christiansen (2009), and McKean and others (2013); unit symbols in parentheses for units identified in the Goshen Pass quadrangle.

LITHOLOGIC COLUMN



CORRELATION OF GEOLOGIC UNITS





Some thin surficial deposits omitted for clarity.
Created using data from Cook and Berg (1961), Zoback (1983), Hurlow (2004), Biek and others (2009), Jordan and Sabbah (2012), PACES (2012) gravity database, and newly acquired UGS gravity data.

Folds projected northward from Allens Ranch quadrangle (McKean and others, in press).

GEOLOGIC MAP OF THE GOSHEN PASS QUADRANGLE, UTAH COUNTY, UTAH

by Adam P. McKean

MAP 286DM
UTAH GEOLOGICAL SURVEY
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2020

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GEOLOGIC MAP OF THE GOSHEN PASS QUADRANGLE, UTAH COUNTY, UTAH

by Adam P. McKean

Cover photo: *View to the northeast of Cedar Valley with outcrops of sheared Mississippian Great Blue Limestone in the foreground and Lake Mountain in the background.*

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MAP 286DM
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2020

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TABLES

GEOLOGIC MAP OF THE GOSHEN PASS QUADRANGLE, UTAH COUNTY, UTAH

by Adam P. McKean

INTRODUCTION

The Goshen Pass 7.5' quadrangle is located in the southern half of Cedar Valley in western Utah County, in the eastern Basin and Range Province. The quadrangle occupies the basin valley between Lake Mountain to the east and the Thorpe Hills to the west. Located in the northeastern corner of the quadrangle, the Sinks (shown on the 1997 and previous USGS topographic maps) is a seasonally ponded and marshy area fed by Fairfield Spring, north of the map area. The highest point in the quadrangle is just above the Bonneville shoreline (5140 feet [1567 m]) at the west end of cross section A-A' (see plate2). Except for this small knob, the entire quadrangle is below the elevation of the Lake Bonneville highstand. The Sinks is the lowest spot in Cedar Valley with an approximate elevation of 4830 feet (1472 m), for approximately 310 feet (95 m) total relief in the quadrangle. Most of the quadrangle is currently farm and pasture land. Goshen Pass, in the southeastern corner of the quadrangle, provides a topographic pass and connection between Utah and Cedar Valleys. The map area is directly south of the Town of Fairfield and Eagle Mountain City and includes parts of each. The Goshen Pass quadrangle was mapped to provide geologic data for a variety of derivative uses, including to identify and delimit potential geologic hazards for Utah Geological Survey (UGS) geologic hazard maps of urban and rapidly developing areas being prepared as part of the UGS Geologic Hazards Mapping Initiative.

GEOLOGY

Bedrock Stratigraphy and Geologic Structure

Most of the Goshen Pass quadrangle is covered by surficial geologic deposits. Near the margins, small hills and knobs of Mississippian to Pennsylvanian sedimentary bedrock, and Tertiary volcanic and sedimentary deposits are exposed.

The Paleozoic strata represent a period of subsidence along the rifted continental margin of North America when thick sections of mostly shallow-marine sediments were deposited on the passive margin of the continent (Dickinson, 2006). The oldest bedrock in the quadrangle comprises marine deposits of the Mississippian Deseret Limestone (Md), Humbug Formation (Mh), and Great Blue Limestone (Mgb). Marine deposits of the Pennsylvanian Butterfield Peaks Formation (ℙobp) of the Oquirrh Group are exposed on the western margin of the quadrangle in the Thorpe Hills. The Oquirrh Group was deposited in the Oquirrh basin during the late Paleozoic. This basin was probably created by crustal subsidence associated with a deformational episode of the Ancestral Rocky Mountains (Hintze and Kowallis, 2009). During that time about 12,000 feet (~3700 m) of marine strata of the Oquirrh Group was deposited in the basin (Constenius and others, 2011).

Following the Triassic breakup of Pangea, eastward subduction of oceanic crust and the accretion of terranes began on the western margin of North America during the Late Jurassic Cordilleran orogeny (DeCelles, 2004). Deformation proceeded eastward. By the Late Cretaceous, steep- and then flat-slab subduction related to the Sevier orogeny affected central Utah and folded and faulted the Paleozoic strata, creating the East Tintic area fold and thrust system. The thrusts are considered internal thrust sheets of the Provo salient of the Sevier fold-thrust belt (Kwon and Mitra, 2004). The East Tintic thrust system deformed Paleozoic units in the area (McKean and others, 2011), including those in the Goshen Pass quadrangle.

Following the Sevier orogenic period of rapid flat-slab subduction, the subducting slab beneath western North America began to founder or roll back allowing extensional collapse of the fold and thrust belt in Utah during the late Paleogene (Constenius, 1996; Constenius and others, 2003) and producing a flare-up of subduction-related volcanic activity (Best and Christiansen, 1991; Christiansen and others, 2007). During this time, erosional valleys were filled by late Paleogene volcanic and sedimentary rocks (e.g., Morris and Lovering, 1979; McKean, 2011). The Paleogene volcanic section consists of a suite of high-potassium extrusive rocks. Rhyolite, trachydacite and trachytic ignimbrites, and latite lavas and block-and-ash flows dominate the sequence (Morris and Lovering, 1979; Moore, 1993; Christiansen and others, 2007; Moore and others, 2007; McKean, 2011). Locally, the Soldiers Pass volcanic field is the source of Paleogene volcanism (Christiansen and others, 2007). In the Goshen Pass quadrangle, the lower Oligocene to upper Eocene volcanic and sedimentary members of the Soldiers Pass Formation are exposed. The andesite member (Tsa) is a small andesitic lava flow that underlies the breccia member and White Knoll Member. The White Knoll Member (Tsw) is a lacustrine and hot-spring deposit. The breccia member (Tsb) is a shoshonitic flow breccia that laterally interfingers with and is partially overlain by the White Knoll Member (Christiansen and others, 2007).

Following this volcanically active period, tectonics changed and the region experienced bimodal volcanism (Best and Christiansen, 1991), the onset of basin-and-range extension, and the eruption of extension-related basaltic lavas of the Mosida Basalt (Tb) (Christiansen and others, 2007). The East Cedar Valley fault zone is a Quaternary expression of continued basin-and-range extensional normal faulting. The fault's last rupture was likely before or during the latest Pleistocene, as evidence of surface offset is mostly concealed by Lake Bonneville deposits. However, the most recent fault rupture on the southernmost strand of the fault is likely late Pleistocene or Holocene.

Surficial Geology

Lake Bonneville

Surficial geologic units within the quadrangle consist of unconsolidated lacustrine, alluvial, eolian, marsh, and colluvial deposits of mostly late Pleistocene and Holocene age. Late Pleistocene Lake Bonneville covered much of northwestern Utah and adjacent parts of Idaho and Nevada between 30,000 and 13,000 years ago (all ages in this section are in calibrated years, see table 1), and can be divided into transgressive, overflowing, and regressive phases (Oviatt and others, 1992; Godsey and others, 2005, 2011; Oviatt, 2015; see table 1). During the Bonneville shoreline highstand almost the entire quadrangle was underwater. Table 1 provides time constraints and elevations for Lake Bonneville geologic features and map units in the quadrangle.

Cedar Valley Lake

After the Bonneville flood 18,000 years ago, the lake dropped to the Provo shoreline (over a 300-foot [100 m] decline) and below the lowest elevation of Cedar Valley (table 1). After the flood the Cedar Valley drainage basin was isolated from Lake Bonneville and became its own closed basin (Wambeam, 2001). A small lake, here named Cedar Valley Lake, likely remained during the overflowing phase and potentially during the regressive phase of Lake Bonneville (see also McKean and Davis, 2019). A similar isolated lake existed in Rush Valley to the west (Burr and Currey, 1989, 1992; Nelson and Jewell, 2019). The sections below discuss the topographic thresholds during Lake Bonneville, the stabilized Cedar Valley Lake elevation, and age range of the Cedar Valley Lake.

Thresholds: During the transgressive phase and Bonneville flood, the northern and southern thresholds of Cedar Valley controlled water flow into and out of the valley. The southern threshold is the lower of the two and thus the longer-lived connection between Cedar Valley and Utah Valley during Lake Bonneville.

The northern threshold at Cedar Pass is located in the adjacent Cedar Fort quadrangle (Biek, 2004a) on the northern side of the Lakeside Mountains at an elevation of approximately 4985 feet (~1519 m). Transgressive-phase and Bonneville floodwaters would have flowed through this threshold for a short time due to its high elevation relative to Lake Bonneville's highstand shoreline. Biek (2004a) mapped an alluvial deposit and channel near the northern threshold that formed when a stream flowed down into Cedar Valley and incised through the transgressive Lake Bonneville deposits. The origin of this channel near Cedar Pass is somewhat unclear. The channel postdates the Bonneville transgression and flood. It may represent a predecessor to West Canyon Wash (see northeastern corner of Cedar Fort quadrangle; Biek, 2004a) that flowed south from the Oquirrh Mountains into Cedar Valley instead of Utah Lake. Currently it merges with Tickville Gulch near Cedar Pass and is part of the Utah Lake drainage basin. West Canyon Wash may represent an example of stream capture or stream avulsion. Alternatively, post-Bonneville flood groundwater seepage and spring flow may have created an alluvial channel that incised the Bonneville deposits (C.G. Oviatt, Kansas State University, email communication, June 5, 2018).

The southern threshold, just south of Goshen Pass in the southeastern corner of the quadrangle, has an approximate elevation of 4945 feet (~1507 m), which is 40 feet (12 m) lower than the northern threshold. The southern threshold is about 170 feet (51 m) above the Provo shoreline in Utah County. This threshold would likely have had more water flow through it during the Bonneville flood due to its lower elevation. The Bonneville floodwaters appear to have scoured some of the surficial deposits, as well as the White Knoll Member of the Soldiers Pass Formation (see plate 1, section 12, T. 8 S., R. 2 W., Salt Lake Base Line and Meridian [SLBLM]).

Lake elevation: The post-Bonneville, Cedar Valley Lake appears to have stabilized at an elevation of about 4900 feet (1494 m) or about 45 feet (14 m) below the southern threshold. Evidence for a stabilized lake in Cedar Valley includes shorelines, gravel bars, beach deposits, and oversized alluvial channels. In the southern half of the Goshen Pass quadrangle, shorelines eroded the aprons of older alluvial-fan deposits (Ql/Qafo and Qaf_3) at an elevation of about 4900 feet (1494 m). In addition to the shorelines, offshore gravel bars (Qlg) and beach deposits (Qls) formed at elevations at and below 4900 feet (1494 m) in the southern half of the valley. At the southern edge of the Cedar Valley Lake, between the Goshen Pass and Allens Ranch quadrangles, large shallow alluvial channels (Qaly) incised through the beach and gravel bar deposits (Qls and Qlg). These alluvial channels are wider than other post-Bonneville channels in the area, and they lack a clearly defined source or headwater in the Allens Ranch quadrangle. They may represent post-Bonneville flood stream channels that collected and transported water and sediment toward the Cedar Valley Lake from coalescing sheet flood events, dewatering surficial deposits, and/or groundwater-fed spring flow.

Table 1. *Ages of major shoreline occupations of Lake Bonneville and Cedar Valley Lake with shoreline elevations in the Goshen Pass quadrangle.*

Lake Cycle and Phase	Shoreline (map symbol)	Age		Shoreline Elevation feet (meters)
		radiocarbon years (^{14}C yr B.P.)	calibrated years (cal yr B.P.)[1]	
Lake Bonneville				
Transgressive phase	Stansbury shorelines	22,000–20,000[2]	26,000–24,000	Not present[3]
	Bonneville (B)	~15,000[4]	~18,000	5140–5175 (1567–1577)
	flood			
Overflowing phase	Provo	15,000–12,600[5]	18,000–15,000	Not present[3]
Regressive phase	Regressive shorelines	12,600–11,500[5]	15,000–13,000	Not present[3]
Cedar Valley Lake	Cedar Valley (C)	15,000[4,6]	18,000	4885–4900 (1489–1494)

[1] All calibrations made using OxCal ^{14}C calibration and analysis software (version 4.3.2; Bronk Ramsey, 2009; using the IntCal13 calibration curve of Reimer and others, 2013), rounded to the nearest 500 years.
[2] Oviatt and others (1990)
[3] Stansbury, Provo, and regressive shorelines are provided for reference only, as they are only present downslope of the lowest elevations in the quadrangle.
[4] Bonneville shoreline highstand duration may have been shorter than our rounding error of 500 years; age represents lake culmination (Oviatt, 2015; Miller, 2016 and references therein)
[5] Godsey and others (2005, 2011), Oviatt (2015), Miller (2016) for the timing of the occupation of the Provo shoreline and subsequent regression of Lake Bonneville to near Great Salt Lake level. Alternatively, data in Godsey and others (2005) may suggest that regression began earlier, shortly after 16.5 cal ka (see sample Beta-153158, with an age of 13,660 ± 50 ^{14}C yr B.P. [16.5 cal ka] from 1.5 m below the Provo shoreline). Also, lacustrine carbonate deposits in caves reported by McGee and others (2012) seem to support an earlier Lake Bonneville regression beginning around 16.4 cal ka.
[6] Estimated age when Lake Bonneville dropped below the Cedar Valley thresholds during the flood, from data in Oviatt (2015 and references therein). Length of Cedar Valley Lake occupation unknown.

The southern threshold clearly did not control the elevation of the Cedar Valley Lake. Other factors likely contributed to the stabilized elevation of the lake well below the southern threshold, including precipitation, climate, stream flow, springs, evaporation, seepage through bedrock, and groundwater.

Age: Cross-cutting relationships in the southern half of the Goshen Pass quadrangle bracket the age of the Cedar Valley Lake, including the observation that only younger alluvial deposits seem to overlie or cross-cut the gravel bars and shoreline deposits of the Cedar Valley Lake. This indicates that the Cedar Valley Lake deposits are likely late Pleistocene and occupied Cedar Valley during the overflowing and potentially regressive phases of Lake Bonneville. The valley is higher than the Provo shoreline, eliminating the ability to use that shoreline or regressive Lake Bonneville features to more accurately constrain the age of the Cedar Valley Lake using cross-cutting relationships.

Post-Cedar Valley Lake Processes

Following desiccation of Cedar Valley Lake to the present-day level (an intermittently wet playa), alluvial, eolian, and wetland processes dominated the valley. Alluvial fans flank the margins of Cedar Valley on all sides. Older fine-grained lacustrine and alluvial deposits are the potential sources for the eolian deposits of sand, silt, and clay. Eolian deposits in the Goshen Pass quadrangle cover approximately 15 square miles (~39 km^2), with more eolian deposits thinly mantling other surficial deposits. Fairfield Spring, to the north in the Cedar Fort quadrangle, is the main source of alluvial stream flow into the Sinks, an alluvial mud flat and wetlands area (Hurlow, 2004; Jordan and Sabbah, 2012).

PREVIOUS WORK

The geology of the Goshen Pass quadrangle has not previously been mapped at 1:24,000 scale. The surficial and bedrock geology was mapped at intermediate scale (1:62,500) by Clark and others (2012). I revised and added to their mapping for this geologic map. The bedrock geology of the surrounding quadrangles is mapped at 1:24,000 scale; most of these maps also include detailed surficial geologic mapping (figure 1 on plate 2). Recent groundwater and hydrogeology studies of Cedar Valley by Hurlow (2004), Jordan and Sabbah (2012), and Jordan (2013) provided thorough descriptions of the groundwater conditions in the area, as well as details regarding Fairfield Spring, which contributes stream flow and alluvium to the marsh deposits of the Sinks.

METHODS

Mapping of surficial deposits by the UGS is based on age and depositional environment or origin (Doelling and Willis, 1995). The letters of the map units indicate (1) age (Q = Quaternary), (2) depositional environment or origin, determined from landform morphology, bedding, or other distinctive characteristics of the deposits, (3) grain size(s), and (4) age as related to the phases of Lake Bonneville. For example, unit Qaf_3 is a Quaternary (Q) surficial deposit of alluvial-fan origin (af), and the subscript number "3" indicates it overlaps in age with Lake Bonneville. Letters "y" and "o" in place of a subscript indicate deposits younger and older than Lake Bonneville, respectively. Unit numbers indicate relative age with "1" being the youngest and increasing with age.

Mapping for the project was done using stereographic pairs of aerial photographs, including black-and-white aerial photographs at a scale of 1:20,000 from the U.S. Department of the Interior (DOI), Bureau of Reclamation (1939) and U.S. Department of Agriculture (USDA) Agricultural Stabilization and Conservation Service (1972), and natural-color aerial photographs at approximately 1:24,000 scale from IntraSearch (1980). Some unit contacts were mapped with the aid of U.S. Natural Resources Conservation Service (2017) soil map data. Landfill outlines and some contacts were revised using Google 2017 archive orthophotographs (Utah Automated Geographic Reference Center [AGRC], 2017), and 0.5-meter lidar (AGRC, 2018). The geologic map was made by transferring the geology from the aerial photographs to a geographic information system (GIS) database in ArcGIS for a target scale of 1:24,000, using 1990s digital orthophoto quadrangles (DOQ) (AGRC, 1990s) and Google 2017 archive orthophotographs (AGRC, 2017).

Cross section A-A' (plate 2) was created by interpreting available subsurface and gravity data from Cook and Berg (1961), Zoback (1983), Hurlow (2004), Jordan and Sabbah (2012), the Pan-American Center for Earth and Environmental Studies (PACES) (2012) gravity database, and newly acquired UGS gravity data. UGS gravity data will be available on the UGS website in the future. Water well logs in the area (online well data from Utah Division of Water Rights [2009] and in Hurlow [2004] and Jordan and Sabbah [2012]) were used to estimate the subsurface contact between Quaternary unconsolidated deposits and Tertiary semiconsolidated to consolidated strata. Tertiary volcanic and sedimentary thickness beneath valley fill is estimated from exposed thicknesses in the Soldiers Pass quadrangle (Biek and others, 2009). Beneath the basin fill the actual depth to Paleozoic bedrock could be much greater. At the western end of cross section A-A' the thickness of the Butterfield Peaks Formation of the Oquirrh Group is estimated due to the cross section being oriented nearly parallel to strike.

SELECTED GEOLOGIC HAZARDS

Known and potential geologic hazards in the map area include surface fault rupture (scarps), windblown deposits (Qe, Qed, and Qe/Qlf), flooding (Qaly, Qac, Qafy, Qam, Qla, and Qlam), debris flows (Qac, Qaly, and Qafy), earthquake ground shaking, liquefaction, tectonic subsidence/tilting, expansive soils, collapsible soils, shallow groundwater, corrosive soils, radon, and other problem soils. Alluvial and marsh deposits (Qla, Qlam, and Qam) can indicate potential areas of shallow groundwater, whereas clay-rich lacustrine deposits (Qlf, Qls, Qla, and Qlam) can indicate potential areas of soil problems. Four hazards are briefly discussed below. See the map unit descriptions and geologic map (plate 1) for more information and the location of these and other potential hazards. Additional geologic hazards may exist but are not addressed in this report. We recommend comprehensive site-specific geotechnical and geologic hazard investigations. See the UGS website (geology.utah.gov) for additional information on these and other geologic hazards.

Surface Fault Rupture and Ground Shaking

The study area contains the mapped trace of the southern end of the East Cedar Valley fault zone. Much of the fault length in Cedar Valley is concealed by younger upper Pleistocene and Holocene deposits. The most recent surface faulting along the fault likely occurred in the Pleistocene as it is mostly concealed by Lake Bonneville deposits. In the southeastern corner of the quadrangle (plate 1), fault offsets occur in Bonneville deposits, older alluvial-fan deposits, and Tertiary bedrock. Other mapping of the fault in Cedar Valley shows offsets in Bonneville and pre-Bonneville deposits; see the adjacent geologic maps of the Cedar Fort (Biek, 2004a), Saratoga Springs (Biek, 2004b), and Soldiers Pass (Biek and others, 2009) quadrangles. In the Goshen Pass quadrangle it is unclear if the scarps offset only older sediments that were later draped by a thin mantle of Lake Bonneville sediments, or if the Bonneville mantle is actually offset. Offset Lake Bonneville sediments would indicate late Pleistocene or early Holocene faulting occurred later than previously identified. However, the southernmost strand of the fault in the quadrangle clearly offsets Cedar Valley Lake gravel bar deposits. The most recent surface fault rupture on this strand is late Pleistocene or Holocene.

Some previously mapped faults (McKean, 2018) in the southeastern corner of the quadrangle have been removed after evidence from survey-grade GPS profiles and new 0.5-meter lidar indicated that they were not faults but likely bedrock lineaments and erosional features related to Lake Bonneville.

A queried down-to-the-west fault in the southwestern quarter of the quadrangle was identified using the 0.5-meter lidar acquired by the UGS. The fault has an approximately 8-inch (0.2 m) vertical displacement of the valley floor surface. The north-south-trending fault is 1.5 miles (2.3 km) long. The fault offsets Lake Bonneville and Cedar Valley Lake deposits and appears to be modified by the eolian deposits. Perhaps the fault scarp represents a single small-magnitude-earthquake surface-fault rupture. The fault also may be antithetic to the western basin-bounding fault inferred from gravity data.

Destructive earthquake ground shaking from the East Cedar Valley fault zone and several other faults in the area, including the Wasatch fault zone about 20 miles (~32 km) to the east (Constenius and others, 2011), is a hazard throughout the quadrangle.

Wind-Blown Sand

Surficial deposits in the quadrangle are mostly fine-grained deposits (e.g., Qlf, Qla, Qlam, and Qafy) and if disturbed may be susceptible to wind erosion. Wind-blown sand can be an adverse construction condition and the moving sand may form deposits that can surround structures and bury agricultural fields and transportation corridors. During high-wind events, blowing sand and dust may become a hazard to driving. Other concerns include potential for wind erosion, as well as soil and vegetation loss in areas of agricultural use. Wind-blown deposits (Qe, Qed, and Qe/Qlf) in this area include not only sand but also aggregate grains of sand, silt, and clay. See the map unit descriptions and geologic map (plate 1) for more information and the location of these deposits.

Flooding

Flood and debris-flow hazard areas are primarily in, but are not limited to, alluvial channels (Qaly, Qac, Qam, Qla, and Qlam) and mapped alluvial-fan deposits (Qafy), particularly steep alluvial fans. Locations of these deposits are included on the geologic map (plate 1) and descriptions of areas and additional information are included in the map unit descriptions. Delineation of flood and debris-flow hazards requires detailed geotechnical investigation.

MAP UNIT DESCRIPTIONS

QUATERNARY

Alluvial Deposits

Qaly **Young stream deposits, undivided** (Holocene to upper Pleistocene?) – Poorly to moderately sorted pebble gravel with a matrix of sand, silt, and clay; mapped in ephemeral channels in the southern part of the quadrangle that are incised into lacustrine sand, silt, and clay (Qls, Qlg); may represent stream channels that formed soon after the Lake Bonneville flood that collected and transported water and sediments toward the Cedar Valley Lake from coalescing sheet flood events, possible dewatering surficial deposits, and/or groundwater-fed spring flow, as the channels diminish in width and depth upslope with no large alluvial channels feeding them in southern Cedar Valley (McKean and others, in press); thickness is probably less than 15 feet (5 m).

Qafy **Younger alluvial-fan deposits, undivided** (Holocene to upper Pleistocene?) – Poorly to moderately sorted pebble to cobble gravel, with boulders near bedrock sources, with a matrix of sand, silt, and clay; gradational downslope into mixtures of sand, silt, and clay on gentler slopes; clasts subangular to well-rounded; located along valley margins where it forms coalesced aprons of post-Bonneville alluvial deposits from Lake Mountain, the Mosida Hills, and the Thorpe Hills; likely postdates the Bonneville highstand (table 1), may coincide with the regression of Lake Bonneville, locally may include some undifferentiated thin Bonneville transgressive deposits or pre-Bonneville alluvial-fan deposits; Lake Bonneville shorelines are not present on these alluvial fans; thickness unknown, but likely up to several tens of feet thick.

Qaf_3 **Alluvial-fan deposits related to the transgressive and regressive phases of Lake Bonneville** (upper Pleistocene) – Poorly to moderately sorted pebble to cobble gravel, with boulders near bedrock sources, with a matrix of sand, silt, and minor clay; clasts subangular to well-rounded; incised by younger alluvial channels; downslope parts eroded by Cedar Valley Lake shorelines; located on the western side of Cedar Valley; likely deposited before or during the transgressive phase of Lake Bonneville and etched after the Bonneville flood during Cedar Valley Lake occupation of the valley bottom; thickness unknown, but likely up to several tens of feet thick.

Qafo **Older alluvial-fan deposits, pre-Lake Bonneville** (upper to middle Pleistocene?) – Poorly sorted pebble to cobble gravel with boulders, with a matrix of sand, silt, and minor clay; composed mostly of Paleozoic and Tertiary volcanic clasts that are subangular to rounded; located in two exposures in the southeastern corner of the quadrangle; located along the eastern quadrangle boundary near Goshen Pass; forms dissected, stranded alluvial deposits south of Goshen Pass that predate Lake Bonneville; locally may include some undifferentiated thin Bonneville transgressive deposits; lacks distinctive alluvial-fan morphology on aerial imagery; thickness unknown, but likely up to several tens of feet thick.

Colluvial Deposits

Qc **Colluvial deposits** (Holocene to middle Pleistocene?) – Poorly to moderately sorted, angular, clay- to boulder-size, locally derived sediment deposited by slope wash and soil creep on moderate slopes and in shallow depressions; locally includes some subrounded to rounded, recycled lacustrine gravel below the Bonneville shoreline; estimated thickness 0 to 20 feet (0–6 m).

Eolian Deposits

Qe **Eolian deposits, undivided** (Holocene to upper Pleistocene?) – Well- to very well sorted, well-rounded, windblown, very fine to medium-grained sand, and aggregates of clay, silt, and sand in both sheet and dune forms; bedding ranges from cross-bedded, to laminar, to no distinct bedding; located in the central part of Cedar Valley; on aerial photos the deposits are distinguished from lacustrine deposits (Qlf) by characteristic hummocky sheet and dune forms; active to partially stabilized with vegetation; some areas of dry farming have removed vegetation cover and developed into eolian source and deposition areas; a thin veneer of eolian deposits may exist on other units that are not differentiated at map scale; 0 to 20 feet thick (0–6 m).

Qed **Eolian dune deposits** (Holocene to upper Pleistocene?) – Well- to very well sorted, well-rounded, windblown, very fine to medium-grained sand, and aggregates of clay, silt, and sand in dune forms; located in the central part of Cedar Valley; on aerial photos the deposits are distinguished from other eolian deposits by distinctive parabolic, linear, and lunette dune types; dunes are active to partially stabilized with vegetation; 0 to 20 feet thick (0–6 m).

Human-Derived

Qh **Fill and disturbed land** (historical) – Undifferentiated fill and disturbed land related to the construction of two landfills in the northwestern quadrant of the quadrangle (see plate 1, SW1/4 section 5 and NW1/4 section 16, T. 7 S., R. 2 W., SLBLM) and small dams (see plate 1, NE1/4 section 15, T. 8 S., R. 2 W., SLBLM) for livestock watering ponds; only the larger areas of disturbed land are mapped; unmapped fill is locally present in most developed areas, but only the larger deposits are mapped; smaller watering ponds are not mapped due to map scale limitations; thickness variable and unknown.

Lacustrine Deposits

Deposits related to Lake Bonneville and Cedar Valley Lake: Located below the elevation of the southern Cedar Valley threshold (see plate 1, section 12, T. 8 S., R. 2 W., SLBLM), near Goshen Pass, which is between 4940 and 4950 feet (1506–1508 m). Likely includes both Lake Bonneville transgressive- and overflowing-phase deposits, as well as Cedar Valley Lake deposits. Cedar Valley Lake stabilized (likely after the Bonneville flood) at about 4900 feet (1494 m) (see table 1).

Qlg **Lacustrine gravel and sand** (upper Pleistocene) – Well-sorted, subrounded to rounded, matrix-supported, pebble gravel, with a matrix of sand with minor silt and clay; very fine to medium sand; formed as offshore gravel bars in the southern half of the Cedar Valley Lake and near the southern Cedar Valley threshold just south of Goshen Pass; Goshen Pass deposits likely deposited during the Bonneville flood, the gravel bars formed just offshore in the Cedar Valley Lake; grades into Qls and incised by younger Qaly deposits; 3 to 20 feet thick (1–6 m).

Qls **Lacustrine sand and silt** (upper Pleistocene) – Moderately to well-sorted, subrounded to rounded, very fine to medium sand, silt, clay, and minor pebbly gravel; deposited in relatively shallow water nearshore; gastropod shells are locally common; mapped in the southern half of the quadrangle near and above the Cedar Valley Lake shoreline, up to the approximate Cedar Valley threshold elevation where the deposit may include both Lake Bonneville and subsequent Cedar Valley Lake deposits; grades laterally into Qla, Qlf, and Qlgb; locally may include unmapped thin eolian deposits; incised by younger Qaly; estimated thickness 3 to 15 feet (1–5 m).

Qlf **Lacustrine fine-grained deposits** (upper Pleistocene) – Moderately sorted silt, clay, marl, and very fine to medium-grained sand; deposited in shallow to moderately deeper water; commonly gradational upslope into lacustrine sand and silt (Qls); contact with distal parts of younger alluvial-fan deposits (Qafy) is difficult to identify and commonly based on subtle geomorphic differences; locally may include unmapped thin eolian deposits; major source of windblown sand, silt, and clay, especially in areas of dry farming after plowing, or in areas lacking vegetation; includes both Bonneville and Cedar Valley Lake deposits; estimated thickness less than 15 feet (5 m).

Ql **Lacustrine deposits, undifferentiated** (upper Pleistocene) – Lacustrine sand, silt, clay, and pebble gravel; see other detailed descriptions; only mapped as cover of stacked units (Ql/Tb, Ql/Tsw, Ql/Tv, Ql/Qafo, Ql/Mgbp); lacustrine deposits are 0 to 20 feet (0–6 m) thick.

Deposits related to the Bonneville shoreline and transgressive phase of Lake Bonneville: Mapped between the Bonneville and Cedar Valley Lake shorelines. The Bonneville shoreline is at elevations of about 5140 to 5175 feet (1567–1577 m) in and near the Goshen Pass quadrangle (table 1).

Qlgb **Lacustrine gravel and sand** (upper Pleistocene) – Moderately to well-sorted, clast to matrix supported, pebble to cobble gravel, with boulders near bedrock sources, with a matrix of sand and pebbly sand; locally interbedded with thin beds and lenses containing silt and clay; clasts commonly subrounded to rounded, but some deposits consist of poorly sorted, angular gravel derived from nearby bedrock outcrops; clast types include local and transported Paleozoic limestone and sandstone, and Tertiary volcanic and sedimentary rocks from the Soldiers Pass Formation and Mosida Basalt (Christiansen and others, 2007; Biek and others, 2009); bedding is planar and cross-bedded; overlies bedrock in the southeast corner of the quadrangle near Goshen Pass; some thin unmapped areas of gravel and sand overlie exposed bedrock; estimated thickness less than 50 feet (15 m).

Qlsb **Lacustrine sand and silt** (upper Pleistocene) – Well-sorted, subrounded to rounded, fine to coarse sand, with silt and minor pebbly gravel; typically laminated; gastropods locally common; deposited in relatively shallow water nearshore, downslope from transgressive gravel and sand (Qlgb); overlies coarser-grained beach gravel, indicating deposition in increasingly deeper water in the transgressing lake; distinguished on aerial imagery from surrounding and incised alluvial-fan deposits by bench geomorphology and lighter color; estimated thickness less than 30 feet (10 m).

Mixed-Environment Deposits

Qac **Alluvial and colluvial deposits, undivided** (Holocene to upper Pleistocene) – Poorly to moderately sorted, generally poorly stratified, clay- to boulder-size, locally derived sediment; rounded to angular clasts; mapped where alluvium and colluvium (slope wash and soil creep) grade into one another or are intermixed and cannot be shown separately at map scale; mapped where the alluvium is mostly fan alluvium and in small drainages where stream and fan alluvium and colluvium from the sides of the drainage are intermixed; small, unmapped deposits are likely present in most small drainages; thickness less than 15 feet (5 m).

Qam **Alluvial mud-flat and marsh deposits, undivided** (Holocene to upper Pleistocene) – Well-sorted, fine-grained, alluvial mud-flat and marsh deposits, with organic-rich sediment associated with wetlands; main source of stream flow is the Fairfield Spring to the northwest of the deposit in the Cedar Fort quadrangle (Biek, 2004a; Hurlow, 2004; Jordan and Sabbah, 2012); commonly wet, but seasonally dry; may locally contain peat deposits and gastropods; overlies lacustrine fine-grained deposits (Qlf) and grades laterally into undivided lacustrine, alluvial, and marsh deposits (Qla, Qlam); supports the growth of short reeds; distinguished from undivided lacustrine and alluvial and marsh deposits (Qlam) by the separation of lacustrine deposit mounds (Qlf) from low-lying alluvial mud-flat and marsh deposits; estimated thickness less than 15 feet (5 m).

Qla **Lacustrine and alluvial deposits, undivided** (Holocene to upper Pleistocene) – Well-sorted sand, silt, clay, marl, pebble gravel, and sandy gravel; mapped in areas of spring- fed mixed alluvial and lacustrine deposits that cannot be shown separately at map scale, or because the deposits are gradational into each other, or thin patches of one unit overlie the other; gastropods locally common; located near the Sinks, below the Cedar Valley Lake shoreline in the southern half of the quadrangle, and near Goshen Pass; likely includes areas of mixed lacustrine, alluvial, and marsh deposits (Qlam) too small to be mapped separately; estimated thickness less than 20 feet (6 m).

Qlam **Lacustrine, alluvial, and marsh deposits, undivided** (Holocene to upper Pleistocene) – Silt, clay, marl, and minor sand, with organic-rich sediment associated with wetlands; commonly wet, but seasonally dry; mapped near the Sinks where spring-fed marsh, alluvial, and lacustrine deposits are patchy and intermixed; supports the growth of short reeds; Qlam is distinguished from undivided lacustrine and alluvial deposits (Qla) and alluvial mud-flat and marsh deposits (Qam) by the presence of numerous small low-lying lacustrine mounds incised by alluvial channels too small to map separately; estimated thickness 20 feet (6 m).

Qlay **Lacustrine and younger alluvial-fan deposits, undivided** (Holocene to upper Pleistocene) – Poorly to well-sorted sand, silt, clay, marl, and gravel; mapped below the Bonneville shoreline elevation on the distal margins of younger alluvial-fan deposits (Qafy) where lacustrine and alluvial deposits are intermixed and cannot be shown separately; distinguished from Qls and Qla by distinct parallel alluvial channel texture on 1939 aerial photographs (DOI, Bureau of Reclamation, 1939) and from Qafy by low gradient of deposits; thickness likely less than 15 feet (5 m).

Stacked-Unit Deposits

Qe/Ql **Eolian deposits over lacustrine deposits related to Lake Bonneville and Cedar Valley Lake** (Holocene to upper Pleistocene? over upper Pleistocene) – Eolian deposits over lacustrine deposits; lacustrine deposits may include thin alluvial deposits (see Qlay and Qla); mapped in the central part of Cedar Valley where areas of thin eolian sheet and dune deposits partially conceal lacustrine deposits; the eolian deposits are 0 to 10 feet (0–3 m) thick.

Ql/Tb **Lacustrine deposits, undifferentiated over Mosida Basalt** (upper Pleistocene over lower Miocene) – Lacustrine sand, silt, clay, and pebble gravel over subangular to rounded pebble to boulder float dominated by Mosida Basalt clasts; mapped in one location on eastern map boundary; lacustrine deposits are 0 to 10 feet (0–3 m) thick.

Ql/Tsw **Lacustrine deposits, undifferentiated over Soldiers Pass Formation, White Knoll Member** (upper Pleistocene over lower Oligocene to upper Eocene) – Lacustrine sand, silt, clay, and pebble gravel over subangular to rounded pebble to boulder float dominated by White Knoll limestone, travertine, and other sedimentary clasts; mapped in the southeastern corner of the quadrangle adjacent to Tsw; small bedrock knobs are included in the unit and not mapped separately due to map scale limitations; lacustrine deposits are 0 to 20 feet (0–6 m) thick.

Ql/Tv **Lacustrine deposits, undifferentiated over Tertiary volcanic and sedimentary rocks, undifferentiated** (upper Pleistocene over Miocene to Oligocene) – Lacustrine sand, silt, clay, and pebble gravel over subangular to rounded pebble to boulder float dominated by Mosida Basalt and Soldiers Pass Formation (Christiansen and others, 2007; Biek and others, 2009) lava, breccia, limestone, travertine, and other sedimentary clasts; mapped in three exposures in the southeastern part of the map; on aerial imagery the stacked deposits have a lighter color than the surrounding lacustrine deposits; lacustrine deposits are 0 to 20 feet (0–6 m) thick.

Ql/Qafo

Lacustrine deposits, undifferentiated over older alluvial-fan deposits, pre-Lake Bonneville (upper Pleistocene over upper to middle Pleistocene?) – Older alluvial-fan deposits are partially concealed with a discontinuous veneer of lacustrine deposits consisting of sand, silt, clay, and pebble gravel; alluvial deposits are subangular to rounded pebble to boulder deposits with a matrix of sand, silt, and minor clay; clasts are Tertiary volcanic rocks, limestone, travertine, and other sedimentary clasts, and Paleozoic limestone and sandstone; mapped along the eastern map boundary; on aerial imagery the older alluvial-fan deposits have a lighter-colored appearance (similar to Ql/Tv) when compared to the surrounding younger alluvial-fan deposits (Qafy); lacustrine deposits are 0 to 15 feet (0–5 m) thick.

Ql/Mgbp

Lacustrine deposits, undifferentiated over Great Blue Limestone, Paymaster Member (upper Pleistocene over Upper Mississippian) – Paymaster Member is partially concealed by a discontinuous veneer of lacustrine deposits consisting of sand, silt, clay, and pebble gravel; mapped in one location in the southeastern corner of the quadrangle; small bedrock knobs are included in the unit and not mapped separately due to map scale limitations; lacustrine deposits are 0 to 10 feet (0–3 m) thick.

Qlgb/Mgb

Lacustrine gravel and sand related to the Bonneville shoreline and transgressive phase of Lake Bonneville over Great Blue Limestone, undifferentiated (upper Pleistocene over Upper Mississippian) – Great Blue Limestone is partially concealed by a discontinuous veneer of lacustrine deposits consisting of sand, silt, clay, and pebble gravel; mapped in one location along the southern border of the map area; small bedrock knobs are included in the unit and not mapped separately due to map scale limitations; lacustrine deposits are 0 to 15 feet (0–6 m) thick.

Major unconformity

TERTIARY

Whole-rock geochemical data for igneous units in the Goshen Pass quadrangle are available in McKean and others (2013), McKean (2019), and Clark and others (in preparation). Geochemical compositions and age data for igneous units in the Soldiers Pass volcanic field are also available in Christiansen and others (2007) and Christiansen (2009). Geochemical rock names are from the total alkali-silica classification diagram for igneous rocks (see figure 2 on plate 2).

Tb **Mosida Basalt** (lower Miocene) – Medium-dark-gray, weathering to light-olive-gray and gray, porphyritic, potassic trachybasalt lava flow; phenocrysts (10% to 20%) of olivine, plagioclase, and clinopyroxene in a fine-grained groundmass (Biek and others, 2009); olivine commonly altered to iddingsite and appears as rust-colored blebs; locally vesicular to scoriaceous; locally the base is altered to a light-gray, low-density deposit with phenocrysts of altered plagioclase, appears to be alteration at the base of the lava flow or an eruption into water, it crops out only as weathered chips (see sample location GP2018-42 on plate 1, not shown on figure 2 due to alteration); mapped in the southeastern corner of the quadrangle near Goshen Pass where the unit forms resistant caps and ridges; unconformably overlies the White Knoll Member (Tsw) and breccia member (Tsb) of the Soldiers Pass Formation; vent probably located near Soldiers Pass (Biek and others, 2009); three geochemical samples in the quadrangle (see samples AR-408, GP2018-41, and GP2018-42 on figure 2 and plate 1); $^{40}Ar/^{39}Ar$ isochron age on groundmass from adjacent Allens Ranch quadrangle is 19.74 ± 0.05 Ma (McKean, 2011; Christiansen and others, 2013), this age correlates well with Mosida Basalt samples dated using $^{40}Ar/^{39}Ar$ methods by Christiansen and others (2007) that were found to be 19.47 ± 0.14 and 19.65 ± 0.17 Ma; 0 to 40 feet (0–12 m) thick in the map area; Biek and others (2009) reported a thickness in the Soldiers Pass quadrangle of 0 to 120 feet (0–35 m).

Unconformity

Soldiers Pass Formation – Consists of volcanic, lake, and hot-spring deposits, in descending order: White Knoll Member, breccia member, andesite member, Chimney Rock Pass Tuff Member, and trachydacite tuff member (Christiansen and others, 2007). Only the breccia member (Tsb), White Knoll Member (Tsw), and andesite member (Tsa) are exposed in the Goshen Pass quadrangle.

Tsb **Soldiers Pass Formation, breccia member** (lower Oligocene to upper Eocene) − Dark-gray, white, and medium-gray shoshonite lava flow; exposed mostly as distinctive, brecciated, carbonate-impregnated lava (Biek and others, 2009); locally vesicular lava flow; fine-grained with groundmass of plagioclase, olivine (typically altered), and Fe-Ti oxides (Biek and others, 2009); angular blocks and locally common pillow structures, a coarse-grained vuggy calcite surrounds the pillow structures (Christiansen and others, 2007); interfingers with and is partly overlain by the carbonate and clastic strata of the White Knoll Member (Tsw); forms ledges, slopes, rounded knobs, and boulder fields of a single clast type; mapped in the southeast corner of the quadrangle near Goshen Pass and in one isolated knob on the western side of the quadrangle (see sample RV-32 on plate 1, NW1/4 section 30, T. 7 S., R. 2 W., SLBLM); geochemically sample RV-32 is a latite and is similar to other samples of the breccia member in the area (see figure 2; Clark and others, 2012), but lacks the distinctive brecciation and is vesicular; likely formed as a shoshonitic lava flow that entered a shallow lake (Christiansen and others, 2007); source vent unknown (Biek and others, 2009); informal status due to limited lateral extent, see Christiansen and others (2007); $^{40}Ar/^{39}Ar$ isochron groundmass age from the Solders Pass quadrangle is 33.73 ± 0.65 Ma (Christiansen and others, 2007); thickness in the quadrangle ranges from 0 to 170 feet (0–50 m); Biek and others (2009) reported thickness in the Soldiers Pass quadrangle of 0 to 160 feet (0–50 m).

Tsw **Soldiers Pass Formation, White Knoll Member** (lower Oligocene to upper Eocene) − White and pale-yellowish-orange, yellowish-gray-weathering limestone with interbedded very pale orange, white, and pale-red claystone (Biek and others, 2009); bedding is laminated to medium to indistinct; locally contains thin, light-gray pyroclastic-fall beds, altered to clay, and the limestone is locally sandy; locally exhibits vertical laminae of travertine and algal laminations suggestive of spring deposits; deposited in a shallow lake over paleotopography developed on Paleogene volcanic rocks and Paleozoic strata (Biek and others, 2009); interfingers locally with the breccia member (Tsb); these generally flat-lying deposits form ledges and slopes in the southeastern corner of the quadrangle near Goshen Pass; age about 33.7 Ma from coeval breccia member (Christiansen and others, 2007); greater than 80 feet (24 m) thick in the quadrangle; Biek and others (2009) reported a thickness range in the Soldiers Pass quadrangle of 0 to 240 feet (0–75 m).

Unconformity?

Tsa **Soldiers Pass Formation, andesite member** (upper Eocene) – Medium-gray vesicular flow-layered andesitic lava with no phenocrysts (Biek and others, 2009); locally contains lithic clasts of rounded sandstone 1 to 1.5 inches (2–4 cm) in diameter; mapped in one location where only weathered cobble- to boulder-sized clasts remain of the flow (see sample GP2018-64 on plate 1, SE1/4 section 1, T. 8 S., R. 2 W., SLBLM); west of Goshen Pass the unit typically forms ledges and round hills (Biek and others, 2009); one geochemical sample (GP2018-64) in the quadrangle is an andesite and is geochemically similar to other andesite member samples in the Soldiers Pass quadrangle (see figure 2; Clark and others, 2012); source vent unknown; informal status due to limited lateral extent, see Christiansen and others (2007); $^{40}Ar/^{39}Ar$ isochron groundmass age is an imprecise 34.90 ± 4.20 Ma (Christiansen and others, 2007), whereas McKee and others (1993) reported a K-Ar age of 32.6 ± 1.0 Ma, both samples were collected from the type locality (Christiansen and others, 2007); thickness in the quadrangle is estimated to be more than 10 feet (3+ m); Biek and others (2009) reported thicknesses in the Soldiers Pass quadrangle of 0 to 40 feet (0–12 m).

Tv **Tertiary volcanic and sedimentary rocks, undifferentiated** (Miocene to lower Oligocene and upper Eocene) – Undifferentiated Mosida Basalt and Soldiers Pass Formation composed of lava, breccia, limestone, travertine, and sedimentary strata (see Christiansen and others, 2007; Biek and others, 2009); may include some unmapped Salt Lake Formation in the subsurface (Hurlow, 2004; Jordan and Sabbah, 2012); only mapped as a stacked unit and as undivided Tertiary unit on the cross section (plate 2); estimated thickness is 0 to 450 feet (0–140 m).

Major unconformity

PALEOZOIC

PENNSYLVANIAN

IPobp, IPobp?

Oquirrh Group, Butterfield Peaks Formation (Middle to Lower Pennsylvanian, Desmoinesian-Morrowan) – Interbedded limestone and calcareous sandstone intervals; limestone is medium gray and locally fossiliferous, arenaceous, cherty, and argillaceous in thin to thick beds; limestone contains locally abundant brachiopod, bryozoan, coral, and fusulinid fauna (Clark and others, 2012); diagnostic black chert weathers brown and locally occurs as spherical nodules and laterally linked masses; light-brown calcareous sandstone is thin to medium bedded and locally cross-bedded; includes some poorly exposed light-gray siltstone and mudstone interbeds (Clark and others, 2012); overall limestone dominates over calcareous sandstone; unit forms ledges and cliffs with regularly intervening slopes; corresponds to Oquirrh Formation units 2 through 5 of Disbrow (1957); age from Clark and others (2012, and references therein); lower contact with the Oquirrh Group Bridal Veil Limestone (formally West Canyon Limestone) is not exposed in the quadrangle but is described in the Thorpe Hills by Derenthal (2011); isolated knobs of the unit are exposed only at the western quadrangle boundary, one of these knobs is queried due to poor exposure, of these exposures none has an estimated incomplete thickness greater than 850 feet (260+ m); just to the west of the quadrangle in the Thorpe Hills, Clark and others (2012) reported an incomplete thickness of about 3650 feet (1110 m), top not exposed; to the north on Butterfield Peaks in the Oquirrh Mountains Tooker and Roberts (1970) reported a measured section thickness of 9072 feet (2765 m).

Not in contact (see Biek and others, 2009, and Clark and others, 2012, for bedrock units not exposed in Goshen Pass quadrangle).

MISSISSIPPIAN

Great Blue Limestone –The Great Blue Limestone has a variety of formal and informal members mapped in the nearby quadrangles and mountain ranges (see Disbrow, 1957, 1961; Morris and Lovering, 1961; Biek and others, 2009; Clark and others, 2012; McKean and others, in press). Clark and others (2012) revised the extent of the Great Blue Limestone in the southern Oquirrh and northern East Tintic Mountains. They included Great Blue Limestone Members previously mapped by Disbrow (1957, 1961) and Morris and Lovering (1961) as the Poker Knolls Limestone Member and Chiulos Shale Member of the Manning Canyon Formation. They did not map separately the Paymaster and Topliff Limestone Members of the Great Blue Limestone. In the quadrangle, the Great Blue Limestone is mapped as the following:

Mgb **Great Blue Limestone, undivided** (Upper Mississippian) – Tectonically sheared limestone, argillaceous limestone, silty limestone, and shale; locally includes silicic jasperoid breccias too small to map separately at map scale; gray to maroonish-gray fossiliferous limestone and fossil hash beds; silty orange to pinkish stringers in argillaceous limestone; forms slopes to ledges; mapped on the southern boundary of the quadrangle where the Great Blue Limestone members are indistinguishable at map scale due to tectonic deformation and alteration, likely includes Topliff Limestone and Paymaster Members; age from Morris and Lovering (1961); estimated incomplete thickness greater than 650 feet (200+ m); Clark and others (2012) provided a thickness of 1080 feet (330 m) in the Thorpe Hills and northern East Tintic Mountains for their combined Great Blue Limestone, undivided unit (Paymaster and Topliff Limestone Members); in the East Tintic Mountains Morris and Lovering (1961) reported a combined thickness of about 2500 feet (760 m) for their four members of the Great Blue Limestone.

Mgbp **Great Blue Limestone, Paymaster Member** (Upper Mississippian) – Blue-gray to medium-gray limestone, with interbedded, brown-weathering, olive-green shale and sandstone; limestone is medium to well bedded, shale is thin bedded; argillaceous limestone commonly streaked with tan and red to maroon siltstone and claystone; nodules and thin layers of chert common; locally contains fossils of crinoids, corals, bryozoans and brachiopods (Morris and Lovering, 1961); slope former; mapped in the southeastern corner of the quadrangle where distinct ledge-forming, fossiliferous beds of the Topliff Member can be distinguished from more argillaceous limestones of the Paymaster Member; lower contact mapped at the first shale or sandstone above the Topliff Member; age from Morris and Lovering (1961); estimated incomplete thickness greater than 500 feet (150+ m); 590 to 660 feet (180–200 m) thick in the Allens Ranch quadrangle (McKean and others, in press); Morris and Lovering (1961) reported a thickness of 623 feet (190 m) from Edwards Canyon in the northern East Tintic Mountains.

Mgbt **Great Blue Limestone, Topliff Member** (Upper Mississippian) – Blue-gray to medium-gray, fine- to medium-grained limestone; thin to thick bedded; locally fossiliferous with rugose corals, crinoids, bryozoans, brachiopods, and gastropods (Morris and Lovering, 1961); ledge former; mapped in the southeastern corner of the quadrangle where distinct ledge-forming, fossiliferous beds can be distinguished from more argillaceous limestones of the Paymaster Member; lower contact mapped below last ledge-forming limestone above the interbedded calcareous quartz sandstone and limestone of the Humbug Formation; age from Morris and Lovering (1961); estimated complete thickness 200 feet (60 m); 295 to 330 feet (90–100 m) thick in the Allens Ranch quadrangle (McKean and others, in press); Morris and Lovering (1961) reported a thickness of 462 feet (140 m) from Edwards Canyon and 300 feet (90 m) from Paymaster Hill in the East Tintic Mountains.

Mh **Humbug Formation** (Upper Mississippian) – Interbedded, calcareous, quartz sandstone and limestone that weathers to ledgy slopes; sandstone is light to dark brown, weathering pale yellowish brown to olive gray; medium to very thick bedded; variably calcareous or siliceous; locally with planar or low-angle cross-stratification; limestone rarely contains dark-gray chert nodules and is (1) light-gray weathering, medium dark gray, medium to thick bedded, and fine grained with local small white chert blebs, (2) dark gray, very thick bedded with small white calcite blebs, or (3) locally medium to coarse grained with sparse fossil hash (Biek and others, 2009); where not in fault contact the lower contact is gradational with the Deseret Limestone; age from Morris and Lovering (1961); only exposed in southeastern corner of quadrangle; estimated incomplete thickness greater than 600 feet (180+ m); in the Soldiers Pass quadrangle Biek and others (2009) reported a complete thickness of about 700 to 750 feet (210–230 m).

Md **Deseret Limestone** (Upper to Lower Mississippian) − Medium-dark-gray, variably sandy and fossiliferous limestone; medium to very thick bedded; contains distinctive white calcite nodules and blebs and local to common brown-weathering chert nodules and brown-weathering bands (case-hardened surfaces); fossils include rugose corals, uncommon brachiopods, crinoids, bryozoans, and fossil hash; locally contains few thin calcareous sandstone beds; the lower part of the formation is not exposed in the quadrangle, but regionally is marked by slope-forming, light-red, phosphatic shale and thin-bedded cherty limestone of the Delle Phosphatic Member; in the East Tintic mining district, Morris and Lovering (1961) subdivided the Deseret above the Delle into the Tetro Member and Uncle Joe Member based on lithology, but I did not map these members separately due to lack of outcrops; age from Morris and Lovering (1961) and Sandberg and Gutschick (1984); only exposed as a faulted block in the southeastern corner of the quadrangle; estimated incomplete thickness greater than 200 feet (60+ m); in the Soldiers Pass quadrangle Biek and others (2009) reported a complete thickness of about 700 to 750 feet (210–230 m) in the Lake Mountains and about 1000 feet (300 m) in the Mosida Hills.

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