UTAH GEOLOGICAL SURVEY
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Plate 1
Utah Geological Survey Map 294DM
Geologic Map of the Rush Valley 30' x 60' Quadrangle

GEOLOGIC MAP OF THE RUSH VALLEY 30' X 60' QUADRANGLE, TOOELE, UTAH, AND SALT LAKE COUNTIES, UTAH

by

Donald L. Clark[1], Stefan M. Kirby[1], and Charles G. Oviatt[2]

2023

[1]Utah Geological Survey, Salt Lake City, Utah
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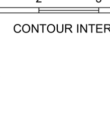
SCALE 1:62,500

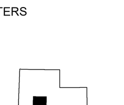
1 0.5 0 1 2 3 4 MILES

1 0.5 0 1 2 3 4 5 6 KILOMETERS

CONTOUR INTERVAL 50 METERS



APPROXIMATE MEAN DECLINATION, 2023



MAP LOCATION

This geologic map was funded by the Utah Geological Survey and the U.S. Geological Survey, National Cooperative Geologic Mapping Program through USGS STATEMAP award numbers 08HQAG0096 (2008-09), G09AC00152 (2009-10), G10AC00386 (2010-11), G12AC20226 (2012-13), and G20AC00244 (2020-21). The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government. This map and explanatory information are submitted for publication with the understanding that the U.S. Government is authorized to reproduce and distribute reprints for governmental use.

Base from U.S. Geological Survey
Rush Valley 30' x 60' Quadrangle (1979)
Projection: UTM Zone 12
Datum: NAD 1927

Slope-enhanced shaded relief derived from 10-meter NED

Mapping by authors 2008-2013, 2019-2020
Project Manager: Robert F. Biek
Program Manager: Stefan M. Kirby
GIS and Cartography: Kent D. Brown, Donald L. Clark, Stefan M. Kirby, Basia Matyjasik, and Lori Steadman

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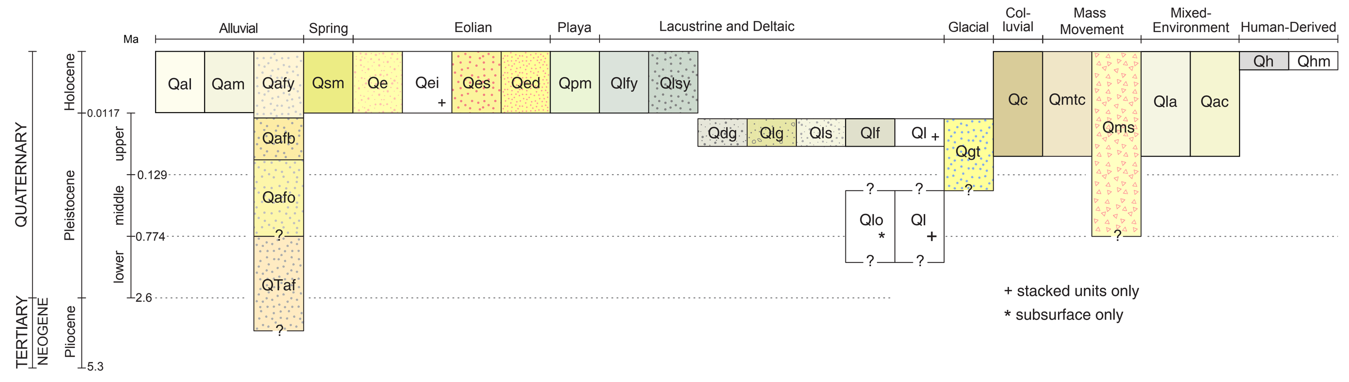
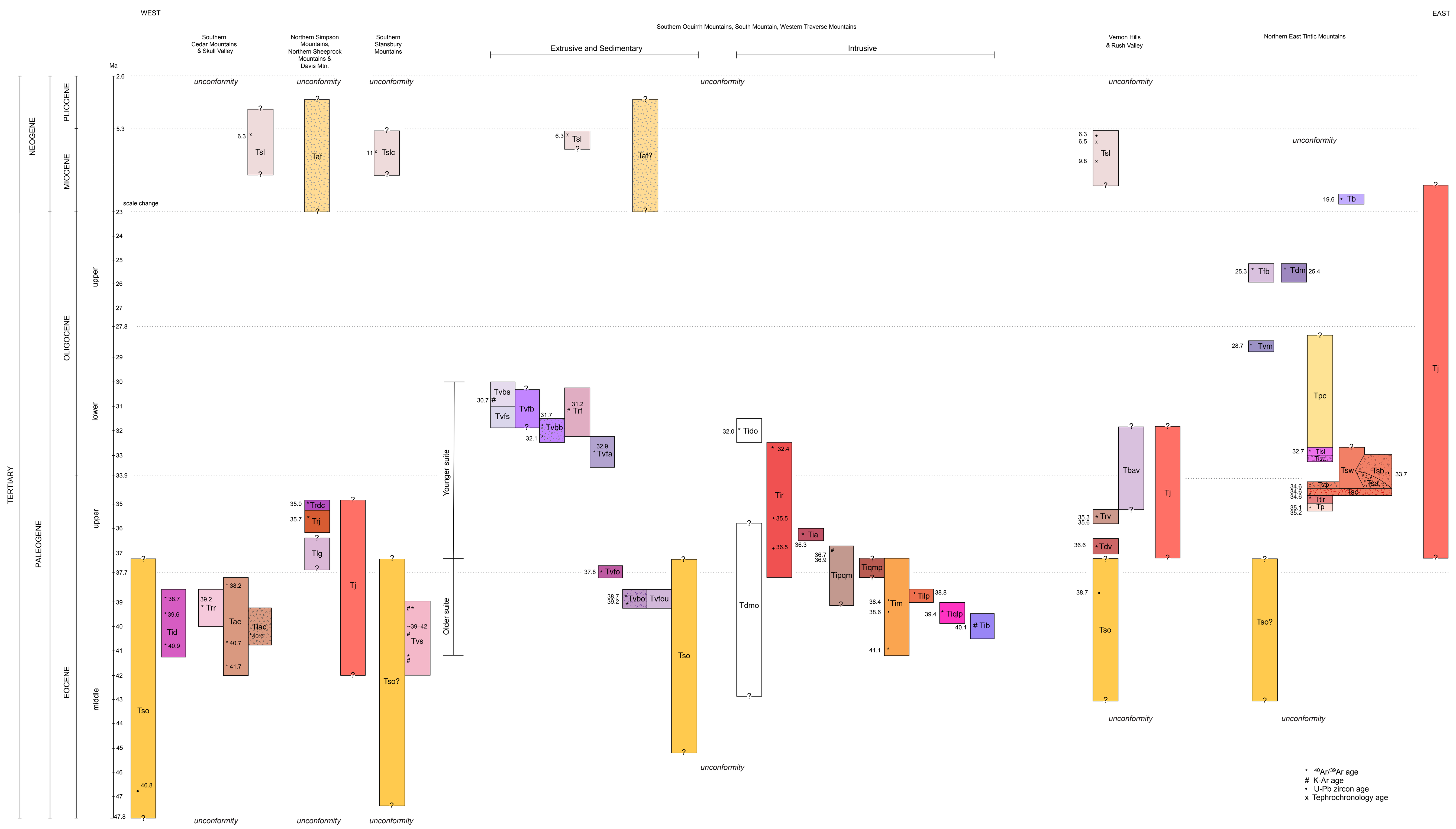
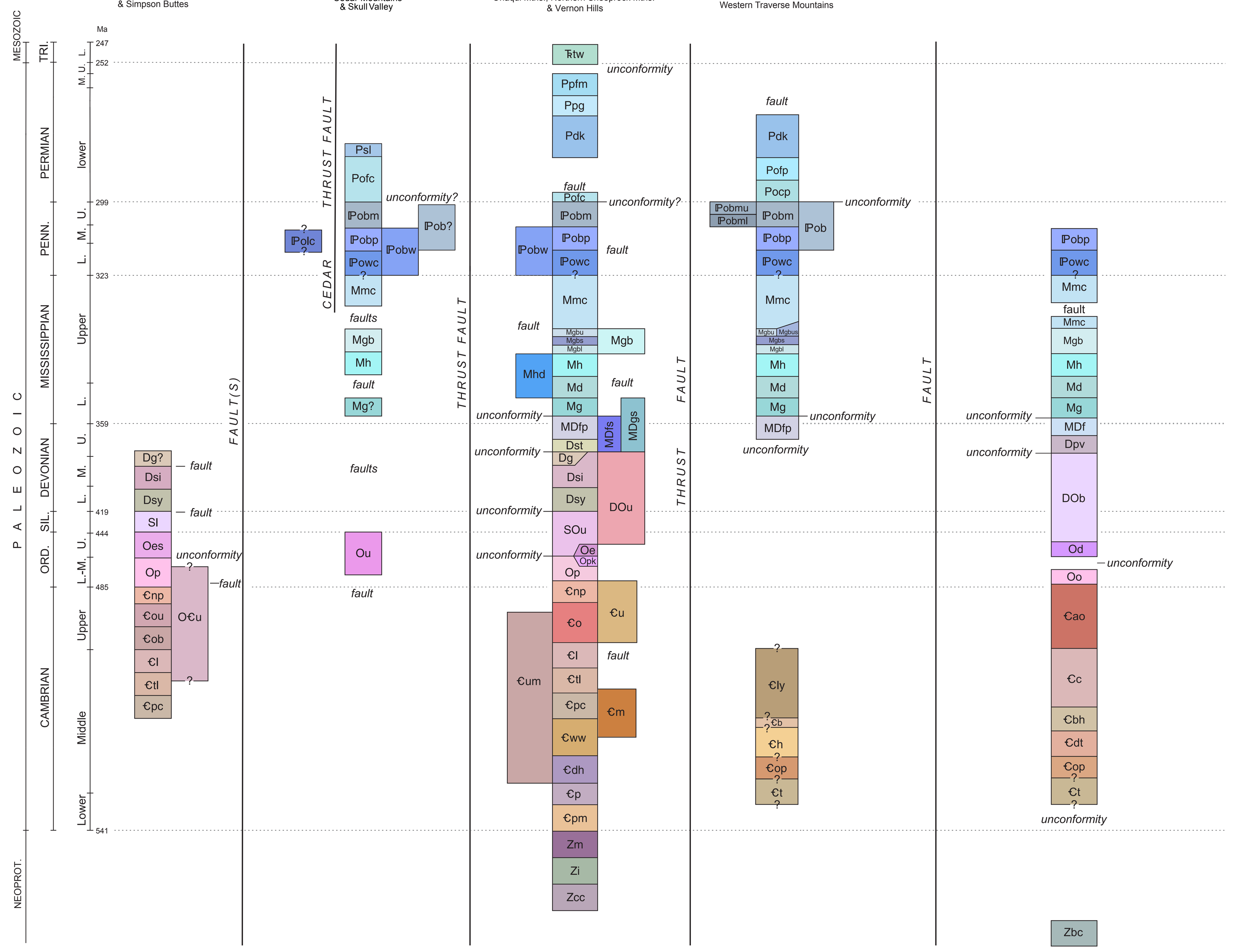
CORRELATION OF QUATERNARY–LATE TERTIARY (NEOGENE) GEOLOGIC UNITS



CORRELATION OF TERTIARY (NEOGENE-PALEOGENE) GEOLOGIC UNITS



CORRELATION OF MESOZOIC, PALEOZOIC, AND NEOPROTEROZOIC GEOLOGIC UNITS



Boundary ages from International Chronostratigraphic Chart v2020/03

GEOLOGIC UNITS

- Qal — Stream alluvium
- Qam — Alluvial mud
- Qafy — Younger fan alluvium, post-Lake Bonneville
- Qafb — Fan alluvium, graded to Lake Bonneville
- Qafo — Older fan alluvium, pre-Lake Bonneville
- QTaf — High-level fan alluvium
- Taf — Tertiary fan alluvium
- Qsm — Spring and marsh deposits
- Qe — Eolian deposits, undivided
- Qes — Eolian sheet sand deposits
- Qed — Eolian dune sand deposits
- Qpm — Playa mud
- Qlfy — Younger lacustrine fine-grained deposits
- Qlsy — Younger lacustrine sand deposits
- Qdg — Deltaic gravel, Lake Bonneville
- Qlg — Lacustrine gravel, Lake Bonneville
- Qls — Lacustrine sand, Lake Bonneville
- Qlf — Lacustrine fine-grained deposits, Lake Bonneville
- Qlo — Older lacustrine deposits [subsurface only]
- Qgt — Glacial till
- Qc — Colluvium
- Qmtc — Talus and colluvium
- Qms — Landslide deposits
- Qla — Lacustrine and alluvial deposits, undivided
- Qac — Alluvial and colluvial deposits, undivided
- Qh — Human disturbance
- Qhm — Mine dumps [see symbols]
- Qei/Qal — Eolian silt over stream alluvium
- Qei/Qlf — Eolian silt over lacustrine fine-grained deposits
- Qes/Qafy — Eolian sheet sand over younger fan alluvium
- Qes/Qafo — Eolian sheet sand over older fan alluvium
- Qes/Qlf — Eolian sheet sand over lacustrine fine-grained deposits
- Qes/Qla — Eolian sheet sand over lacustrine and alluvial deposits
- Qed/Qlf — Eolian dune sand over lacustrine fine-grained deposits
- Qed/Qla — Eolian dune sand over lacustrine and alluvial deposits
- Qed/Tac — Eolian dune sand over andesitic and dacitic rocks of southern Cedar Mountains
- Qe/Qlf — Eolian deposits over lacustrine fine-grained deposits
- Qpm/Ql — Playa mud over undivided lacustrine deposits over older lacustrine deposits
- Qlf/Qls — Lacustrine fine-grained deposits over lacustrine sand deposits
- Ql/Tv — Lacustrine deposits over undivided Tertiary volcanic rocks
- Qlg/rx — Lacustrine gravel over undivided bedrock
- QTaf/Tslc — High-level fan alluvium over Salt Lake Fm., conglomerate lithosome
- Tj — Jasperoid
- Tsl — Salt Lake Formation
- Tso — Older Tertiary strata
- Trdc — Rhyodacite of Cherry Springs
- Trj — Rhyolite of Judd Creek
- Tlg — Latite of Government Creek
- Trr — Rhyolite of Rydalch Canyon area
- Tid — Dacitic intrusions of Little Granite Mountain and White Rock
- Tac — Andesitic and dacitic rocks of southern Cedar Mountains
- Tiac — Andesitic intrusions of southern Cedar Mountains
- Tvs — Rhyolitic to andesitic volcanic rocks of Stansbury Mountains
- Tvbs — Younger volcanic breccia
- Tvfs — Younger lava flows
- Tvfb — Intermediate lava flows of Black Ridge
- Tvbb — Block-and-ash flows and lahars of Black Ridge
- Trf — Rhyolitic lava flows of Tickville Gulch
- Tvfa — Basaltic andesite lava flow
- Tido — Dacitic dike [see symbols]
- Tir — Rhyolitic intrusions
- Tia — Andesitic intrusion
- Tvfo — Nepheline minette and shoshonite lava flows
- Tvfou — Older intermediate lava flows
- Tvbo — Older block-and-ash flows and lahars
- Tdmo — Mafic dikes [see symbols]
- Tipqm — Porphyritic quartz monzonite intrusions
- Tiqmp — Quartz monzonite porphyry intrusion
- Tim — Monzonite intrusions
- Tilp — Latite to dacite porphyry sills and dikes
- Tiqlp — Quartz latite porphyry dikes and sills
- Tib — Basalt sill
- Tbav — Basaltic andesite
- Trv — Rhyolite
- Tdv — Dacite
- Tb — Mosida Basalt
- Tfb — Shoshonite of Broad Canyon
- Tdm — Mafic dikes
- Tvm — Minette of Black Rock Canyon
- Tpc — Pinyon Creek Conglomerate
- Tlsl — Laguna Springs Volcanic Group, lava flow unit
- Tlsa — Laguna Springs Volcanic Group, tuff unit
- Tsw — Soldiers Pass Formation, White Knoll Member
- Tsb — Soldiers Pass Formation, breccia member
- Tsa — Soldiers Pass Formation, andesite member
- Tstp — Soldiers Pass Formation, tuff of Twelvemile Pass member
- Tsc — Soldiers Pass Formation, Chimney Rock Pass Tuff Member
- Ttlr — Tintic Mountain Volcanic Group, Latite Ridge Latite
- Tp — Packard Quartz Latite, undivided
- T̶Rtw — Thaynes Formation and Woodside Formation, undivided
- Ppfm — Park City Formation, Franson Member and Phosphoria Formation, Meade Peak Member, undivided
- Ppg — Park City Formation, Grandeur Member
- Psl — Permian sandstone, limestone and dolomite
- Pdk — Diamond Creek Sandstone and Kirkman Formation, undivided
- Pofc — Oquirrh Group, Freeman Peak and Curry Peak Formations, undivided
- Pofp — Oquirrh Group, Freeman Peak Formation
- Pocp — Oquirrh Group, Curry Peak Formation
- IPob — Oquirrh Group, Bingham Mine and Butterfield Peaks Formations, undivided
- IPobm — Oquirrh Group, Bingham Mine Formation, undivided
- IPobmu — Oquirrh Group, Bingham Mine Formation, upper member
- IPobml — Oquirrh Group, Bingham Mine Formation, lower member
- IPobw — Oquirrh Group, Butterfield Peaks Formation and West Canyon Limestone, undivided
- IPobp — Oquirrh Group, Butterfield Peaks Formation
- IPowc — Oquirrh Group, West Canyon Limestone
- IPolc — Oquirrh Group, limestone unit, Cedar thrust sheet
- Mmc — Manning Canyon Formation
- Mgb — Great Blue Limestone, undivided
- Mgbus — Great Blue Limestone, upper limestone and shale member
- Mgbu — Great Blue Limestone, upper limestone member
- Mgbs — Great Blue Limestone, shale member
- Mgbl — Great Blue Limestone, lower limestone member
- Mhd? — Humbug Formation and Deseret Limestone, undivided?
- Mh — Humbug Formation
- Md — Deseret Limestone
- MDgs — Gardison Limestone, Fitchville Formation, Pinyon Peak Limestone, Stansbury Formation, undivided
- Mg — Gardison Limestone
- MDfs — Fitchville Formation, Pinyon Peak Limestone, Stansbury Formation, undivided
- MDfp — Fitchville Formation and Pinyon Peak Limestone, undivided
- Dst — Stansbury Formation
- DOu — Guilmette Formation?, Simonson, Sevy, Laketown, and Ely Springs Dolomites, undivided
- Dg — Guilmette Formation
- Dsi — Simonson Dolomite
- Dsy — Sevy Dolomite
- SOu — Laketown Dolomite and Ely Springs Dolomite, undivided
- Sl — Laketown Dolomite
- Ou — Ordovician strata, undivided
- Oes — Ely Springs Dolomite
- O€u — Lower Ordovician and Upper-Middle Cambrian strata, undivided
- Oe — Eureka Quartzite
- Opk — Pogonip Group, Kanosh Shale
- Op — Pogonip Group, undivided
- €u — Upper Cambrian strata, undivided
- €um — Upper and Middle Cambrian strata, undivided
- €np — Notch Peak Formation
- €o — Orr Formation
- €ou — Orr Formation, upper part
- €ob — Orr Formation, Big Horse Limestone Member
- €l — Lamb Dolomite
- €m — Middle Cambrian strata, undivided
- €tl — Trippe Limestone
- €pc — Pierson Cove Formation
- €ww — Wheeler Formation, Swasey Limestone, Whirlwind Formation, undivided
- €dh — Dome Limestone, Chisholm Formation, Howell Limestone, undivided
- €p — Pioche Formation
- €pm — Prospect Mountain Quartzite
- Zm — Mutual Formation
- Zi — Inkom Formation
- Zcc — Caddy Canyon Quartzite

Cambrian Rock Units of Southern Oquirrh Mountains

- €ly — Lynch Dolomite
- €b — Bowman Limestone
- €h — Hartmann Limestone
- €op — Ophir Formation
- €t — Tintic Quartzite

Mississippian to Neoproterozoic Rock Units of Northern East Tintic Mountains

- MDf — Fitchville Formation
- Dpv — Pinyon Peak Limestone and Victoria Formation, undivided
- DOb — Bluebell Dolomite
- Od — Ordovician dolomite
- Oo — Opohonga Limestone
- €ao — Ajax Dolomite and Opex Formation, undivided
- €c — Cole Canyon Dolomite
- €bh — Bluebird Dolomite and Herkimer Limestone, undivided
- €dt — Dagmar Dolomite and Teutonic Limestone, undivided
- Zbc — Big Cottonwood Formation
- Water

Note - Repeated queried labels not included here, see Description of Map Units in booklet

GEOLOGIC SYMBOLS

- Contact – Angled where scratch
- Geomorphic surface (Stockton Bar and Cedar Valley Lake outlet)
- High-angle normal fault – Dashed where approximately located, dotted where concealed, queried where uncertain; bar and ball on down-thrown side
- Normal fault, geophysical, gravity – Located from gravity data, concealed and very approximately located; bar and ball on downthrown side
- Strike-slip or oblique-slip fault – Dashed where approximately located, dotted where concealed; arrows and bar and ball indicate relative displacement; T for toward, A for away on cross sections
- Fault, unknown geometry and offset – Dashed where approximately located, dotted where concealed; queried where uncertain
- Thrust fault – Dashed where inferred, dotted where concealed; queried where uncertain; teeth on hanging wall; bar and ball where later normal offset
- Low-angle fault – Dotted where concealed; boxes on hanging wall
- Low-angle normal fault – Dashed where approximately located, dotted where concealed; boxes on hanging wall
- Lineament – From aerial photo interpretation
- Igneous dike (map units Tiqlp, Tdmo, Tipqm, and Tir)
- Igneous dike (map unit Tido)
- Axial trace of anticline – Dashed where approximately located, dotted where concealed; arrow shows plunge
- Axial trace of asymmetric anticline - Dashed where approximately located, dotted where concealed; arrow shows plunge; double arrows on steep limb
- Axial trace of overturned anticline – Dashed where approximately located, dotted where concealed; queried where uncertain; arrow shows plunge
- Axial trace of syncline – Dashed where approximately located, dotted where concealed; arrow shows plunge
- Axial trace of overturned syncline – Dashed where approximately located, dotted where concealed; arrow shows plunge
- Axial trace of monocline - Dotted where concealed
- A——A′ Line of cross section
- Unconformity (on cross sections)
- Water boundary

Major shorelines of the Bonneville lake cycle and related lakes (see table 2) –
- B — Bonneville shoreline
- P — Provo shoreline
- Sh — Shambip shoreline (regressional)
- Sm — Smelter shoreline (regressional)
- S — Stansbury shoreline
- CV — Cedar Valley shoreline (undetermined)

- Lake Bonneville crest of barrier ridge or delta ridge
- Delta distributary channel crest (on map unit Qlf/Qls in Skull Valley)
- Glacial cirque headwall
- Nivation hollow headwall and adjacent ridge crests
- H — Holocene shoreline of Rush Lake

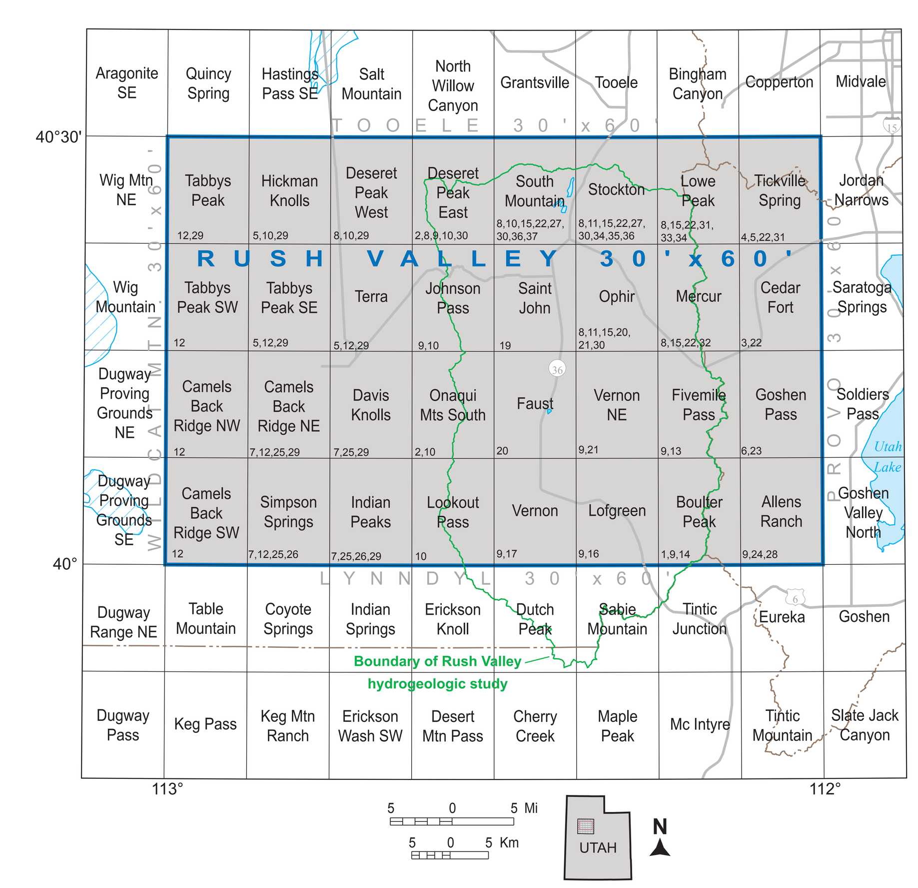
Strike and dip of bedding (black-this study and six Kirby 7.5′ quadrangles, red-prior mapping; refer to index to mapping sources) –
- 20 Inclined
- 30 Inclined approximate, approximate dip included where known
- Inclined, approximate, photo-interpreted
- Vertical
- 50 Overturned

- Volcanic foliation, inclined
- Spring
- Sand and gravel pit
- Mine or quarry
- Adit
- Shaft

Drill holes/wells (see table 1) –
- Water well
- Drill hole
- Oil/Gas well, dry hole
- Oil/Gas well, abandoned

- Tephrochronology sample (see table 4)
- U-Pb zircon age sample (see table 5)
- Geochemical sample (see table 6)
- Geochemical/radiometric age samples (see tables 6, 7)
- Radiometric age sample (see table 7)
- Fossil age sample (see table 8)
- Palynology age sample (see table 9)
- Qei/Qlf Stacked unit – Indicates thin cover of the first unit overlying the second unit
- Areas of mine waste rock (Bingham mine)

Gravity data (see GIS data) –
- Points/station
- -170 Contour lines
- New Quaternary faults (see GIS data)



Index map showing primary sources of geologic mapping, 7.5′ quadrangles, 30′ x 60′ quadrangles, and boundary of Rush Valley hydrogeologic study (Gardner and Kirby, 2011).

1. Allen (2012)
2. Armin and Moore (1981)
3. Biek (2004)
4. Biek and others (2005)
5. Clark, D.L. (UGS), 2008-2009, photogeologic and limited field mapping
6. Clark, D.L. (UGS), 2009-2010, photogeologic and limited field mapping
7. Clark, D.L. (UGS), 2010-2011, photogeologic and limited field mapping
8. Clark, D.L. and Kirby, S.M. (UGS), 2008-2009, photogeologic and limited field mapping
9. Clark, D.L. and Kirby, S.M. (UGS), 2009-2010, photogeologic and limited field mapping
10. Clark, D.L. and Kirby, S.M. (UGS), Oviatt (KSU), 2010-2011, photogeologic and limited field mapping
11. Clark and others (2015)
12. Clark and others (2016)
13. Disbrow (1957)
14. Disbrow (1961)
15. Gillully (1932)
16. Kirby (2010a)
17. Kirby (2010b)
18. Kirby (2012)
19. Kirby (2013a)
20. Kirby (2013b)
21. Kirby (2013c)
22. Laes and others (1997)
23. McKean (2020)
24. McKean (2011), McKean and others (2020)
25. Moore and Sorensen (1977)
26. Morris and Kopf (1986)
27. Nelson and Jewell (2009), Nelson (2012)
28. Proctor (1985)
29. Sack (1993)
30. Solomon (1993)
31. Swenson and Kennecott staff (1991)
32. Tooker (1987)
33. Tooker (1992)
34. Tooker and Roberts (1988)
35. Tooker and Roberts (1992)
36. Tooker and Roberts (1998)
37. Welsh and James (1998)

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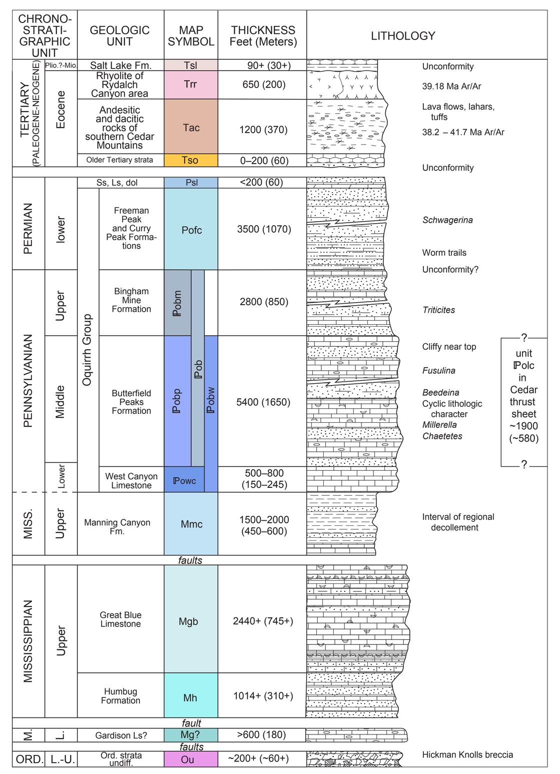
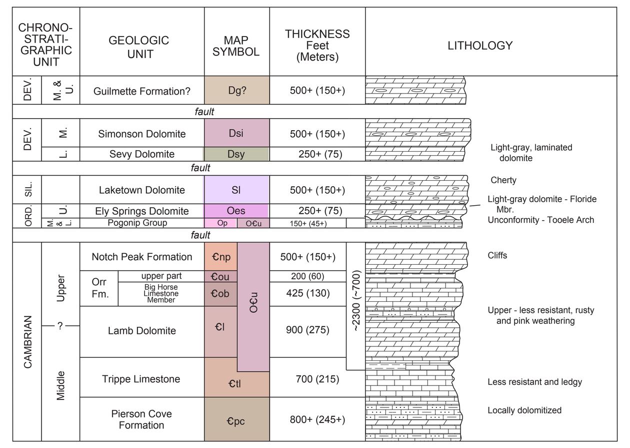
LITHOLOGIC COLUMN

Southern Cedar Mountains, Skull Valley



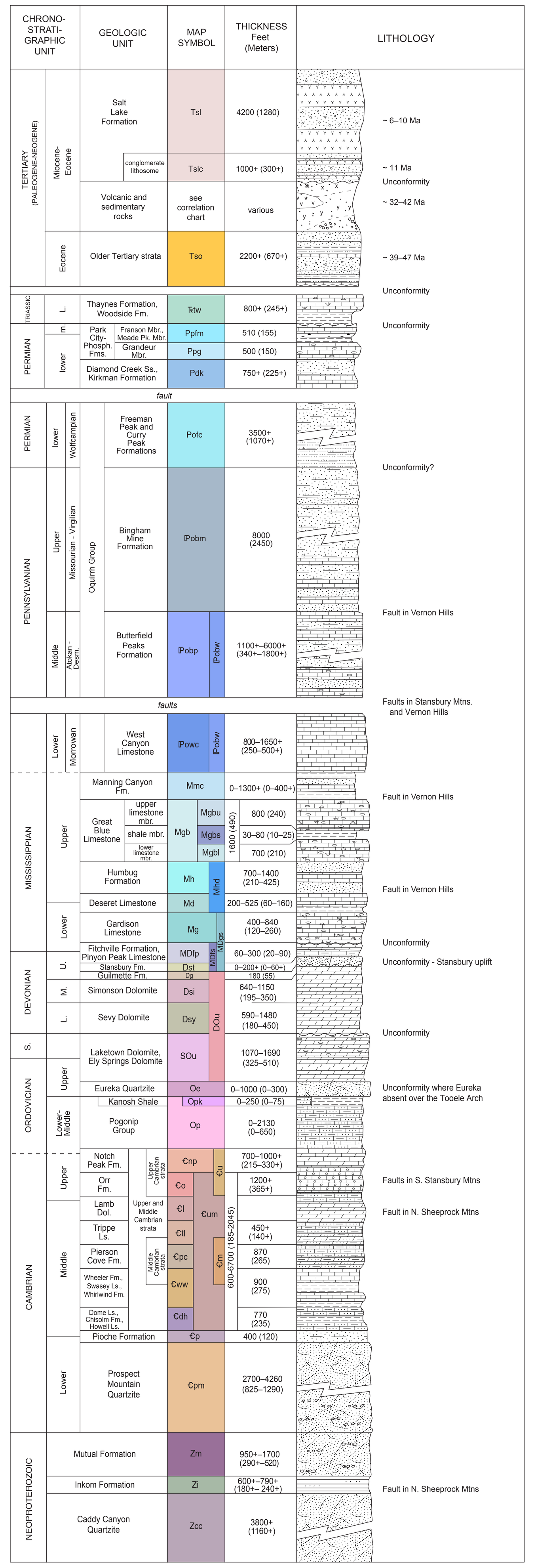
LITHOLOGIC COLUMN

Camels Back Ridge and Simpson Buttes



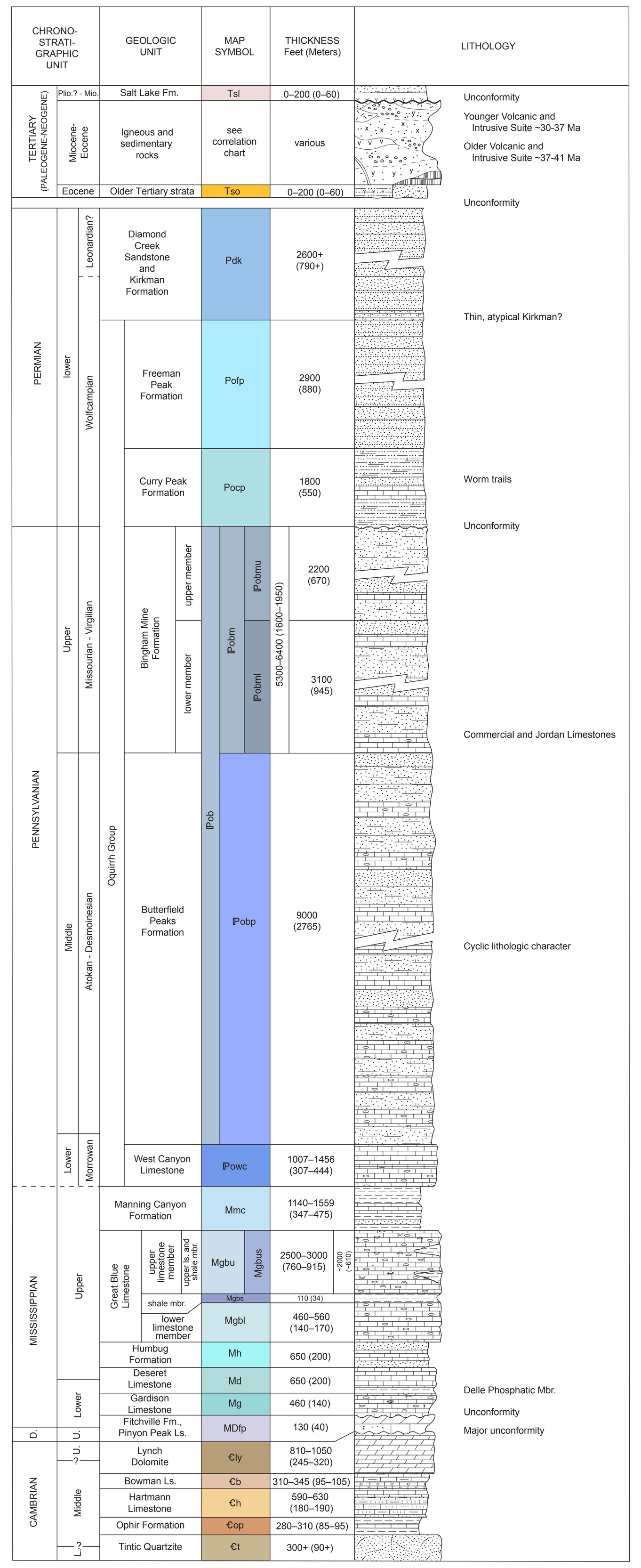
LITHOLOGIC COLUMN

Davis and Little Davis Mountains, Northern Simpson Mountains, Southern Stansbury Mountains, Onaqui Mountains, Northern Sheeprock Mountains, Vernon Hills



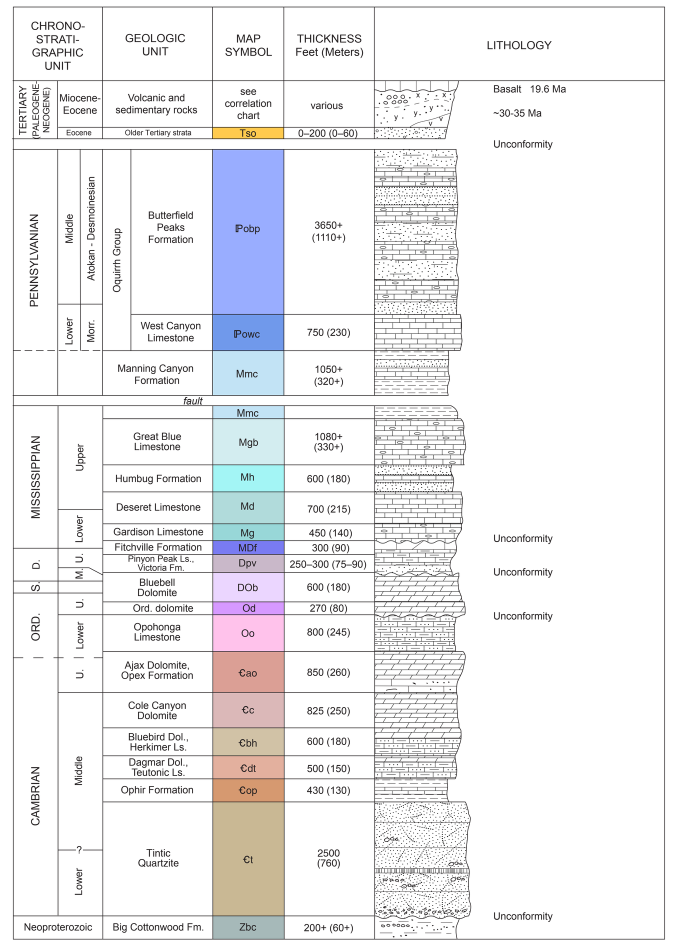
LITHOLOGIC COLUMN

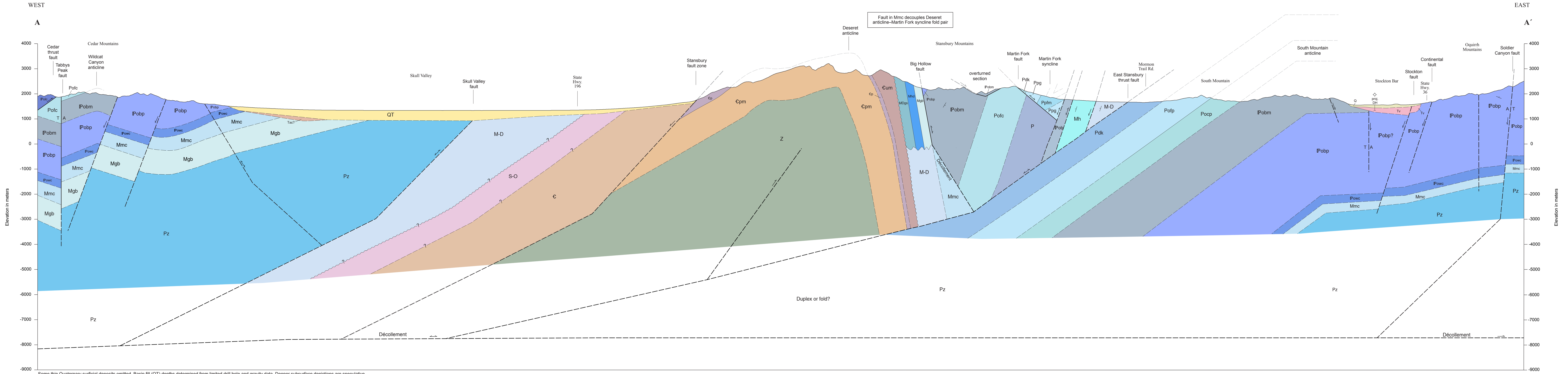
Southern Oquirrh Mountains, South Mountain, Western Traverse Mountains

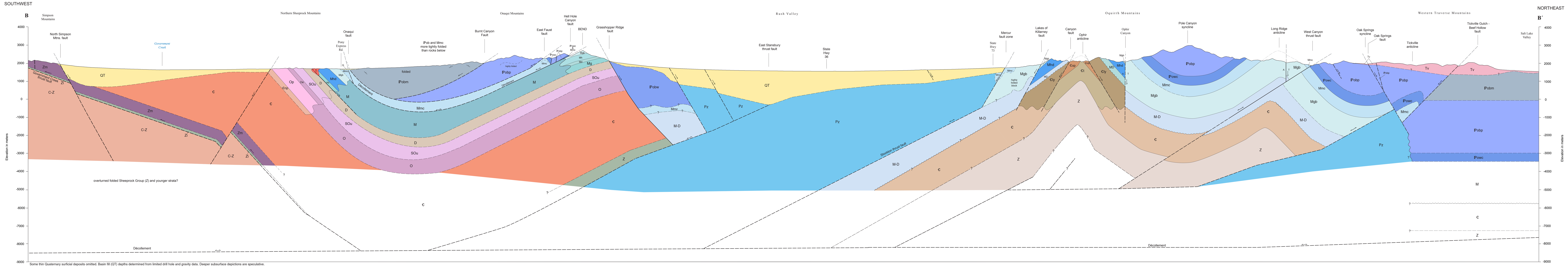


LITHOLOGIC COLUMN

Thorpe Hills and Northern East Tintic Mountains







GEOLOGIC MAP OF THE RUSH VALLEY 30' X 60' QUADRANGLE, TOOELE, UTAH, AND SALT LAKE COUNTIES, UTAH

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2023

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by Donald L. Clark [1], Stefan M. Kirby [1], and Charles G. Oviatt [2]

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[2] Emeritus, Department of Geology, Kansas State University, Manhattan, Kansas

Cover photo: *View across southern Rush Valley of the northern Sheeprock Mountains. Photo by Stefan Kirby.*

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MAP 294DM
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UTAH DEPARTMENT OF NATURAL RESOURCES
2023

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CONTENTS

FIGURES

PLATES

GEOLOGIC MAP OF THE RUSH VALLEY 30' X 60' QUADRANGLE, TOOELE, UTAH, AND SALT LAKE COUNTIES, UTAH

by Donald L. Clark, Stefan M. Kirby, and Charles G. Oviatt

ABSTRACT

The Rush Valley 30' x 60' quadrangle extends southwest and west from the greater Salt Lake City–Provo metropolitan area with land use varied between public, military, Indian reservation, and private. This 1:62,500-scale geologic map will aid the proper management of land, water, and other resources. The map area lies within the eastern Basin and Range Province. Mountain ranges are composed of unexposed basement rocks overlain by exposed Neoproterozoic through Triassic rocks that are about 10.4 miles (16.8 km) thick, and by numerous Tertiary sedimentary and volcanic units (~47 to 20 Ma). The intervening valleys include bedrock covered with Miocene-Pliocene? rocks (~11 to 4 Ma) and Neogene-Quaternary surficial deposits. The map area is on the southern flank of the Uinta-Tooele structural zone. This area is in the Charleston-Nebo (Provo) salient of the Sevier fold-thrust belt and some thrust faults are exposed, but the overall Sevier belt geometry is obscured by extensive Cenozoic cover and later faulting. Following Sevier deformation, calk-alkaline volcanism occurred from several Paleogene volcanic centers (42 to 25 Ma). Extensional tectonism created the distinctive basin and range topography from about 20 Ma to the present. Early extensional basin fill includes Miocene sedimentary and volcanic rocks followed by Pliocene-Holocene surficial deposits primarily from lacustrine and alluvial depositional environments. Valley areas were covered by late Pleistocene Lake Bonneville, and deposits are associated with three levels of regional shorelines. Normal faults cut the ranges and are known to bound some valley margins where not concealed. Although deep drill hole data are relatively sparse, gravity data were used to help constrain basin geometries.

INTRODUCTION

The Rush Valley 30' x 60' quadrangle is located southwest of Salt Lake City, in Tooele, Utah, and Salt Lake Counties, northwest Utah. The quadrangle is within the eastern Basin and Range Province and includes several mainly north-south-trending ranges and intervening valleys (plates 1, 2, 3; figure 1). The map area is sparsely populated and includes the towns of Dugway, Stockton, Vernon, Fairfield, Cedar Fort, and Eagle Mountain, but parts of Tooele, Rush, and Cedar Valleys are rapidly urbanizing. Land use is varied between public, military, Indian reservation, and private. Public lands are administered by the U.S. Bureau of Land Management (including the Cedar Mountains Wilderness), the U.S. Forest Service (Uinta-Wasatch-Cache National Forest including Deseret Peak Wilderness), and the State of Utah (SITLA–School and Institutional Trust Lands Administration). Military installations include parts of Dugway Proving Ground (DPG), Tooele Army Depot (TAD North and South areas), and Camp Williams Military Reservation (Utah National Guard). The TAD South area (a.k.a. Deseret Chemical Depot) was closed in 2013. A Goshute Indian reservation is in Skull Valley. Private lands are mostly in the eastern half of the quadrangle.

The impetus for this mapping was two-fold: (1) a joint U.S. Geological Survey (USGS) and Utah Geological Survey (UGS) hydrogeologic study in Rush Valley conducted on behalf of the Utah Division of Water Resources (Gardner and Kirby, 2011), and (2) the need to complete additional intermediate-scale geologic mapping in northwestern Utah (see Willis, 2017). Other key groundwater studies were conducted in Cedar Valley (Hurlow, 2004; Jordan and Sabbah, 2013; Jordan, 2013). The map area contains other significant economic resources including metals mining districts (Bingham, Stockton, Ophir, Mercur, East Tintic), industrial mineral localities (sand and gravel, limestone, clay, volcanic ash), and other potential or undeveloped resources (see, for example, Stein and others, 1989; Tripp and others, 1989). Our geologic mapping also aided environmental and hydrogeologic studies at DPG and TAD. In addition, our mapping connects with recent mapping projects on the west (DPG area, Clark and others, 2016), east (Provo 30' x 60' quadrangle, Constenius and others, 2011, in preparation), north (Tooele 30' x 60' quadrangle, Clark and others, 2020b), and northwest (Bonneville Salt Flats 30' x 60' quadrangle, Clark and others, 2020a). Older adjacent mapping to the south is by Pampeyan (1989, 2005). We benefitted from the prior regional-scale (1:250,000) geologic maps of this area by Stokes (1963) and Moore and Sorensen (1979).

This geologic map was compiled and modified from several sources. The primary mapping sources are indicated in the map explanation (plate 2), but numerous other sources were evaluated that are referenced throughout the text. The main sources include the eastern part of the DPG area map, a map of Skull Valley, eleven 7.5' quadrangles in the eastern half of the quadrangle, and several maps of the southern Oquirrh Mountains. Kirby conducted detailed mapping in six of the 7.5' quadrangles covering Rush Valley in conjunction with the USGS groundwater framework study. For intervening areas, we revised prior mapping using aerial photograph interpretation and intermediate-scale geologic mapping in the field. Oviatt substantially contributed to the DPG area map and assisted with mapping of Quaternary surficial deposits in the remainder of the map area. We collected field data with recreational-grade Global Positioning System (GPS) devices and geologic-grade compasses. We mapped on a patchwork of stereo aerial photographs (U.S. Department of Agriculture NAIP, U.S. Forest Service, and U.S. Bureau of Land Management, various scales and years) and digital orthophotographs, and compiled data in CAD (Computer Aided Design) and GIS (geographic information system) software. Spring and gravel pit, and selected mine, adit, and quarry data were taken from topographic basemaps. Kent Brown (UGS) managed the GIS data over the project's entirety. The mapping was conducted over three years (2008–09, 2009–10, 2010–11), with interim (progress report) geologic maps prepared each year (UGS Open-File Reports 555, 568, and 593). We presented a poster of the map at the May 2011 Geological Society of America meeting in Logan, Utah (Kirby and Clark, 2011). We conducted a field review of the map area October 18–19, 2011. We submitted a STATEMAP Contract Deliverable of the map and GIS data to the USGS in September 2013. Clark's other mapping priorities in northwest Utah led to delays in final map publication. This map and GIS data supersedes the open-file reports and contract deliverable. The geology is intended for use at 1:62,500 scale.

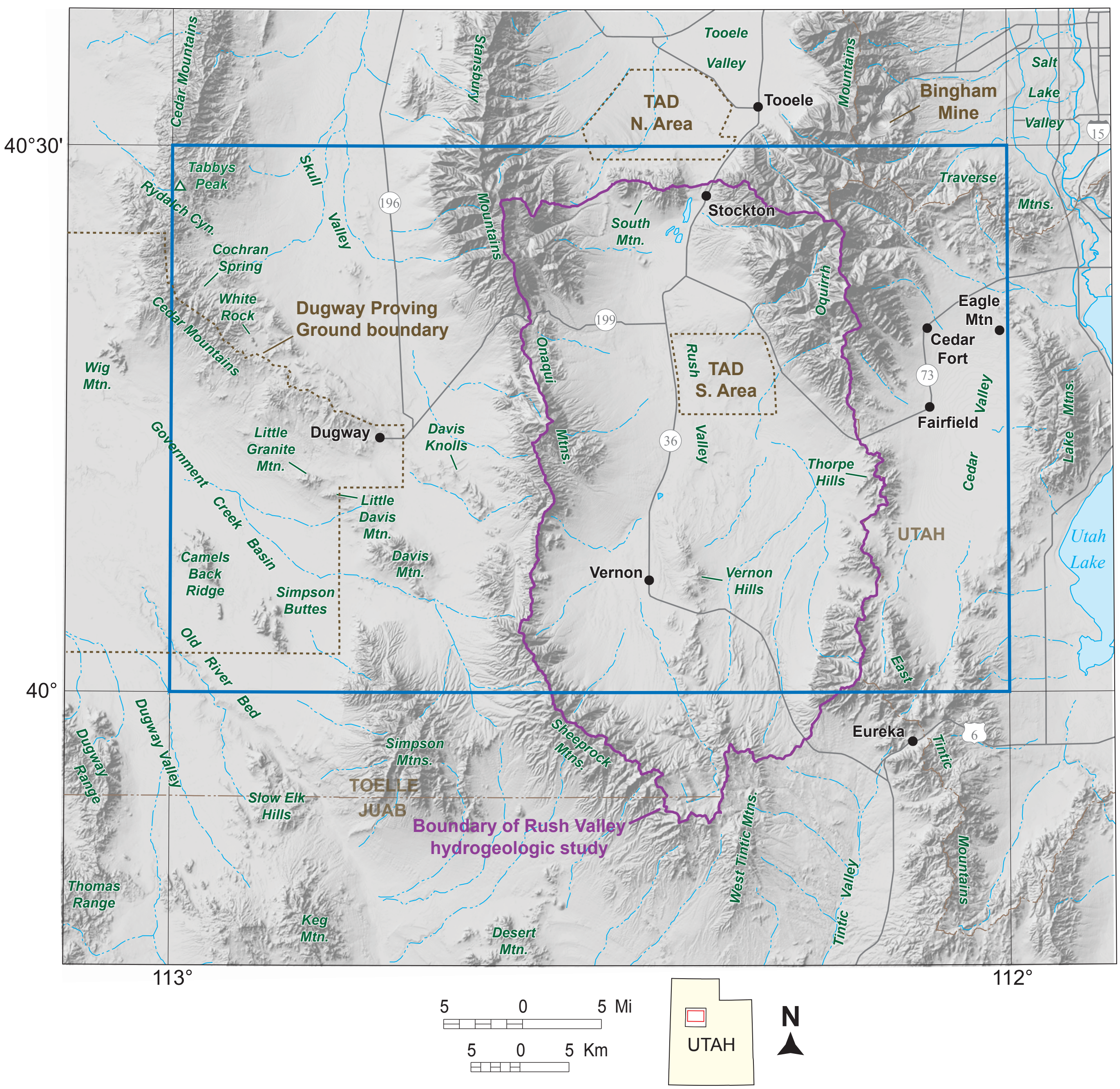


Figure 1. Primary geographic features in the Rush Valley 30' x 60' quadrangle (blue rectangle), and hydrogeologic study area (Gardner and Kirby, 2011). TAD is the Tooele Army Depot.

GEOLOGIC OVERVIEW

The quadrangle contains exposed rocks from late Precambrian (Neoproterozoic) to Neogene (Miocene) age that are mantled by late Tertiary and Quaternary surficial deposits. Although no basement rocks are exposed here, rocks of the Mojave and Yavapai provinces were accreted onto the older continental core consisting of the Grouse Creek block, Farmington zone, and Wyoming province about 1.7 billion years ago, presumably along an east-west-trending suture zone near the latitude of Salt Lake City and near the northern margin of the map area (Yonkee and others, 2014; see also Willis, 2021).

Sedimentary rocks from Neoproterozoic through Triassic age crop out in the ranges and cumulatively are roughly 55,000 feet (10.4 mi, 16.8 km) thick. These rocks were deposited over a span of about 500 million years (~770 to 247 Ma), initially in basins and rifting environments (Neoproterozoic to Early Cambrian), followed by largely marine environments along a subsiding passive margin (miogeocline) west of the Wasatch hingeline (Stokes, 1986; Hintze and Kowallis, 2009; Yonkee and Weil, 2011). Mississippian to Permian strata were deposited in the Oquirrh basin located between the Antler orogenic belt on the west and Ancestral Rocky Mountains on the east (Jordan and Douglass, 1980; Hintze and Kowallis, 2009). Paleozoic strata were affected by tectonic features coincident with reactivation of the basement suture zone (this suture zone is known by several names; we call it the Uinta-Tooele structural zone [Clark, 2020]). This recurring tectonic reactivation included the Ordovician Tooele arch (Webb, 1958; Hintze, 1959), Devonian Stansbury uplift (Rigby, 1959a), Uinta-Cottonwood arch (Tooker, 1983, 1999; Bradley and Bruhn, 1988; Presnell, 1997; Paulsen and Marshak, 1999), and aligned Tertiary igneous rocks and mineralization (John, 1989; Rowley, 1998; Tooker, 1999).

Utah lies within the Cordilleran orogenic belt of North America (DeCelles, 2004; Yonkee and Weil, 2011). Northern Utah contained a hinterland metamorphic belt on the west and an eastern transitional zone (Jurassic and Cretaceous), with a frontal thrust belt farther east (Early Cretaceous to Eocene, about 145 to 50 Ma) (Miller and others, 1992; DeCelles, 2004; DeCelles and Coogan, 2006; Yonkee and Weil, 2011). The map area lies in the Charleston-Nebo (Provo) salient of the Sevier fold-thrust belt (DeCelles, 2004; Kwon and Mitra, 2004). Discordant lithofacies in Paleozoic rocks across Rush Valley are attributed to the western and eastern thrust systems, each carrying distinctive rock packages on different thrust sheets (see Yonkee and others, 2014).

Low-angle normal faults in this map area are related to post-compressional collapse or relaxation of the Sevier orogenic belt (Constenius, 1996; Constenius and others, 2003). Local basins developed during this early phase of extension and collected sediment deposited in alluvial, floodplain, and lacustrine environments during the Eocene (~47 to 39 Ma) and possibly from the Paleocene to Oligocene.

Eocene to Oligocene (42 to 25 Ma) volcanic rocks and intrusions are present across the map area. They are part of an episode of middle Cenozoic volcanism that swept from north to south across the western U.S. and that is related to a change in subduction at the western margin of North America (see, for example, Lipman and others, 1972; Christiansen and Lipman, 1972; Best and Christiansen, 1991). Geochemical data indicate these rock units are largely intermediate to silicic in composition, although a few mafic units occur.

Basin and Range extension began about 20 Ma (Miocene) and continues to the present; it is characterized by its distinctive topography (north-trending ranges and basins) and bimodal volcanism (see, for example, Christiansen and McKee, 1978; Zoback, 1983). Numerous normal faults in the ranges and exposed and inferred along the valley margins are related to this Neogene extension. The basins in northern Utah preserve sedimentary and volcanic rocks of the Miocene-Pliocene Salt Lake Formation; some of these rocks (~11 to 4 Ma) are present in Skull and Rush Valleys and the Stansbury and Oquirrh Mountains.

Extensive late Tertiary to Quaternary surficial deposits blanket the area. Basins contain Pliocene and Pleistocene deposits that are generally not well understood since they are typically deeply buried. Three levels of alluvial fans are considered to predate Lake Bonneville because they are higher than, or eroded by, the lake. Another level of fans was graded to the lake level.

Late Pleistocene Lake Bonneville was the youngest and deepest of several large pluvial lakes in northern Utah (Oviatt and others, 1992, 1999; Oviatt, 2015; Oviatt and Shroder, 2016). Threshold control was maintained at Red Rock Pass, Idaho. The lake generally increased in size (transgressive phase) from about 30,000 to 18,000 calendar calibrated years before present (cal yr B.P.) (figure 2). The Stansbury shoreline and shoreline zone were formed during lake oscillations near 25,000 cal yr B.P. Subsequently, after transgressing up to its highest level, the lake quickly fell (Bonneville flood) from its greatest extent (Bonneville shoreline) to establish the Provo shoreline (18,000 to 15,000 cal yr B.P.) (overflowing phase), and then continued to regress (regressive phase) until about 13,000 cal yr B.P. After about 13,000 cal yr B.P., the level of Great Salt Lake averaged close to the modern elevation (4200 feet, 1280 m), and the Gilbert episode lake peaked at about 11,500 cal yr B.P. (Oviatt, 2014, 2015). Evidence of Lake Bonneville is recorded in lake deposits (mud, marl, sand, and gravel), and shoreline remnants, including the Stansbury, Bonneville, and Provo shorelines. The deepest part of Lake Bonneville, and the center of post-Bonneville isostatic rebound, was centered to the north near the Lakeside Mountains (Crittenden, 1963; Currey, 1982; Adams and Bills, 2016). Lake water overflowed northward from the Sevier basin (Lake Gunnison) to the Great Salt Lake basin (Lake Bonneville) along the Old River Bed (river valley) in the southwestern part of the map area. This drainage formed a delta at the Lake Bonneville margin that has been dated at about 10,000 to 13,000 cal yr B.P. (Oviatt and others, 2003).

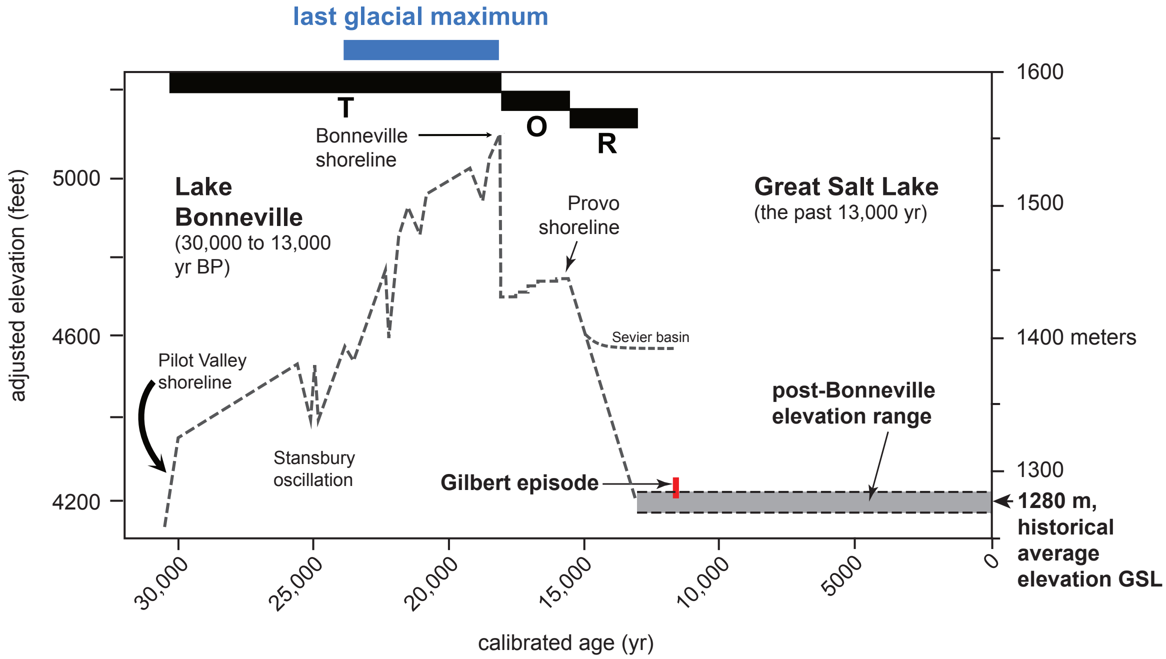


Figure 2. *Simplified Lake Bonneville and Great Salt Lake hydrograph and chronology (based on Oviatt, 2015; Oviatt and others, 2021). Elevations are adjusted for isostatic rebound. T is Transgressive Phase, O is Overflowing Phase, and R is Regressive Phase for Lake Bonneville. GSL is Great Salt Lake. See Oviatt (2014) for information about the Gilbert-episode lake. Another GSL lake rise to about 4230 feet (~1289 m) has been documented at Locomotive Springs with a maximum age of 11,000 years BP (Oviatt and others, 2015). Dashed line labeled "Sevier basin" represents the altitude of the overflowing lake in that basin during the regressive phase; overflow to the Great Salt Lake Desert stopped after the Gilbert episode.*

A unique lacustrine feature of the quadrangle is Stockton Bar, a transverse barrier bar and spit complex between Tooele and Rush Valleys. Construction of the bar caused the lake in Rush Valley to become isolated from the main body of Lake Bonneville. During the regression from the Bonneville highstand, the lake level in Rush Valley varied independently of the level in the rest of the Bonneville basin. Two shorelines in Rush Valley (Shambip and Smelter Knolls) record this variation (Gilbert, 1890; Burr and Currey, 1988, 1992; Nelson, 2012). Similarly, a lake existed in Cedar Valley below the Bonneville highstand with local threshold control (McKean, 2020).

Coeval with Lake Bonneville, small alpine glaciers occupied cirque basins and valleys in the higher elevations of the Stansbury and Oquirrh Mountains during the Last Glacial Maximum at 21 ± 2 ka (Laabs and Monroe, 2016). These Pleistocene glacial deposits are primarily of Angel Lake or Pinedale age (~24 to 12 ka), but limited older deposits are probably Lamoille or Bull Lake in age (Marine Oxygen Isotope Stage 6, ~190 to 130 ka) (Laabs and Carson, 2005; Laabs and Monroe, 2016; Pierce and others, 2018).

Holocene deposition included sediments largely of alluvial and eolian environments. Younger alluvial fans continued to develop. Eolian silt and sand deposits likely emanated from the Great Salt Lake Desert and locally from Lake Bonneville deposits. Sediments from spring, colluvial, mass movement, and mixed depositional environments also occur.

Some Basin and Range faults have developed Quaternary-age scarps along the margins and within several major valleys. These faults and other unobserved faults present potential seismic risk. Some areas of the quadrangle have undergone human disturbance.

NOTES ON STRATIGRAPHY

Several stratigraphic issues warrant further discussion, particularly to clarify where we have departed from prior work. These issues relate to ages, Paleozoic nomenclature, Cambrian strata, Mississippian units, the Permian-Pennsylvanian Oquirrh Group, and Tertiary volcanic rocks.

Although U-Pb detrital zircon analyses were conducted on several Cambrian and Neoproterozoic geologic units in northern Utah (see, for example, Yonkee and others, 2014), few have yielded younger grains for maximum depositional ages (to constrain formation ages).

For selected Cambrian through Devonian strata of Camels Back Ridge, we apply regional stratigraphic names of Hintze and Robison (1975) and Hintze (1980). This terminology departs from the prior use of local names from the Dugway Range by Staatz and Carr (1964) and Staatz (1972).

Clark and Kirby (2009) reevaluated Cambrian stratigraphy of the Stansbury and northern Sheeprock Mountains. All sections of Cambrian rock are incomplete due to structural disturbance, but we evaluated sections in South Broons Canyon (Stansbury Mountains, north of map area) and on Red Pine Mountain (Sheeprock Mountains). Although we have no new biostratigraphic age control, lithofacies sequences closely resemble western Utah strata (western thrust system; see, for example, Hintze and Robison, 1975) rather than the East Tintic Mountains section (eastern thrust system) as initially applied by Rigby (1958) and perpetuated by subsequent mappers in the Stansbury Mountains, and the "mixed" stratigraphic nomenclature used by Cohenour (1957, 1959) in the Sheeprock Mountains (figure 3). Our revised terminology is indicated in the map explanation and figure 3. We lumped Middle Cambrian map units in a similar fashion to Hintze and Davis (2003) and Clark and others (2020b).

Cambrian rock units are also exposed in the core of the Ophir anticline of the southwestern Oquirrh Mountains. Gilluly (1932) noted the lithologic similarities of Cambrian strata in the Oquirrh Mountains to the East Tintic Mountains area but was unsure of direct correlations and thus applied local names; these names were later used by Tooker (1987, 1999). Rigby (1959b) used East Tintic terminology for the Cambrian rock units in the Oquirrh Mountains, and this terminology was also used on Laes and others' (1997) map. We conclude that although there are similarities to the East Tintic section, the lithofacies present warrant use of the local names of Gilluly (1932), and correlation to the East Tintic section needs further study.

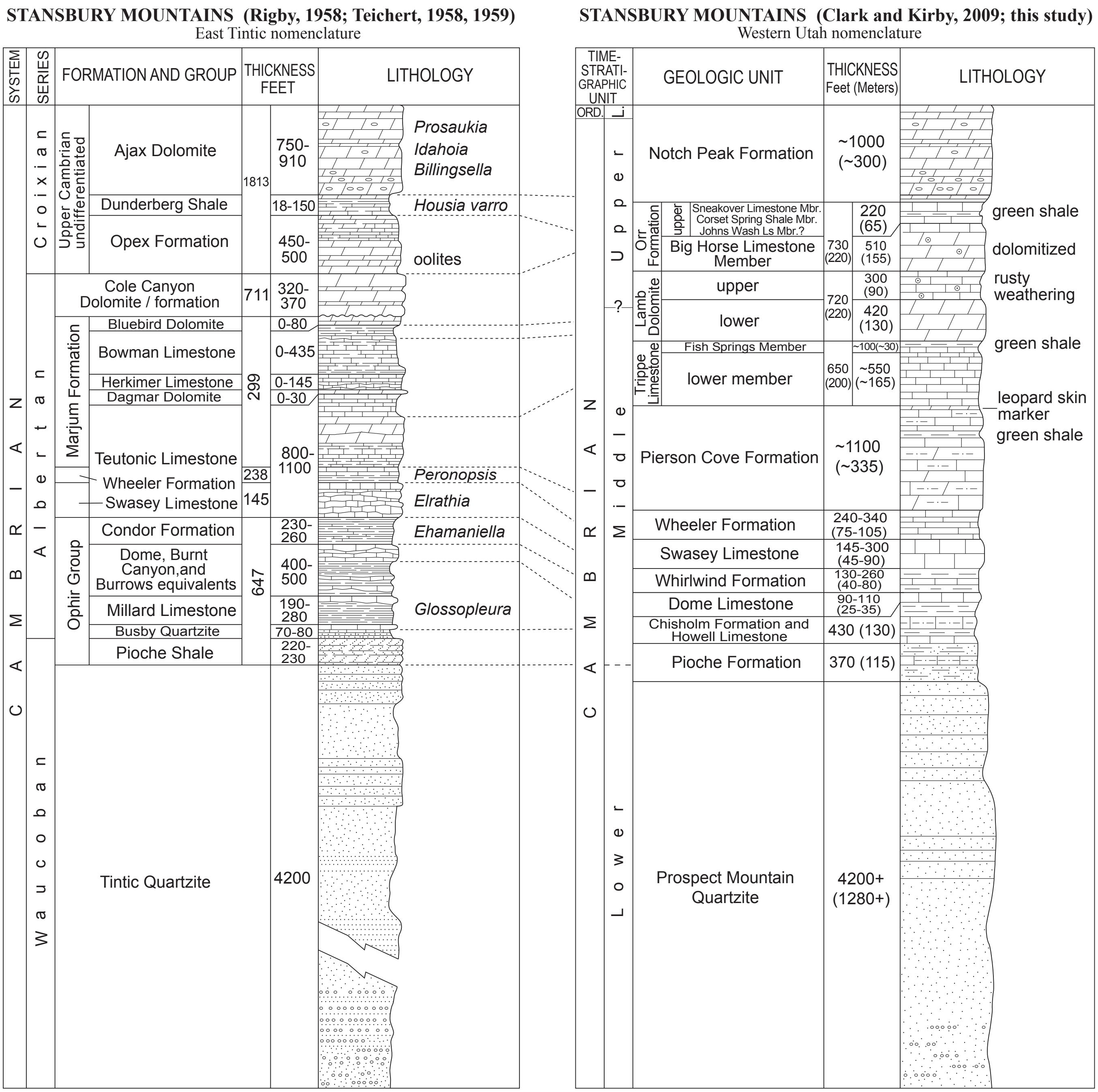


Figure 3. *Comparison of Cambrian stratigraphic nomenclature of the Stansbury Mountains.*

We re-evaluated the stratigraphic nomenclature of the Great Blue Limestone in the southern Oquirrh and northern East Tintic Mountains. Based on limitations of the exposures and age control in the East Tintic Mountains and Topliff Hill–Tenmile Pass area, lithofacies relationships over a broader area, and limited new palynology data, we include strata previously mapped by Disbrow (1957, 1961) and Morris and Lovering (1961) as the Poker Knoll Limestone and Chiulos Members of the Great Blue with the Manning Canyon Formation, and the locally used Paymaster Member and Topliff Limestone Member as the Great Blue Limestone, undivided. We applied similar nomenclature to the northern Sheeprock Mountains and Davis Mountain areas mapped by Cohenour (1957, 1959) and Moore and Sorensen (1977). We included an additional member of the Great Blue near Fivemile Pass (unit Mgbus) that appears to be associated with a different structural block, an interpretation similar to Tooker (1987).

One of the largest challenges of this mapping project was the Oquirrh Group rocks. Geologists have struggled for decades with the thick, monotonous, and structurally deformed unit for which formational nomenclature has been slow to become established (see, for example, Hintze and Kowallis, 2009). We applied a consistent nomenclature across the quadrangle based on lithofacies successions and fossil age data. This nomenclature builds on prior work in the Cedar Mountains (Maurer, 1970; Clark and others, 2016) (figure 4), Stansbury and Onaqui Mountains (Wright, 1961; Armin, 1979; Jordan, 1979a, 1979b; Armin and Moore, 1981), Oquirrh Mountains/South Mountain/western Traverse Mountains (Welsh and James, 1961, 1998; Tooker and Roberts, 1970, 1998; Moore, 1973c; Swenson, 1975; Jordan, 1979a, 1979b; Tooker, 1999; Biek and others, 2005), and Thorpe Hills (Disbrow, 1957). The Permian-Pennsylvanian rocks of the southern Oquirrh Mountains are referred to as part of the Bingham sequence (Tooker and Roberts, 1970). Considering regional relations and following Laes and others (1997), we combine Lower Permian (Curry Peak and Freeman Peak Formations) and Pennsylvanian formations from the Bingham area with the Oquirrh Group. This scenario makes similar sections of Oquirrh Group strata in the southern Oquirrh Mountains and the Wasatch Range stratigraphically equivalent (figure 5). This nomenclature differs from terminology established in the Oquirrh Mountains (Welsh and James, 1961; Tooker and Roberts, 1970), which restricted the Oquirrh Group to strata of Pennsylvanian age. Oquirrh Group rocks of the southern Oquirrh Mountains total nearly 20,000 feet (6100 m) thick (Tooker and Roberts, 1970; Swenson, 1975), while equivalent strata in the Wasatch Range total approximately 29,000 feet (8850 m) thick (Baker, 1976; Constenius and others, 2011, in preparation).

Although we applied this consistent stratigraphic nomenclature to the Oquirrh Group based on lithostratigraphy and age relations (paleontologic data), we recognize that different parts of the Oquirrh basin are juxtaposed against one another in structural blocks of the Sevier fold-thrust belt. The presence of these different structural blocks led Tooker and Roberts (1998) to use different stratigraphic nomenclature in each block. Sequence stratigraphic work of Scott Ritter and Brigham Young University students (Shoore and Ritter, 2007; Derenthal, 2011) has begun to reveal more details on Oquirrh Group stratigraphy.

Maurer (1970)

Time-stratigraphic Unit		Cochran Spring Section Feet (Meters)	Overall Feet (Meters)	Oquirrh Formation Unit
PERMIAN	Wolfcampian	340+ (104+)	1935+ - 2750 (590+ - 838)	Unit 5
PENNSYLVANIAN	Virgilian	2762 (842)	2762 - 3000 (842 - 915)	Unit 4
PENNSYLVANIAN	Desmoinesian-Missourian	2556 (779)	2556 - 3000+ (779 - 915+)	Unit 3
PENNSYLVANIAN	Morrowan - Atokan	715 (218)	715 - 1400 (218 - 427)	Unit 2
MISS.	? Chest.	434 (132)	434 (132)	Unit 1
Total Thickness		6807 (2075)	8402+ - 10,584+ (2562+ - 3229+)	

Clark and others (2016)

Map Unit		Cochran Spring Section Feet (Meters)	Overall Feet (Meters)	Sample Numbers	Time-stratigraphic Unit		
P₱o	Pofc	2713 (827)	3500 (1070)	— D-60 — D-75 D-69	Wolfcampian	lower	PERMIAN
P₱o	₱obm	1000 (305) fault	2800 (850)	— D-76 D-68 — D-52 D-57 — D-71	Misso.-Virgil.	Upper	PENNSYLVANIAN
P₱o	₱obp	fault 2660 (811)	5400 (1650)	— D-70	Atokan-Desmoinesian	Middle	PENNSYLVANIAN
P₱o	₱owc	500 (150)	500-800 (150-245)	— D-50	Morrowan	Lower	PENNSYLVANIAN
		6873 (2095)	12,350 (3770)				

__Figure 4.__ Comparison of Oquirrh Group strata nomenclature of the southern Cedar Mountains. The nomenclature used on this map for the lower Permian (Wolfcampian) and Pennsylvanian formations is largely based on that of the Oquirrh Mountains/Bingham mining district.

Interpretations on Tertiary volcanic rocks of the quadrangle were updated from the prior work of Moore and McKee (1983), with new radiometric ages and whole-rock geochemical data. These new data assist with local and some regional correlations. Figures 6 and 7 summarize age and geochemical data for Tertiary volcanic rocks in the Rush Valley quadrangle. Volcanic centers and deposits are located at the Cedar Mountains and Skull Valley, northern Simpson Mountains, southern Stansbury Mountains, southern Oquirrh Mountains and western Traverse Mountains, Vernon Hills, and northern East Tintic Mountains. Most of these Tertiary rocks have informal names, except for some in the northern East Tintic Mountains.

On the geologic map, several map units in Quaternary-Tertiary surficial deposits and older bedrock units are locally queried. The queries indicate uncertainties due to poor exposures, lack of field checking, and difficulties with unit assignments.

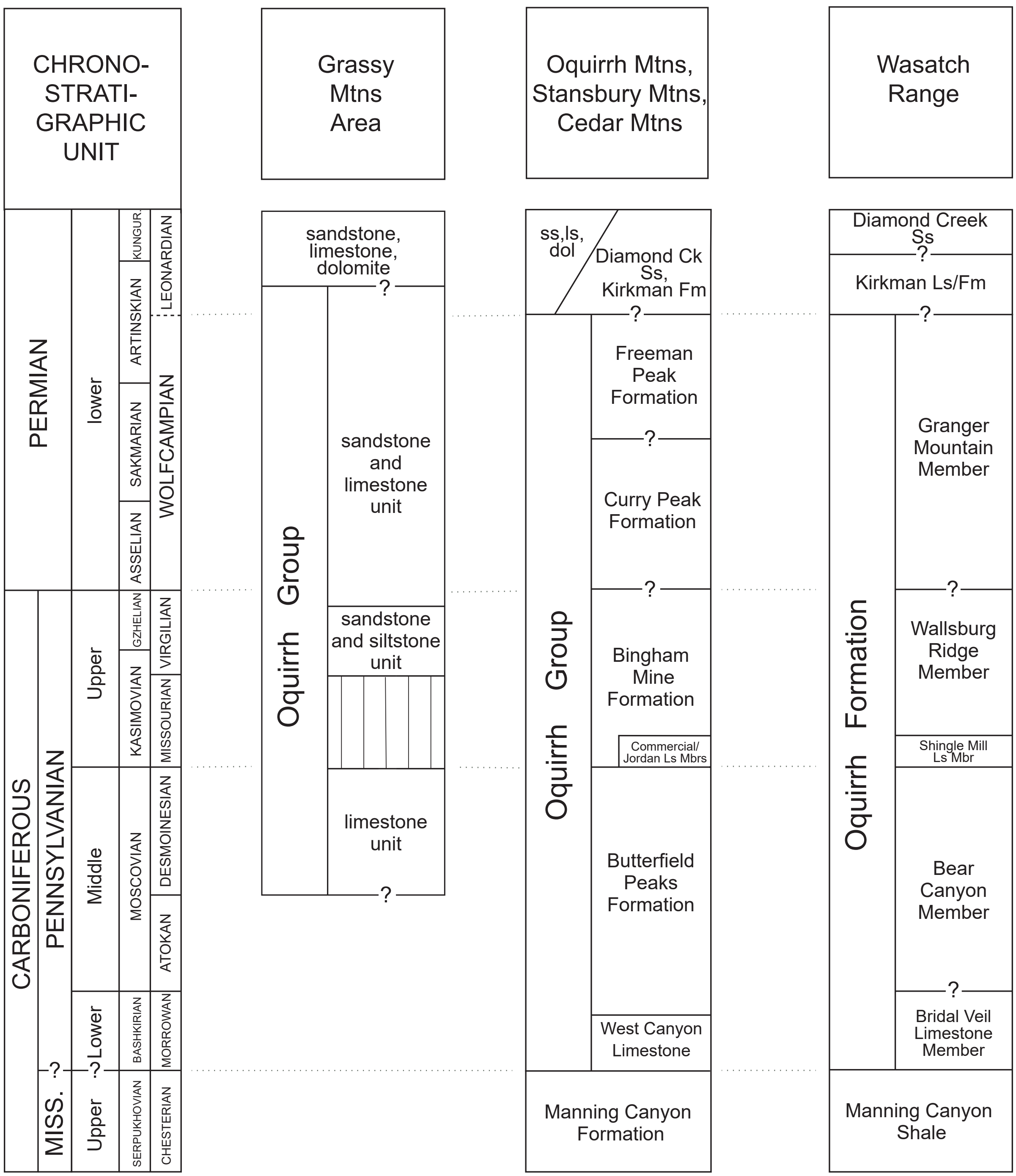


Figure 5. *Comparison of Permian-Pennsylvanian nomenclature of the Oquirrh Group/Formation and other units used on this map and in adjacent areas. Grassy Mountains modified from Doelling (1964) and Jordan (1979a, 1979b). See Clark and others (2020b) for Oquirrh, Stansbury, and Cedar Mountains. See Constenius and others (2011) for Wasatch Range.*

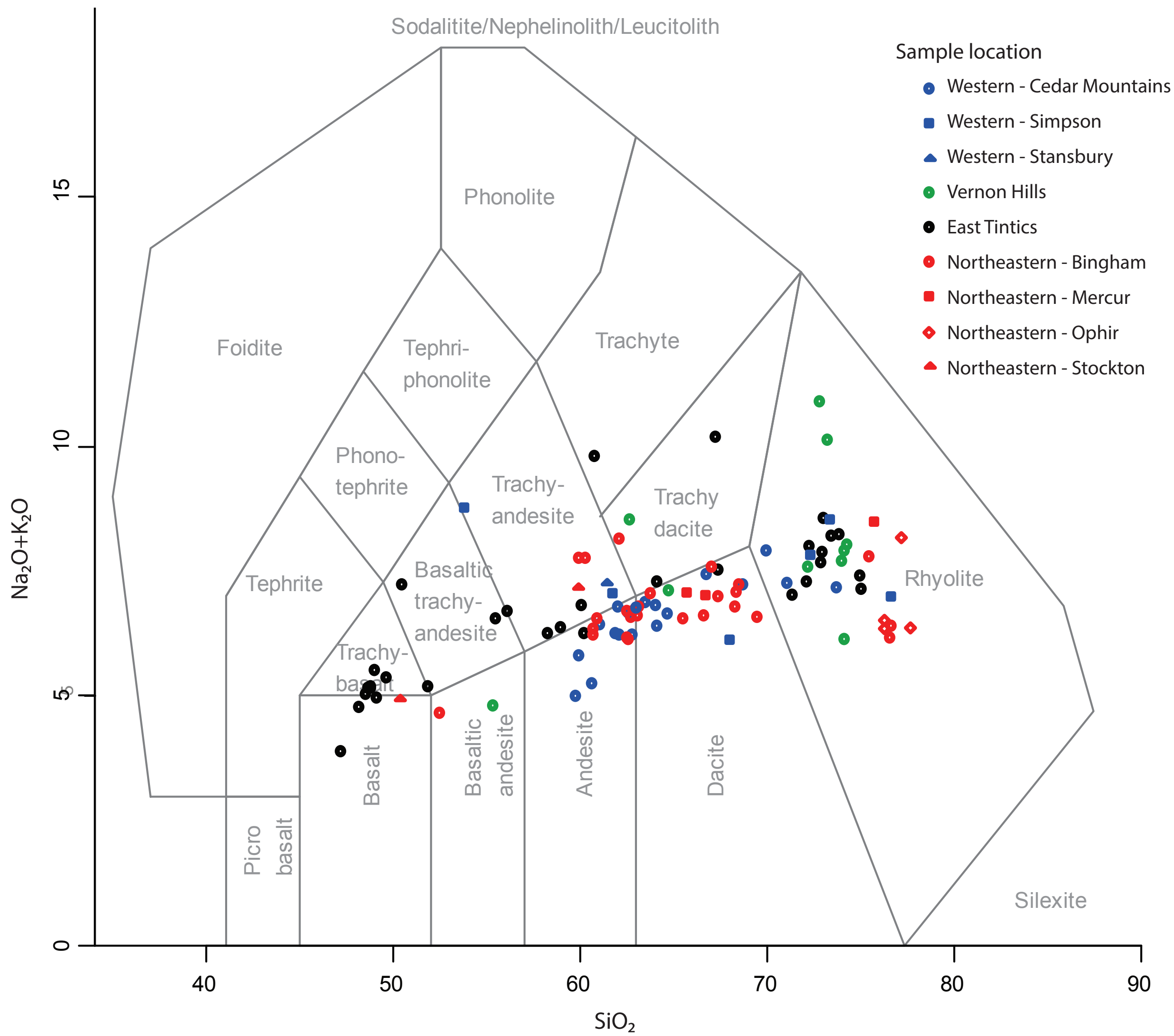


Figure 6. *Selected geochemical data depicted on the total alkali-silica diagram of Middlemost (1994) for igneous rocks in the Rush Valley quadrangle. Axes in weight percent. Complete sample geochemical data are presented in table A6.*

NOTES ON STRUCTURE

Geologic structure of the map area is largely related to episodes of compression (Sevier orogeny) and extension (Sevier belt collapse/relaxation, Basin and Range normal faulting). Interpretation of Sevier thrust belt architecture was challenging considering disruption by later Cenozoic faulting and concealment by valleys of the Basin and Range. In addition, linking thrust geometries and timing in the Provo (Charleston-Nebo) salient northward to the Wyoming salient of the Sevier belt, across the Uinta-Tooele structural zone, has been problematic (see, for example, Coogan and Constenius, 2003; DeCelles, 2004). We omit speculative thrust fault extensions and connections on this geologic map (plate 1) but include a sketch of potential thrust geometries on figure 8. Likewise, basin structure is not well known. Some valley margins are bounded by normal faults, but other steep range fronts show no surface or geophysical evidence of faulting (plate 1, figure 8).

Some of the structure in the southern Stansbury Mountains could be related to the Devonian Stansbury uplift associated with reactivation of the Tooele arch (see Rigby, 1959a; Foose, 1989; Cashman, 1992). Complications lead us to lump Cambrian map units there. Further mapping and structure evaluation work are needed.

There are several significant Sevier-age thrust faults with older-on-younger relations in the map area. These are internal thrust sheets of the Provo (Charleston-Nebo) salient (Makul and Mitra, 1998; Kwon and Mitra, 2004; McKean and others, 2011). Our map and cross sections reinterpret some of the prior thrust belt geometry (see, for example, Tooker, 1983, Morris, 1987; Kwon and Mitra, 2004). The main thrusts include the Cedar, Skull Valley, Government Creek, East Stansbury, Stockton, Beef Hollow, and Pinyon Peak (figure 8). Clark and others (2020b) discussed the Cedar thrust in more detail. We interpret the Skull Valley fault as a thrust with later normal offset. The Government Creek thrust is enigmatic considering its east-west orientation, which may be related to the complicated structure

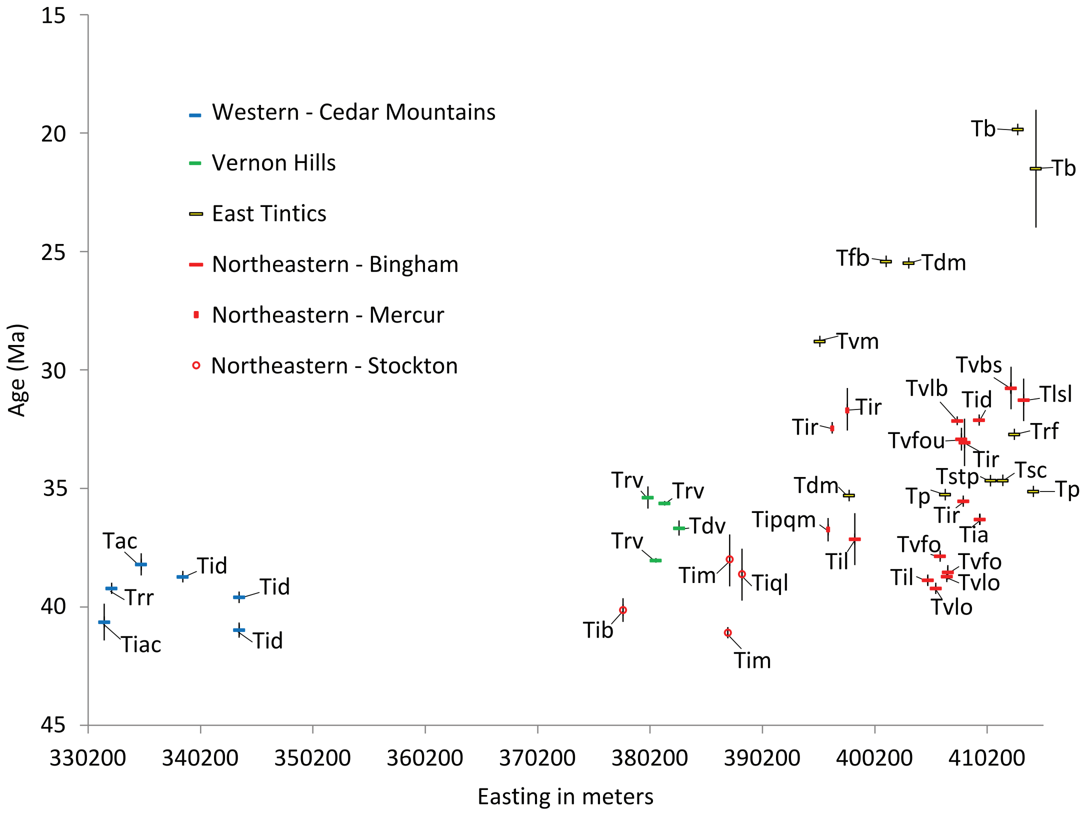


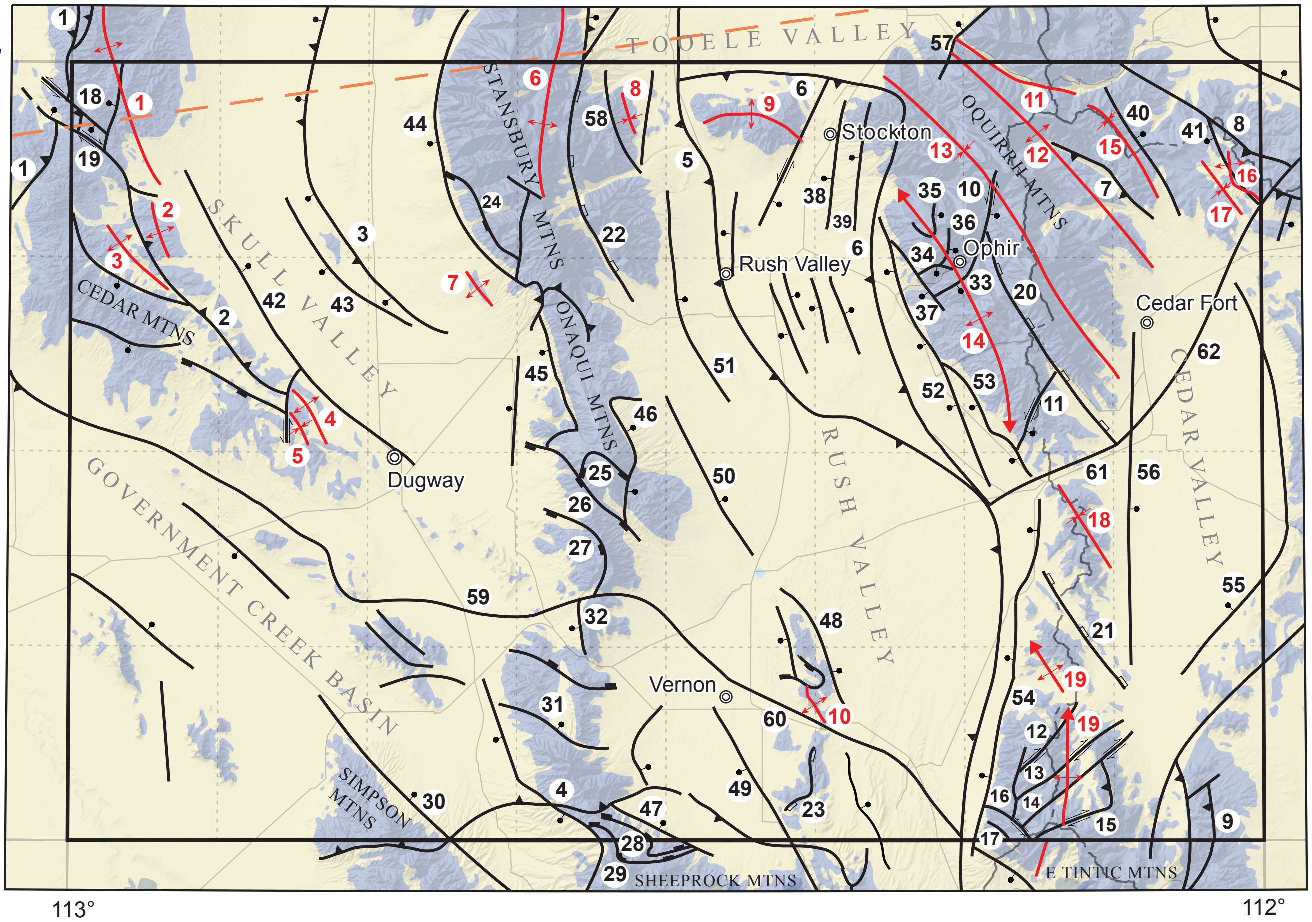
Figure 7. *Selected radiometric ages for igneous rocks in the Rush Valley quadrangle showing differences in volcanic centers from west to east across the area. West is to the left and east is to the right on the figure. Vertical bars represent error range, units correspond with map units on plate 1. Complete sample age and location data are presented in table A7. Easting is in NAD27 UTM zone 12N.*

in the Sheeprock and Simpson Mountains. The East Stansbury thrust (called Tintic Valley by many workers) is a significant structure that separates disparate lithofacies successions on the west and east and is the leading edge of the western thrust system (see, for example, Yonkee and others, 2014). There are some differences between the structural interpretations of our Rush Valley map and those of the Lynndyl 30' x 60' quadrangle (Pampeyan, 1989) and Makul and Mitra's map (1998). Makul and Mitra (1998) did not include the North Sheeprock thrust (figure 8, unnumbered thrust north of Sheeprock Mountains); we are uncertain of its location to the east. Kirby thinks Makul and Mitra's (1998) Sabie Mountain thrust may be a detachment fault based on map relations and topography. Kroko and Bruhn (1992) discussed the structure of the Mercur area, southern Oquirrh Mountains, as related to a blind thrust. Locally, west-directed backthrusting is also evident based on map relations. Several Sevier-related strike-slip and oblique-slip faults exist that helped to accommodate slip of the various thrust sheets (figure 8) (see McKean and others, 2011). The Onaqui fault and Cedar Valley fault could be transverse faults bounding different thrust sheets.

We mapped low-angle faults (called attenuation faults by some) associated with the Manning Canyon Formation. These include the Manning Canyon fault, Tenmile Pass fault, south part of the Big Hollow fault, and South Vernon Hills fault. These faults omit stratigraphic section and may have been involved in compression and/or extension during formation, realignment, or relaxation of the Sevier fold-thrust belt.

Low-angle normal faults with younger-on-older relations are interpreted to be a result of extensional collapse of the Sevier belt , although some prior Sevier compressional history is possible. Some of these faults were previously mapped as thrust faults. These include the Dry Canyon fault, Hell Hole Canyon fault, East Faust fault, Burnt Canyon fault, Sheeprock–Lion Hill fault, Sheeprock-Harker fault, and other unnamed faults. Christie-Blick (1983) reported on faults in the Sheeprock Mountains.

Several faults apparently had complicated histories, probably with dual or multiple senses of movement, and some likely reused preexisting Sevier structures. Examples are indicated on figure 8 and some are reported by McKean and others (2011). The Big Hollow fault (southern Stansbury Mountains) has been particularly enigmatic with several names and interpretations (Rigby, 1958; Tooker and Roberts, 1971; Sorensen, 1982; Tooker, 1983; Taylor, 1992; Cashman, 1992; Copfer and Evans, 2005), and it is likely a different structure than the Broad Canyon fault to the north (this study; Clark and others, 2020b). We interpret the Big Hollow fault as an east-dipping (and in part folded) structure that detached or separated at the Manning Canyon interval and allowed for differential folding of sections above and below. The Onaqui fault and Vernon Hills fault may also have had a similar history.



Sevier Thrust Faults
1. Cedar thrust
2. Cochran Spring thrust
3. Skull Valley Fault
4. Government Canyon thrust
5. East Stansbury thrust
6. Stockton thrust
7. West Canyon thrust
8. Beef Hollow thrust
9. Pinyon Peak thrust

Sevier Strike-Slip and Oblique-Slip Faults
10. Soldier Canyon fault
11. Wells-Clay Canyon fault
12. South Essex fault
13. Stroud fault
14. Gardison Ridge fault
15. Tintic Prince fault
16. New Bullion fault
17. Miners Canyon fault
18. Tabby Peak fault
19. Rydalch Canyon fault

Attenuation Faults
20. Manning Canyon fault
21. Tenmile Pass fault
22. Big Hollow fault
23. South Vernon Hills fault

Low-Angle Normal Faults
24. Dry Canyon fault
25. Hell Hole Canyon fault
26. East Faust fault
27. Burnt Canyon fault
28. Sheeprock - Lion Hill fault
29. Sheeprock - Harker fault

High-Angle Normal Faults
30. North Simpson Mountains fault
31. Red Pine fault
32. Lookout Pass fault
33. Lion Hill fault
34. Canyon fault
35. Garber fault
36. Cliff fault
37. Lakes of Killarney fault
38. Stockton fault
39. Continental fault
40. Oak Springs fault
41. Tickville Gulch fault
42. East Cedar Mountains fault
43. Skull Valley (Mid valley) faults
44. Stansbury fault zone
45. West Onaqui fault
46. Grasshopper Ridge fault
47. North Sheeprock fault zone
48. East Vernon Hills fault zone
49. Vernon Creek fault
50. Clover fault zone
51. St. John Station fault zone
52. Mercur fault
53. West Eagle Hill fault
54. Topliff Hill fault zone
55. East Cedar Valley fault zone
56. West Cedar Valley fault
57. Oquirrh fault zone

Faults with Multiple Movement/unknown
58. Martin Fork fault
59. Onaqui fault
60. Vernon Hills fault
61. Fivemile Pass fault
62. Cedar Valley fault

Folds Anticline Syncline
1. Wildcat Canyon anticline
2. SE Rydalch Canyon anticline
3. Cochran Spring anticline
4. Post Hollow anticline
5. Post Hollow syncline
6. Deseret anticline
7. Deadman anticline
8. Martin Fork syncline
9. South Mountain anticline
10. Vernon Hills anticline
11. Middle Canyon fold
12. Long Ridge anticline
13. Pole Canyon syncline
14. Ophir anticline
15. Oak Springs syncline
16. Tickville anticline
17. Tickville Gulch syncline
18. Thorpe Hills syncline
19. North Tintic anticline

Uinta-Tooele structural zone

Figure 8. *Tectonic map schematic showing the possible structural architecture of the Rush Valley quadrangle. Note for simplicity all faults and folds are depicted as solid lines.*

Numerous high-angle normal faults developed through Basin and Range extension, which has shaped the current topography. Extension formed the large valleys, but also affected the range blocks, as they are cut by normal faults of generally smaller displacement and different trend. Quaternary normal faults and scarps occur along the margins of many major valleys and within the valleys (see, for example, Bucknam, 1977; Barnhard and Dodge, 1988; Black and others, 1999, 2003). Quaternary normal faults bound Tooele Valley (Oquirrh fault zone), Skull Valley (East Cedar Mountains fault, Skull Valley mid-valley faults, Stansbury fault zone, West Onaqui fault), Rush Valley (St. John Station fault zone, Clover fault zone, Grasshopper Ridge fault, East Vernon Hills fault zone, Southern Oquirrh Mountains fault zone including Mercur fault and West Eagle Hills fault, Topliff Hill fault zone, and North Sheeprock fault zone), and Cedar Valley (West Cedar Valley fault and East Cedar Valley fault zone). In the quadrangle, paleoseismic studies on the Mercur fault indicate at least one Holocene rupture, with the most recent faulting occurring at 4600 ± 200 cal yr B.P. (URS Greiner Woodward Clyde, 2001). This result concurs with other trenching and mapping studies (Everitt and Kaliser, 1980; Barnhard and Dodge, 1988; Olig and others, 1999; Kirby, 2012). Other studies on the Mercur fault include those by Wu and Bruhn (1994) and Mattson (2004). More recently, a preliminary, unpublished paleoseismic investigation by Toke and students at Utah Valley University was conducted at the Topliff Hills area (Ward and others, 2019). In 2018, lidar was flown over the Tooele and Rush Valleys area. These data were subsequently evaluated, and faults mapped (1:10,000 scale or greater) by UGS geologists (see Hiscock and others, 2021). However, this detailed fault data will need to be merged with updated geologic mapping in the future. We provide the fault mapping from lidar (Hiscock and others, 2021) in the GIS data for this map. The observed normal faults and scarps and other concealed normal faults present potential seismic risk (Everitt and Kaliser, 1980; Black and others, 1999; Geomatrix, 2001; WGUEP, Wong and others, 2016).

Many folds are mapped throughout the quadrangle (plate 1, figure 8). Most of the folding is related to the generally eastward-directed Sevier compressional regime. Some of these folds are expressions of deeper thrust faults and other structural elements. Dramatic folds include the Deseret anticline and Martin Fork syncline, the series of folds in the Oquirrh Mountains, and the North Tintic anticline. In addition, there is folding in the older Tertiary strata of the Vernon Hills which may be related to Sevier belt relaxation. The folded Salt Lake Formation in southern Rush Valley is due to Miocene Basin and Range extensional tectonics.

Geophysical data aided in structural interpretations (see, for example, Stein and others, 1989). Bouguer gravity data (Johnson and Cook, 1957; Cook and others, 1989; Pan-American Center for Earth and Environmental Studies [PACES], 2012) and data from Saltus and Jachens (1995) formed the primary basis for interpretation of subsurface structure and basin geometry. Unfortunately, there are only a few deep drill holes in the east part of the quadrangle to calibrate basin depths with gravity data (table A1). Gravity lows are associated with the primary valleys and show the deeper parts of the basins. Gravity data from PACES (2012) are included in the GIS geodatabase; a simplified gravity map is included as figure 9. Some concealed faults were mapped from the gravity data (see, for

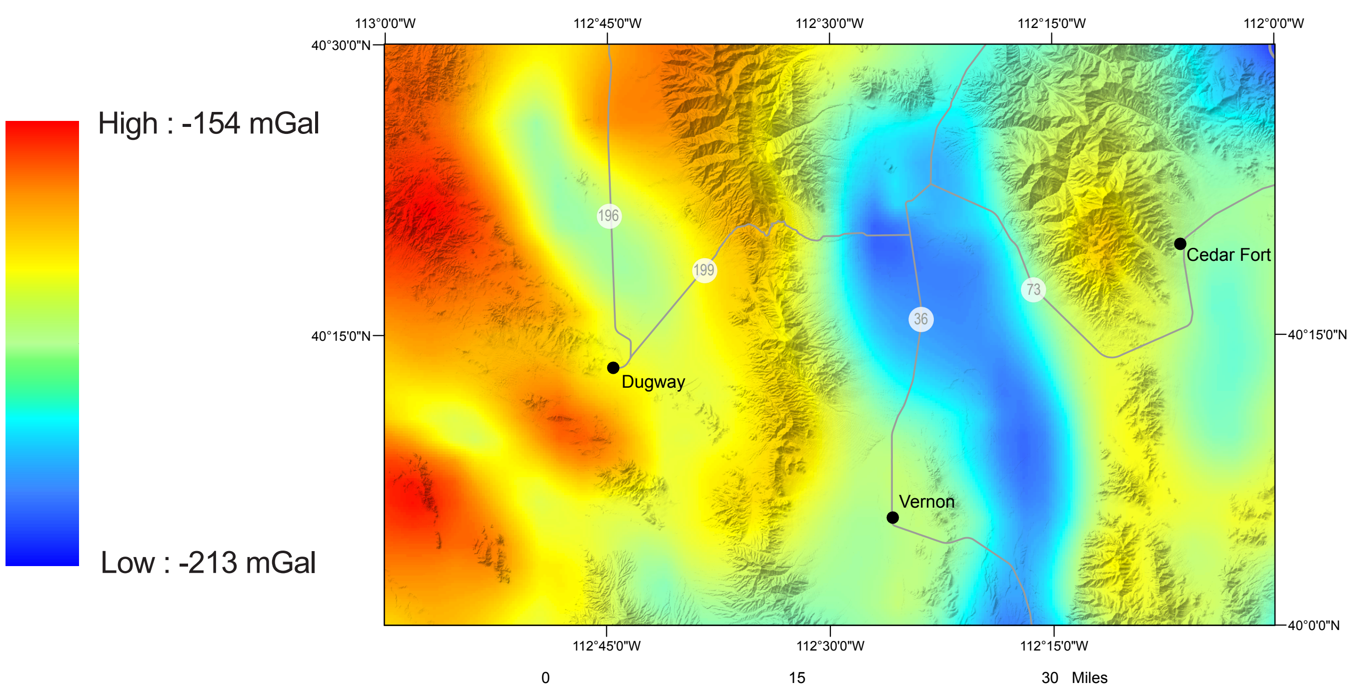


Figure 9. *Simplified isostatic gravity map of the Rush Valley quadrangle; data from Bankey and others (1998). Color ramp in milligals. Cooler colors depict the extent of basins, while warmer colors depict ranges.*

example, Zoback, 1983; Saltus and Blakely, 2011). In addition, aeromagnetic data are available (Stein and others, 1989; Raines and others, 1996; Bankey and others, 1998; K. Krahulec, UGS, written communication on the Stockton-Ophir area, October 24, 2012), but no new data were obtained for this project. Magnetic highs are associated with the Bingham and Stockton volcanic centers, under Tintic Valley (between the Vernon Hills and East Tintic Mountains), and in the southernmost Cedar Mountains and central Skull Valley. These highs are presumed to be associated with magnetic volcanic rocks, some of which are only subsurface expressions. Although some seismic reflection data were reportedly collected in the quadrangle (K.N. Constenius, verbal communication, August 2008), they were not available for our review. Rowley (1998) reported on the Payson transverse zone just south of the map area extending from near Payson to the Deep Creek Mountains in Utah. This zone was based on geophysical and geologic data.

DESCRIPTION OF MAP UNITS

QUATERNARY-TERTIARY SURFICIAL DEPOSITS

Q Quaternary surficial deposits, undivided – Cross sections only.

QT Quaternary-Tertiary surficial deposits and rocks, undivided – Cross sections only.

Alluvial Deposits

Qal **Stream alluvium** (Holocene) – Clay, silt, and sand with some gravel lenses deposited by streams in channels and broad drainages; locally merges with alluvial-fan deposits; locally includes alluvial-fan, colluvial, low-level terrace, and eolian deposits; thickness generally less than about 20 feet (6 m).

Qam **Alluvial mud** (Holocene to upper Pleistocene?) – Silt, clay, some sand, and minor gravel deposited by streams and sheet wash within former lagoonal areas related to Lake Bonneville shorelines; bottom of lagoonal basins may include unexposed, thin, fine-grained lacustrine deposits; thickness less than about 20 feet (6 m).

Qafy **Younger fan alluvium, post-Lake Bonneville** (Holocene to uppermost Pleistocene) – Poorly sorted gravel with sand, silt, and clay; deposited by streams, debris flows, and flash floods on alluvial fans and in mountain valleys; includes alluvium and colluvium in mountain valleys; merges with unit Qal; may include areas of eolian deposits and lacustrine fine-grained deposits below the Bonneville shoreline; includes active and inactive fans younger than Lake Bonneville, but may also include some older deposits above the Bonneville shoreline; locally, unit Qafy spreads out along the lake terraces and, due to limitations of map scale, is shown to abut Lake Bonneville shorelines, even though it is not cut by these shorelines; unit Qafy also drapes over but does not completely conceal shorelines; thickness variable, to 50 feet (15 m) or more.

Qafb **Fan alluvium, graded to Lake Bonneville** (upper Pleistocene) – Poorly sorted gravel with sand, silt, and clay in alluvial fans that are graded to the Bonneville-level shoreline (transgressive) and lower (regressive) shorelines, and the Cedar Valley Lake shoreline; may include small areas of eolian and colluvial deposits; incised by younger alluvial deposits; thickness variable, to 100 feet (30 m) or more.

Qafo, Qafo?

Older fan alluvium, pre-Lake Bonneville (upper to middle? Pleistocene) – Poorly sorted gravel with sand, silt, and clay; similar to unit Qafy, but forms higher level incised deposits that predate Lake Bonneville; includes fan surfaces of different levels; fans are incised by younger alluvial deposits and locally etched by Lake Bonneville; may locally include small areas of lacustrine or eolian deposits and younger alluvium; thickness variable, to 100 feet (30 m) or more.

QTaf **High-level fan alluvium** (lower Pleistocene? to Pliocene?) – Poorly sorted gravel with sand, silt, and clay; unconsolidated to semiconsolidated with calcic soil development on upper surfaces; forms high-level deposits incised by younger alluvial deposits and locally etched by Lake Bonneville; may locally include small areas of lacustrine or younger alluvial deposits; thickness variable, to 100 feet (30 m) or more.

Taf, Taf?

Tertiary fan alluvium (Pliocene? to Miocene?) – Highest level of fan deposits; exposed along west flank of Sheeprock Mountains and near Little Valley; lower part contains limestone clasts whereas upper part contains solely quartzite clasts, suggesting erosional unroofing of the Sheeprock Mountains; lower part of unit is semiconsolidated; in Sheeprock Mountains unit overlies the rhyolite of Judd Creek (unit Trj), and is lapped onto and incised by younger alluvial deposits; unit Taf? also mapped at Fivemile Pass, southern Oquirrh Mountains; exposed thickness is greater than 1200 feet (365 m).

Spring Deposits

Qsm **Spring and marsh deposits** (Holocene) – Clay, silt, and sand that is variably organic-rich, calcareous, or saline; present in ephemerally or perennially saturated (marshy) areas near springs and seeps; mapped in several valleys; thickness as much as 30 feet (10 m).

Eolian Deposits

Qe **Eolian deposits, undivided** (Holocene) – Windblown sand and silt in sheet and dune forms; mapped at Skull Valley, Rush Valley, and Cedar Valley; up to 20 feet (6 m) thick.

Qei **Eolian silt deposits** (Holocene) – Windblown silt and minor sand mapped solely in stacked units.

Qes **Eolian sheet sand deposits** (Holocene) – Windblown sand and silt deposited as sheets rather than well-developed dunes; generally thin with no distinct bedding; mostly silty, well-sorted, fine-grained quartz sand; only thicker deposits mapped; also mapped in stacked units; less than 15 feet (5 m) thick.

Qed **Eolian dune sand deposits** (Holocene) – Well-sorted sand in dunes and dune fields; mostly fine-grained quartz sand but also aggregates of clay, silt, and sand; present as parabolic, linear, dome, lunette, and shrub-coppice dunes (see Dean, 1978); larger dune fields may include a thin fringe of unmapped sheet sand; also mapped in stacked units; thickness to 50 feet (15 m).

Playa Deposits

Qpm **Playa mud** (Holocene) – Clay, silt, and small amounts of sand with local accumulations of gypsum, halite, and other salts; locally reworked by alluvial and eolian processes; probably overlies unit Qlf; present within the playa lake bed of Rush Lake and one other area in central Rush Valley; also present as thin upper part of stacked unit Qpm/Ql comprising mudflats of the Great Salt Lake Desert; thickness is unknown, may be from an inch to a few feet.

Lacustrine Deposits (post-Bonneville lake cycle)

Qlfy **Younger lacustrine fine-grained deposits** (Holocene) – Clay, silt, and small amounts of sand adjacent to Rush Lake playa; deposited by fluctuations of Holocene Rush Lake; thickness probably 15 feet (5 m) or less.

Qlsy **Younger lacustrine sand deposits** (Holocene) – Sand with minor gravel adjacent to Rush Lake playa; deposited by fluctuations of Holocene Rush Lake; thickness probably 15 feet (5 m) or less.

Lacustrine and Deltaic Deposits (Bonneville lake cycle)

Lake Bonneville shoreline elevation ranges (table A2) were determined from 1:24,000-scale topographic maps. These elevations generally increase from southeast to northwest across the map area due to isostatic rebound after regression of Lake Bonneville. Crittenden (1963), Currey (1982), and Chen and Maloof (2017) provided regional data on shoreline elevations and isostatic rebound. Radiocarbon age data are summarized in table A3. Several prominent erosional and depositional landforms related to Lake Bonneville exist in the map area, described below. Lake Bonneville was succeeded by a lake during the Gilbert episode (figure 2), but these deposits are localized, generally thin, and difficult to recognize.

Oviatt and Nash (2014) reported on the Pony Express basaltic ash, observed at two locations on Camels Back Ridge in the map area. This ash is a key stratigraphic marker in transgressive-phase Lake Bonneville deposits (~20,000 ^{14}C yr B.P. [~24,000 cal yr B.P.]).

A small part of the Old River Bed crosses the southwest corner of the map area. The Old River Bed is an abandoned river valley present on the south part of Dugway Proving Ground extending southward to the Sevier River southwest of Delta, Utah. This feature formed during the most recent episode of overflow from the Sevier basin (Lake Gunnison) northward to the Great Salt Lake basin (Lake Bonneville) (Oviatt, 1987; Oviatt and others, 1994). Where the river entered Lake Bonneville, a delta formed with numerous distributary channels (mapped by Clark and others, 2016); radiocarbon dating of the channels ranges from 8800 to 12,500 ^{14}C yr B.P. (about 10,000 to 13,000 cal yr B.P.) (Oviatt and others, 2003).

In the north-central part of the quadrangle, the Stockton Bar developed as a transverse barrier bar and spit complex between Tooele and Rush Valleys (Gilbert, 1890; Burr and Currey, 1988, 1992). Geomorphic surface lines on plate 1 help show the extent of the landforms. Rush Valley contains the Bonneville-level shoreline and two sets of regressive-phase shorelines. These shorelines were described by Burr and Currey (1988, 1992) in conjunction with the Stockton Bar. The construction of the Stockton Bar (during the Bonneville transgression) caused the lake in Rush Valley to be isolated from the main body of Lake Bonneville. During the regression from the Bonneville highstand, the lake level in Rush Valley varied independently of the level in the rest of the Bonneville basin. The higher elevation shorelines present in Rush Valley are attributed to Lake Shambip, about 5050 feet (1540 m) in elevation, and Lake Smelter, about 5010 feet (1527 m) in elevation (Burr and Curry, 1988, 1992), but do not coincide in elevation with the Provo level of Lake Bonneville or the Gilbert episode. These shorelines are higher than the possible equivalents in the main lake and radiocarbon dating by Nelson (2012) indicates that the Lake Shambip level is partially time-equivalent to the Provo lake level. There is no direct age constraint on the Lake Smelter level, but based on map relations this shoreline is developed on regressive deposits that indicate at least a post-Lake Shambip (or Provo level) age.

In Cedar Valley, McKean (2020) reported a Cedar Valley shoreline below the Bonneville highstand shoreline at an elevation of about 4900 feet (1494 m). Impounded lake water drained through outlets on the north and south ends of that valley. Currently, there are few age constraints. Geomorphic surface lines on plate 1 show the probable lake outlet.

Qdg **Deltaic gravel** (upper Pleistocene) – Sand and gravel deposited near the mouth of the Sevier River in the Old River Bed area during the Bonneville lake cycle; well-sorted pebbly sand containing volcanic and sedimentary pebbles; cross-bedded and very thick bedded; regressive deposits were locally reworked by waves into a thin sheet with delta ridge crests; thickness to 50 feet (15 m).

Ql **Lacustrine deposits, undivided** (upper Pleistocene) – Lacustrine sand, silt, clay, and pebble gravel mapped solely as stacked unit Ql/Tv.

Qlg **Lacustrine gravel** (upper Pleistocene) – Sandy gravel to boulders composed of locally derived rock fragments deposited in shore zones of transgressive and regressive phases of Lake Bonneville and related lakes; clasts are typically well rounded and sorted; locally tufa-cemented (especially the Provo shoreline, figure 2) and draped on bedrock; thickness variable, to 100 feet (30 m) or more.

Qls **Lacustrine sand** (upper Pleistocene) – Sand and silt deposited by transgressive and regressive phases of Lake Bonneville; generally thick bedded and well sorted; typically grades downslope to finer-grained lacustrine deposits; thickness to 100 feet (30 m) or more.

Qlf **Lacustrine fine-grained deposits** (upper Pleistocene) – Sand, silt, marl, and calcareous clay of Lake Bonneville; thin to very thick bedded; may include ostracode- and gastropod-rich layers; locally includes the white marl of Gilbert (1890); locally may include small areas of sand and gravel; can include thin eolian sand deposits at surface; thickness to 100 feet (30 m) or more.

Lacustrine Deposits (pre-Lake Bonneville)

Qlo **Older lacustrine deposits** (middle and lower Pleistocene) – Subsurface only and lower part of stacked unit Qpm/Ql; mud and sand; Qlo contains lacustrine ostracodes (*Limnocythere staplini*); present in sediment core GG-19A located southwest of Wildcat Mountain on UTTR-S (C.G. Oviatt, unpublished data, November 25, 2020) and also from a Parsons core (PM-11) near the Carr facility on Dugway Proving Ground (per Oviatt); also present to the northwest in several sediment cores in the Bonneville Salt Flats 30' x 60' quadrangle (Oviatt and Thompson, July 25, 1995, unpublished evaluation of Knolls and Wendover cores; Oviatt and others, 2020; Clark and others, 2020a); Williams (1994) reported ash beds from this unit that provide age control from about 0.2 to 1.15 Ma; may overlie Pliocene? deposits, Pliocene-Miocene Salt Lake Formation, and other Tertiary rock units; incomplete thickness in core GG-19A is 2 feet (0.6 m) (Oviatt, unpublished data), greater than 560 feet (170 m) thick in the Wendover core, and greater than 495 feet (151 m) thick in the Knolls core (Oviatt and Thompson, July 25, 1995, unpublished evaluation of Wendover and Knolls cores).

Glacial Deposits

Qgt, Qgt?

Glacial till (upper to middle? Pleistocene) – Poorly sorted, angular, boulder to pebble gravel, sand, and mud in eroded moraines within and just below cirque basins in the southern Stansbury Mountains and southern Oquirrh Mountains; locally includes glacial outwash, unmapped landslides, and some small areas of younger alluvium and colluvium; deposits are undated, but till is likely associated with the younger Pinedale/Angel Lake glaciation, ~12 to 24 ka, and possibly the older Bull Lake/Lamoille glaciation (associated with Marine Oxygen Isotope Stage 6), ~ 130 to 190 ka (Lisiecki and Raymo, 2005; Laabs and Monroe, 2016; Pierce and others, 2018; Quirk and others, 2018, 2020); older till may be present downslope of the younger till; Osborn and Bevis (2001) reported on glacial deposits at the Stansbury and Oquirrh Mountains, and also see Rigby (1958), Valora (1968), Sorensen (1982), Mulvey (1985), and Laabs and others (2011); nivation hollows are present in the northern Simpson Mountains, but no obvious glacial deposits were noted there; note above that different glacial terminology has been used in the Great Basin versus the Middle Rocky Mountains Province; probably as much as 50 feet (15 m) thick.

Colluvial Deposits

Qc **Colluvium** (Holocene to upper Pleistocene) – Fine- to coarse-grained sediment derived from local bedrock; commonly includes talus in upper parts of deposits; may locally include lacustrine, alluvial, or eolian deposits; thickness to 20 feet (6 m) or more.

Mass-Movement Deposits

Qmtc **Talus and colluvium** (Holocene to upper Pleistocene) – Mixed talus and colluvium locally present on Tabbys Peak of Cedar Mountains, Camels Back Ridge, and the Stansbury and Oquirrh Mountains; thickness to 15 feet (5 m) or more.

Qms, Qms?

Landslide deposits (Holocene to middle? Pleistocene) – Poorly sorted clay- to boulder-size debris, and large, displaced bedrock blocks; generally characterized by hummocky topography, main and internal scarps, and chaotic bedding in displaced bedrock; undivided as to inferred age because research has shown that even landslides with subdued morphology (suggesting they are older and have not moved recently) may continue to creep or are capable of renewed movement (Ashland, 2003); age and stability determinations require detailed geotechnical investigations; thickness highly variable.

Mixed-Environment Deposits

Qla, Qla?

Lacustrine and alluvial deposits, undivided (Holocene to upper Pleistocene) – Sand, gravel, silt, and clay; consists of alluvial deposits reworked by lakes, lacustrine deposits reworked by streams and slopewash, and alluvial and lacustrine deposits that cannot be readily differentiated at map scale; grade into other lacustrine and alluvial deposits; locally includes areas of thicker alluvial-fan deposits at surface in western Skull Valley; thickness locally exceeds 30 feet (10 m).

Qac **Alluvial and colluvial deposits, undivided** (Holocene to upper Pleistocene) – Primarily gravel, with sand, silt, and clay; present within upland valleys and along bases of slopes; also forms aprons of mixed alluvial-fan and colluvial surfaces that grade into alluvial-fan deposits; locally grades into other deposits; thickness generally less than 20 feet (6 m).

Human-Derived Deposits

Qh **Human disturbance** (historical) – Deposits and disturbed areas from development; includes several disturbed areas at Dugway Proving Ground and Tooele Army Depot (South Area); also mapped at landfills on Skull Valley Indian Reservation and at Cedar Valley, several pits and quarries, tailings area north of Stockton Bar, and disturbances associated with mining districts (including Stockton, Bald Mountain, Ophir, Mercur, Fivemile Pass, East Tintic); many smaller or less prominent disturbed areas are not shown; thickness highly variable.

Qhm **Mine dumps** (historical) – Unconsolidated mine waste rock at the south end of the Kennecott/Rio Tinto Bingham Canyon mine; these mine dump areas are depicted on the map as patterned polygons (see geologic symbols) to show the underlying geology; mine dumps are principally coarse rock fragments with lesser sand- and silt-size particles; locally includes small disturbed areas; other smaller mine dumps and mining-disturbed areas are included in unit Qh; mine dump thickness is highly variable, but locally exceeds 200 feet (60 m).

Stacked-Unit Deposits

Consist of thin surficial deposits covering underlying surficial and bedrock map units. The stacked units are limited here due to map scale considerations. Thin surficial deposits may also be present on other geologic units throughout the map area.

Qei/unit (Qei/Qal, Qei/Qlf)

Eolian silt over unit (Holocene over Holocene to upper Pleistocene) – Eolian silt and minor sand forming a mantle on other surficial deposits, particularly at Dugway Proving Ground; Qei/Qlf surface commonly contains distinctive vegetation stripes of uncertain origin but that are characteristic landforms of sheetflow plains in arid to semiarid regions (Oviatt and others, 2003); cover unit thickness typically less than 10 feet (3 m).

Qes/unit (Qes/Qafy, Qes/Qafo, Qes/Qlf, Qes/Qla)

Eolian sheet sand over unit (Holocene over Holocene to upper to middle? Pleistocene) – Eolian sheet sand forming a mantle on other surficial deposits, particularly at Dugway Proving Ground and Skull Valley; cover unit thickness typically less than 15 feet (5 m).

Qed/unit (Qed/Qlf, Qed/Qla, Qed/Tac)

Eolian dune sand over unit (Holocene over upper Pleistocene, middle Eocene) – Eolian dune sand forming a mantle on other surficial deposits and rock units near Dugway Proving Ground; cover unit thickness typically less than 15 feet (5 m).

Qe/Qlf

Eolian deposits over lacustrine fine-grained deposits (Holocene over upper Pleistocene) – Windblown sand and silt deposited in sheets and dunes overlying lacustrine silt, clay, marl, and some sand; present at Skull and Cedar Valleys; cover unit thickness typically less than 10 feet (3 m) thick.

Qpm/Ql

Playa mud over undivided lacustrine deposits (Lake Bonneville) over older lacustrine (pre-Bonneville) deposits (Holocene over upper Pleistocene over Pleistocene) – Three stacked subunits that generally comprise the extensive mudflats of the Great Salt Lake Desert, and here mapped at one small area on the west edge of the map area in the Government Creek basin; upper playa deposits of silt, mud and calcareous mud (commonly mixed eolian, alluvial, and mudflat environments) covering lacustrine marl and fine-grained deposits of Lake Bonneville (unit Qlf), which collectively overlie pre-Bonneville deposits of lacustrine mud and sand (unit Qlo); playa deposits are mud that is locally saline or gypsiferous and locally covers post-Lake Bonneville alluvial channels (see Clark and others, 2016, 2020a); the Lake Bonneville fines (Qlf) subunit was differentiated by lithologies and ostracode fauna (C.G. Oviatt, November 25, 2020, unpublished data from sediment cores WB-19A and GG-19A located about 7 miles [11 km] southwest of Wildcat Mountain on UTTR-South); the pre-Bonneville subunit (Qlo) was differentiated by lithologies and ostracode fauna (Oviatt, unpublished data on core GG-19A; Oviatt and others, 2020; Clark and others, 2020a); an unconformity may exist between subunits Qlf and Qlo; unit Qpm/Ql was previously mapped in adjacent areas as eolian and alluvial deposits over lacustrine fines (Clark and others, 2016); subunit thicknesses include playa mud of about 1 inch (3 cm), Lake Bonneville fines of 5.6 feet (1.7 m), and incomplete pre-Bonneville deposits that exceed 2 feet (0.6 m) (Oviatt, unpublished data from core GG-19A); unit Qpm/Ql thickness locally exceeds 560 feet (170 m) several miles to the northwest near the Bonneville Salt Flats (Clark and others, 2020a).

Qlf/Qls **Lacustrine fine-grained deposits over lacustrine sand deposits** (upper Pleistocene over upper Pleistocene) – Thin marl and reworked marl overlying deltaic sediments of mostly sand and some fine gravel deposited near the Stansbury shoreline; sandy beach ridges (distributary mouth bars) were formed by longshore sediment transport (Currey, 1996, in Geomatrix, 2001), and were previously mapped as faults by Sack (1993); mapped in one area at the north side of Hickman Knolls on the Skull Valley Indian Reservation; cover unit thickness to 6 feet (2 m) or more.

Ql/Tv **Lacustrine deposits over undivided Tertiary volcanic rocks** (upper Pleistocene over Miocene to Oligocene) – Lacustrine (Lake Bonneville) sand, silt, clay, and pebble gravel over subangular to rounded pebble to boulder float dominated by Mosida Basalt and Soldiers Pass Formation lava, breccia, limestone, travertine, and sedimentary clasts; cover unit of undivided lacustrine deposits is 0 to 20 feet (6 m) thick.

Qlg/rx **Lacustrine gravel over undivided bedrock** (upper Pleistocene over Miocene? to Cambrian?) – Sandy and pebbly gravel overlying various bedrock units at the southern Cedar Mountains and Camels Back Ridge; locally includes small bedrock exposures; cover unit thickness typically less than 15 feet (5 m).

QTaf/Tslc

High-level fan alluvium over Salt Lake Formation, conglomerate lithosome (lower Pleistocene? to Pliocene? over Pliocene? to Miocene) – Quartzite-clast gravel overlying conglomerate unit (described below) at east flank of southern Stansbury Mountains at the north edge of the map area; difficult to differentiate units readily at this map scale; thickness of cover unit QTaf increases eastward and is from 0 to about 350 feet (105 m).

TERTIARY (NEOGENE-PALEOGENE) ROCK UNITS

Tv Tertiary volcanic rocks, undivided – Cross sections only.

Tj **Jasperoid** (Tertiary) – Siliceous breccia, commonly dark red to dark reddish brown or moderate gray; probably formed as hydrothermal fluids associated with older Tertiary volcanism altered host rocks; typically occurs as ledges, pods, and rubbly exposures; only larger exposures mapped at Davis Mountain, northern Sheeprock Mountains, Vernon Hills, northern East Tintic Mountains, and southern Oquirrh Mountains; variable thickness.

Tsl, Tsl?, Tslc

Salt Lake Formation (Pliocene? to Miocene) – Tertiary rocks mapped at four areas: (1) southern Skull Valley, (2) South Willow Canyon area of the Stansbury Mountains, (3) central Rush Valley, and (4) Tickville Gulch, west Traverse Mountains. ***Skull Valley***, map unit is queried in a single outcrop of charophytic marl and limestone along State Road 196 north of Dugway, with an exposed thickness of 30 feet (10 m); to the north at the proposed Private Fuel Storage site (located on Skull Valley Indian Reservation north of Hickman Knolls) trenching exposed predominantly claystone and tuffaceous siltstone with interbeds of siliceous vitric ash (tuff) and minor gravelly sandstone with ash correlation ages of about 3 to 4 Ma and 6 Ma (unknown tephras; younger tephras may not be related to Tsl) and 6.31 ± 0.04 Ma (Walcott tuff) (Stone & Webster Engineering Corporation, 1997; Geomatrix, 2001; M.E. Perkins, University of Utah, written communication, November 18, 2009) (table A4); maximum subsurface thickness encountered in Skull Valley is about 90 feet (27 m), and total thickness is unknown, but may be up to several thousand feet. ***Southern Stansbury Mountains***, South Willow Canyon (unit Tslc, conglomerate lithosome; mapped as QTaf/Tslc) exposures are interbedded conglomerate and tuffaceous sandstone that weather rusty orange to light gray with carbonate, igneous, and quartzite pebbles in a fine sandy calcareous matrix (Rigby, 1958; Copfer and Evans, 2005); poorly exposed except in steep south canyon wall; Slentz (1955) measured sections in South Willow Canyon and Davenport Canyon (north of map area); Perkins and others (1998) geochemically correlated a tephra there to the Cougar Point Tuff unit XIII ash, which has an $^{40}Ar/^{39}Ar$ age of 10.94 ± 0.03 Ma (table A4); exposed thickness to about 1000 feet (300 m) (Copfer and Evans, 2005), but total thickness is unknown. ***Rush Valley*** outcrops include varied lithologies of tan, pale-gray, and white interbedded tuffaceous sandstone, limestone, calcareous sandstone, gritty or pebbly sandstone, sandy mudstone, siltstone, marl and claystone; locally the tuffaceous sandstone is poorly consolidated water-lain sandy ash in intervals 60 to 100 feet (23–30 m) thick; forms mostly slopes with some ledges; yielded several tephra correlation and interpolation ages from 6.31 to 9.8 Ma (table A4) (Perkins and others, 1998); new U-Pb detrital zircon age from a sample in southern Rush Valley yielded an age of 6.49 ± 0.38 Ma (table A4) (Kirby, 2013b; Utah Geological Survey and Apatite to Zircon, Inc. [UGS and AtoZ], 2013); unit is up to 4200 feet (1280 m) thick in Rush Valley (Kirby, 2010a, 2013c). ***Tickville Gulch*** exposures include areas with two samples of Walcott ash (unit QTaf of Biek and others, 2005) (table A4); thickness unknown. Regional ages of the Salt Lake Formation extend from about 4 to 16 Ma (Oaks and others, 1999; Perkins and Nash, 2002; M.E. Perkins, formerly University of Utah, written communication, August 2, 2010;). Unit Tsl is unconformable on Tertiary volcanic and sedimentary rocks and older bedrock strata.

Tso, Tso?

Older Tertiary strata (upper? to middle Eocene) – Lithologically diverse Eocene sedimentary strata mapped as patchy exposures across the quadrangle; interbedded conglomerate, sandstone, mudstone, siltstone, limestone, and tuffaceous sandstone in various shades of red, orange, tan, brown, and gray; conglomerate contains rounded to subangular pebbles, cobbles, and boulders of quartzite, sandstone, carbonate, and black chert, and is commonly crudely bedded; limestone is micritic and locally oncolitic; unit is locally silicified; includes small exposure of Oquirrh Group breccia at the Vernon Hills (Kirby, 2010a); crops out as slopes and ledges; unit Tso is interlayered with volcanic units Tvfou and Tvlo (~39 Ma) near Butterfield Canyon in southern Oquirrh Mountains; new U-Pb detrital zircon ages of 46.77 ± 1.28 Ma from Davis Knolls and 38.70 +0.28/-0.62 Ma from Vernon Hills (table A5) (UGS and AtoZ, 2013) indicate maximum depositional ages for the unit there; unit is queried in other areas with no age control; Clark and others (2020b) obtained a 40 Ma detrital zircon age at the northern Oquirrh Mountains; unit Tso is unconformable on older bedrock units; thickness variable, but locally exceeds 2200 feet (>670 m) thick at Davis Knolls (Disbrow, 1961; Harrill, 1962; Moore and Sorensen, 1977; Biek and others, 2005; Copfer and Evans, 2005; Biek, 2006a; Kirby, 2010a, 2010b; Clark and others, 2016, 2020b; this study).

Igneous Rocks

We mapped 44 Tertiary volcanic rock units which we separate into four groups by geographic location for descriptive purposes: (1) western area – includes southern Cedar Mountains, Simpson Springs, southern Stansbury Mountains, (2) northeastern area – includes southern Oquirrh Mountains, South Mountain, and western Traverse Mountains, (3) Vernon Hills, and (4) northern East Tintic Mountains. Geochemical and radiometric age data are discussed as follows.

Igneous rock types, based on total alkali-silica concentrations (see classifications of Le Bas and others, 1986; Middlemost, 1994), range from rhyolite to basalt and trachybasalt through trachydacite (table A6, figure 6). The igneous rocks of the western area range in composition from andesite and trachyandesite to rhyolite. Igneous rocks of the northeastern area are trachyandesite and andesite to rhyolite with significantly less basalt and basaltic andesite. Igneous rocks at the Vernon Hills are mostly rhyolite with additional units that also include dacite and basaltic andesite. The igneous rocks at the northern East Tintic Mountains span a range of geochemistry that includes basalt or trachybasalt to rhyolite. Geochemical data from past research in the map area are voluminous and compilation of all the data is beyond the scope of this project. Therefore, we present selected (representative) geochemical data for the map area in table A6 and figure 6. For additional data, refer to Davis (1959), Waite and others (1997), Biek (2006b), and McKean and others (2013).

The ages of igneous rocks in the Rush Valley quadrangle (excluding unit Tsl) range from 41.1 to 19.6 Ma (Eocene to Miocene, table A7). Ages for rock units are shown on figure 7 and symbolized by area; sample age is plotted west-to-east to show spatial trends in volcanic activity across the quadrangle. The oldest dated volcanic rocks in the quadrangle are in the Cedar Mountains area in the western part of the quadrangle. The youngest dated volcanic rocks are at the northern East

Tintic Mountains. Igneous rocks in the East Tintic area also span the greatest age range extending back to approximately 36 Ma. Ages partially overlap for many of the igneous rock units at the Vernon Hills, East Tintic, Bingham-Mercur-Ophir-Stockton, and Stansbury areas.

For additional information on the volcanic history of parts of the map area see Moore (1973b), Moore and McKee (1983), Swenson (1975), Deino and Keith (1997), Waite and others (1997), Maughan and others (2002), Krahulec (2005), Biek, (2006a, 2006b), Christiansen and others (2007), Clark (2008, 2015), McKean (2011), Allen (2012), Christiansen and others (2013), McKean and others (2013), Clark and others (2016, 2020b), and references therein.

Volcanic Rocks of the Southern Cedar Mountains, Davis Knolls, Northern Simpson Mountains, Northern Sheeprock Mountains, and Southern Stansbury Mountains (Western Area)

Trdc **Rhyodacite of Cherry Springs** (upper Eocene) – Light-green dacitic ash-flow tuff that is moderately welded with phenocrysts (~30%) of plagioclase, quartz, sanidine, and biotite, and also pumice lapilli and volcanic rock fragments to 2 inches (5 cm) diameter; poorly exposed near Simpson Springs, northwestern Simpson Mountains; correlates geochemically to rhyodacite of Cherry Springs (Yambrick, 1990) (table A6); Yambrick (1990) reported an $^{40}Ar/^{39}Ar$ plateau age of 35.05 ± 0.15 Ma on K-feldspar; unit also includes small exposures of probable andesite lava near Simpson Springs; maximum exposed thickness is about 100 feet (30 m).

Trj, Trj?

Rhyolite of Judd Creek (upper Eocene) – Light-gray to light-pink and locally light-green rhyolitic ash-flow tuff that is moderately to densely welded with phenocrysts (~25%) of plagioclase, quartz, and biotite; forms blocky exposures at Simpson Canyon, northwestern Simpson Mountains; underlies unit Taf just south of the quadrangle along the southwest flank of the Sheeprock Mountains; we correlate geochemically to rhyolite of Judd Creek (Yambrick, 1990) (table A6); Yambrick (1990) reported $^{40}Ar/^{39}Ar$ plateau ages of 35.46 ± 0.15 and 35.88 ± 0.15 Ma on biotite; maximum exposed thickness is 210 feet (65 m).

Tlg, Tlg?

Latite of Government Creek (upper to middle Eocene?) – Moderate-gray, latitic lava flow that is aphanitic with a few percent plagioclase and biotite phenocrysts; upper part is locally vesicular in a rubbly matrix; some blocky outcrops near Government Creek between Davis Mountain and Simpson Mountains; does not appear to geochemically correlate to rocks of the eastern Simpson Mountains area (Yambrick, 1990) (table A6); no age data, but may underlie unit Trj; exposed thickness is 40 feet (12 m) or less.

Trr **Rhyolite of Rydalch Canyon area** (middle Eocene) – Light-gray and very pale orange rhyolitic ash-flow tuff and intrusion exposed south and east of Rydalch Canyon in southern Cedar Mountains; contains about 25% phenocrysts of plagioclase, sanidine, quartz, hornblende, and biotite; forms slopes and blocky to ledgy exposures; K.A. Krahulec (UGS, verbal communication, 2014) reported the central part of exposure may be a stock; $^{40}Ar/^{39}Ar$ age of 39.18 ± 0.06 Ma on sanidine (Utah Geological Survey and Nevada Isotope Geochronology Lab [UGS and NIGL], 2012b); exposed tuff thickness to 650 feet (200 m) (Clark and others, 2016).

Tid **Dacitic intrusions of Little Granite Mountain and White Rock** (middle Eocene) – Light-gray weathering to white and yellowish-gray porphyritic dacite stock and plugs with phenocrysts (~25%) of plagioclase, quartz, biotite, and amphibole (0.5–2 mm long average); groundmass is intergrowth of plagioclase, potassium feldspar, and quartz (Maurer, 1970; Moore and Sorensen, 1977); $^{40}Ar/^{39}Ar$ ages of 38.69 ± 0.10 Ma (sanidine) for White Rock, and 39.56 ± 0.10 Ma (biotite) and 40.95 ± 0.32 Ma (hornblende) for Little Granite Mountain (Utah Geological Survey and New Mexico Geochronology Research Laboratory [UGS and NMGRL], 2009a, 2009b); exposures to 9500 feet (2900 m) across (Clark and others, 2016).

Tac **Andesitic and dacitic rocks of southern Cedar Mountains** (middle Eocene) – Dark- to light-gray and pale-red lava flows interlayered with lahars, block-and-ash flows, and tuffs; lava flows are porphyritic to aphanitic, with phenocrysts of plagioclase, quartz, and biotite; lahars and block-and-ash flows contain clasts of intermediate volcanic rocks up to 4 feet (1 m) across; variably welded ash-flow tuffs contain phenocrysts of plagioclase, hornblende, and biotite; calc-alkaline affinities are similar to those of other Oligocene-Eocene rocks in the region (Clark, 2008, 2015); forms slopes to cliffs; erupted from local vents mapped as Tiac; $^{40}Ar/^{39}Ar$ age of 38.17 ± 0.47, and ages (from adjacent map area) of 40.66 ± 0.45 (groundmass) and 41.73 ± 0.24 Ma (hornblende) (UGS and NMGRL, 2009b; Clark and others, 2016); exposed thickness to 1200 feet (370 m) (Clark and others, 2016).

Tiac **Andesitic intrusions of southern Cedar Mountains** (middle Eocene) – Dark-gray porphyritic to aphanitic andesitic intrusions associated with local vents for extrusive calc-alkaline volcanic rocks (unit Tac); contains phenocrysts of plagioclase, hornblende, and lesser biotite; columnar jointing of exposures common; $^{40}Ar/^{39}Ar$ age of 40.61 ± 0.78 Ma (groundmass) from Tabbys Peak (UGS and NMGRL, 2009b); exposures to 1600 feet (490 m) across (Clark and others, 2016).

Tvs **Rhyolitic to andesitic volcanic rocks of Stansbury Mountains** (middle Eocene) – Interlayered volcanic and volcaniclastic rocks including gray to red to brown lava flows, ash-flow tuffs, block-and-ash flows, lahars, and tuffaceous sandstone; coarser deposits contain clasts of intermediate volcanic rocks (see Davis, 1959; Clark and others, 2020b); previously called latite volcanic series (Rigby, 1958) and andesites and associated rocks (Davis, 1959); unit Tvs forms slopes, ledges, and cliffs in South Willow Canyon area of Stansbury Mountains; new geochemical data show a compositional range from rhyolite to dacite, trachydacite, andesite, and latite (table A6) (Clark and Biek, 2017); radiometric ages (K-Ar and $^{40}Ar/^{39}Ar$) from 39.4 to 41.8 Ma were obtained north of the map area (Moore and McKee, 1983; UGS and NIGL, 2017); exposed thickness to about 800 feet (245 m) in map area.

Volcanic Rocks of the Southern Oquirrh Mountains, South Mountain, and Western Traverse Mountains (Northeastern Area)

These rocks are present at and near the Bingham, Stockton (Rush Valley), Ophir, and Mercur mining districts. Bingham district rocks were divided into four informal compositional suites by Waite (1996) and Waite and others (1997): (1) younger volcanic suite, (2) older volcanic suite, (3) nepheline minette-shoshonite suite (within the older volcanic suite), and (4) Bingham intrusive suite. Biek and others (2005) and Biek (2006a) informally referred to the younger suite as the "volcanic and intrusive rocks of the west Traverse Mountains," and combined the latter three suites as the "volcanic and intrusive rocks of the Bingham Canyon Suite." We also group the igneous rocks into younger and older suites, and further separate the suites into extrusive and sedimentary rocks, and intrusive rocks. Older suite rocks are largely comagmatic with the Bingham intrusive complex (Waite and others, 1997) and contain significantly higher chromium and barium concentrations and more magnetic minerals than the younger suite (Pulsifer, 2000). The terminology for the intrusive rocks of the Bingham district (after Lanier and others, 1978) is based on historical usage at the Bingham mine (for the purpose of separating similar rock units); it is entrenched and does not necessarily reflect their geochemical compositions and newer geochemical-based rock classifications. For geochemical and age data, see Moore (1973a, 1973b), Waite (1996), Waite and others (1997), Pulsifer (2000), Maughan (2001), Maughan and others (2002), Biek and others (2005), and Biek (2006b); also refer to tables A6 and A7.

Younger Volcanic and Intrusive Suite (lower Oligocene to upper Eocene, ~30–37 Ma)

<u>Younger Extrusive and Sedimentary Rocks</u>

Tvbs **Younger volcanic breccia** (lower Oligocene) – Dark-gray to black, angular to subangular, pebble- to boulder-size clasts of monolithic, intermediate-composition volcanic rocks set in a well-lithified matrix of reddish-brown devitrified glass and lithic and crystal fragments (called block and ash-fall tuff by Biek and others, 2005); clasts generally make up more than 50% of the rock and contain phenocrysts of plagioclase, hornblende, and biotite in dark-gray to black glassy matrix; forms broad sloping surface of South Mountain and Black Ridge at the west Traverse Mountains; K-Ar age on clast of 30.7 ± 0.9 Ma (Moore, 1973a); thickness to 300 feet (90 m) (Biek and others, 2005).

Tvfs **Younger lava flows** (lower Oligocene) – Intermediate-composition lava flows that are strongly flow foliated (typically subvertical indicating possible vent area) with reddish-brown and dark-gray to black layering; underlies and compositionally identical to volcanic breccia unit (Tvbs) at South Mountain in the west Traverse Mountains; no radiometric age data, but underlies unit Tvbs; maximum exposed thickness likely exceeds 1000 feet (300 m) (Biek and others, 2005).

Tvfb **Intermediate lava flows of Black Ridge** (lower Oligocene) – Dark-gray to pinkish-gray, porphyritic, intermediate-composition lava flows with common phenocrysts of plagioclase and rare to common biotite and hornblende; locally flow banded; forms boulder-covered slopes; likely derived from volcanic centers of west Traverse Mountains including South Mountain, Step Mountain, and nearby smaller vents; no radiometric age data, but overlies unit Tvbb; exposed thickness may exceed 600 feet (180 m) (Biek and others, 2005).

Tvbb **Block-and-ash flows and lahars of Black Ridge** (lower Oligocene) – Pebbles to boulders of intermediate-composition volcanic rocks and uncommon quartzite pebbles in a matrix of white to light-gray crystal lithic tuff; contains some thin, poorly exposed lava flows; forms poorly exposed slopes covered with resistant volcanic clasts at Black Ridge area of west Traverse Mountains; $^{40}Ar/^{39}Ar$ ages from near base of unit are 31.68 ± 0.24 Ma from adjacent map area (Biek, 2005) and 32.12 ± 0.14 Ma (Deino and Keith, 1997); maximum thickness likely exceeds 1000 feet (300 m) (Biek and others, 2005).

Trf **Rhyolitic lava flows of Tickville Gulch** (lower Oligocene) – Rhyolite lava flows with vitrophyres and lesser blocky flow breccia of green, pink, white, and black colors; lava flows contain phenocrysts of biotite and plagioclase in a glassy groundmass and are locally altered and chalky; probably erupted from concealed vent near Tickville Wash; K-Ar age of 31.2 ± 0.9 Ma (Moore and others, 1968; Moore, 1973a); thickness may exceed 1500 feet (460 m) (Biek and others, 2005).

Tvfa **Basaltic andesite lava flow** (lower Oligocene) – Dark-gray, very fine grained basaltic andesite flow with abundant reddish-brown cinders and local volcanic bombs; contains small olivine phenocrysts altered to iddingsite; forms deeply eroded vent area at Camp Williams; somewhat disturbed $^{40}Ar/^{39}Ar$ age of 32.86 ± 0.48 Ma (Biek and others, 2005); exposed thickness to 120 feet (35 m) (Biek and others, 2005).

Younger Intrusive Rocks

Tido **Dacitic dike** (early Oligocene) – Light-gray dacite porphyry with phenocrysts of plagioclase, hornblende, and biotite in a fine-grained matrix; present near Oak Springs Hollow of western Traverse Mountains; $^{40}Ar/^{39}Ar$ age of 32.05 ± 0.13 Ma on biotite (Biek and others, 2005); 75 to 90 feet (23–27 m) thick (Biek and others, 2005).

Tir **Rhyolitic intrusions** (early Oligocene? to middle Eocene) – Rhyolitic intrusions of Shaggy Peak (Rose–Butterfield Canyon area), Tickville Gulch area, Mercur (Eagle Hill area), and Ophir–Bald Mountain area. ***Shaggy Peak*** plug or dome is light- to medium-gray porphyritic rhyolite that contains a border phase with abundant plagioclase, quartz, and biotite phenocrysts and generally near-vertical flow foliations, and an interior phase with slightly larger phenocrysts and little or no flow foliation (Biek, 2006a); $^{40}Ar/^{39}Ar$ age of 35.49 ± 0.13 Ma on sanidine (Biek and others, 2005). ***Tickville Gulch*** intrusion is white, altered and chalky weathering, with common phenocrysts of quartz. ***Mercur and Ophir area*** Eagle Hill Rhyolite and rhyolite of Ophir–Bald Mountain area is white, tan, and pink rhyolite and rhyolite porphyry that is usually aphanitic with <20% phenocrysts of quartz, plagioclase, and rare biotite; locally flow banded and brecciated; occurs as stocks, necks, dikes and sills (Gilluly, 1932; Mako, 1999); geochemical data suggests Mercur and Ophir area rhyolites are different (E.H. Christiansen, Brigham Young University, written communication, May 13, 2014); new $^{40}Ar/^{39}Ar$ isochron age on biotite of 32.38 ± 0.10 Ma from Mercur (UGS and NIGL, 2012b); U-Pb zircon age for a rhyolite dike is 36.46 ± 1.40 Ma from Ophir (table A5) (Kirby, 2012).

Tia **Andesitic intrusion** (late Eocene) – Medium-gray andesite porphyry with abundant plagioclase phenocrysts and common hornblende and minor biotite in a medium-grained matrix; forms resistant plug that includes two dikes with subhorizontal, columnar cooling joints at Step Mountain near mouth of Rose Canyon (Biek, 2006a); $^{40}Ar/^{39}Ar$ age of 36.26 ± 0.18 Ma (Biek and others, 2005).

Older Volcanic and Intrusive Suite (middle Eocene, ~37–41 Ma)

Older Extrusive and Sedimentary Rocks

Tvfo **Nepheline minette and shoshonite lava flows** (upper to middle Eocene) – Dark-gray minette lava flows that vary from including abundant phenocrysts of olivine and minor phlogopite and pyroxene to including minor olivine and more abundant phlogopite and pyroxene; also includes pale-red, aa-type, shoshonite and olivine latite lava flows with abundant small phenocrysts of olivine, pyroxene, and biotite (Maughan and others, 2002; Biek and others, 2005); poorly exposed near the Rose–Butterfield Canyon area of Oquirrh Mountains; minette $^{40}Ar/^{39}Ar$ age of 37.82 ± 0.14 Ma (Deino and Keith, 1997); exposed thickness to 150 feet (45 m) (Biek and others, 2005).

Tvfou **Older intermediate lava flows** (middle Eocene) – Dark-gray lava flows of intermediate composition derived from Bingham intrusive complex; may locally include small areas of lahars and fluvial deposits; interlayered with and difficult to differentiate from unit Tvbo; present between Butterfield and Rose Canyons; geochemical data in Clark and Biek (2017); interlayered with unit Tso near Butterfield Canyon, and $^{40}Ar/^{39}Ar$ age of 38.17 ± 0.09 Ma from recycled volcanic clast (Deino and Keith, 1997), but no direct age data; exposed thickness likely exceeds 1000 feet (300 m) (Biek and others, 2005).

Tvbo **Older block-and-ash flows and lahars** (middle Eocene) – Gray to white pebbles to boulders of intermediate-composition volcanic rocks in a matrix of lithic and crystal fragments; locally contains mostly mafic clasts or lenses of quartzitic and calcareous sandstone clasts derived from Oquirrh Group strata; contains some thin, discontinuous lava flows of intermediate composition (Maughan and others, 2002; Biek and others, 2005); generally forms rubbly slopes between Butterfield and Rose Canyons and along the south flank of the Bingham mine, and on the northeast flank of South Mountain (western Traverse Mountains); Bingham area $^{40}Ar/^{39}Ar$ ages of 38.68 ± 0.13 Ma from water-lain tuff near top of unit (Maughan, 2001) and 39.18 ± 0.11 Ma from clast near base of unit (Deino and

Keith, 1997); also interlayered with unit Tso near Butterfield Canyon; called debris avalanche and lahar deposits by Waite and others (1997) and older lahars and debris avalanches by Clark and others (2020b); thickness may exceed 4000 feet (1200 m) (Biek and others, 2005).

Older Intrusive Rocks

Tdmo **Mafic dikes** (late or middle Eocene?) – Two heavily altered and poorly exposed lamprophyre dikes at Lion Hill near Ophir; Gilluly (1932) described samples from mine workings that consist primarily of altered biotite and olivine; no geochemical or direct age data exist; dikes have a north-south orientation; based on cross-cutting relations, unit Tdmo is older than Tir dikes; dikes are 1 to 4 feet (0.3–1 m) wide (Kirby, 2012).

Tipqm **Porphyritic quartz monzonite intrusions** (late to middle? Eocene) – Intrusions at the former Lark townsite and Porphyry Hill area. ***Lark intrusion*** is light- to medium-gray dacite (granodiorite) porphyry (porphyritic amphibole-biotite quartz monzonite) with abundant phenocrysts of plagioclase, orthoclase, biotite, and lesser hornblende in a fine-grained groundmass; typically weathers to grussy or clayey soils; present near mouth of Butterfield Canyon near former Lark townsite (Laes and others, 1997; Biek and others, 2005, 2007); geochemical data in Clark and Biek (2017); prior K-Ar ages from Bingham tunnel portal (adjacent to map area) of 36.9 ± 0.9 Ma (hornblende) and 36.9 ± 1.0 Ma (biotite) (Moore and others, 1968). ***Porphyry Hill*** area intrusions are medium-gray quartz monzonite porphyry with small phenocrysts of K-feldspar, plagioclase, biotite, and quartz in a fine-grained groundmass of predominantly K-feldspar; present as small dikes and sills at Porphyry Hill and Porphyry Knob north of Mercur (Mako, 1999); K-Ar age of 36.7 ± 0.5 Ma from Porphyry Hill (Moore and McKee, 1983).

Tiqmp **Quartz monzonite porphyry intrusion** (middle Eocene?) – Altered part of the Soldier Canyon stock that is a grayish-brown granitic porphyry with K-feldspar and quartz phenocrysts and limonite staining throughout (Lufkin, 1965); no radiometric age; Laes and others (1997) suggested intrusion may be related to Bingham stock, which has a K-Ar age of 37.6 ± 0.07 Ma (Moore, 1973a) and U-Pb zircon age of 37.94 ± 0.08 Ma (von Quadt and others, 2011).

Tim **Monzonite intrusions** (late to middle Eocene) – Monzonite intrusions of the Stockton/Rush Valley district (Spring Gulch and Soldier Canyon) and Bingham district (Last Chance and Bingham stocks). Medium- to dark-gray, augite-biotite-amphibole (quartz) monzonite; where altered, augite is replaced by actinolite, chlorite, phlogopite, and quartz, whereas plagioclase is replaced by orthoclase; contains pyrite, chalcopyrite, bornite, and molybdenite mineralization; original magnetite is replaced by sulfide minerals; main Bingham ore host (Kennecott Utah Copper Corporation [KUCC], 2009); the Spring Gulch monzonite crops out just north of the Calumet mine east of Stockton (Krahulec, 2005); unit Tim is also present at the Soldier Canyon stock (Lufkin, 1965) and near the axis of Long Ridge anticline (Tooker, 1992, Laes and others, 1997); monzonite porphyry stock of the Calumet mine area yielded an $^{40}Ar/^{39}Ar$ age on K-feldspar of 41.06 ± 0.21 Ma (UGS and NIGL, 2012b); the monzonites of the Stockton/Rush Valley district are similar in appearance and composition to the Last Chance stock in the Bingham district (Krahulec, 2005), which has a U-Pb zircon age of 38.55 ± 0.19 Ma and $^{40}Ar/^{39}Ar$ age of 38.40 ± 0.16 Ma (Parry and others, 2001).

Tilp **Latite to dacite porphyry sills and dikes** (middle Eocene) – Light- to dark-gray, latite to dacite porphyry (hornblende-augite-biotite quartz latite porphyry) with abundant phenocrysts of plagioclase and hornblende and lesser biotite (Laes and others, 1997; Biek and others, 2005; KUCC, 2009); geochemical data in Clark and Biek (2017); present north of Butterfield and Middle Canyons within Oquirrh Group strata of south flank of Bingham mine area; $^{40}Ar/^{39}Ar$ age of 38.84 ± 0.19 Ma (Deino and Keith, 1997)) and U-Pb zircon age of 37.94 ± 0.13 Ma (von Quadt and others, 2011); up to about 400 feet (120 m) across (Biek and others, 2005).

Tiqlp **Quartz latite porphyry dikes and sills** (middle Eocene) – Medium-brown and light-greenish-gray, hornblende-biotite quartz latite porphyry; distinguished from other latitic dikes and sills by the presence of relatively large quartz phenocrysts and higher percentage of aphanitic groundmass (KUCC, 2009); newer geochemical data in Clark and Biek (2017); named the Raddatz porphyry (along Continental fault) at the Stockton/Rush Valley district where it forms dikes (Krahulec, 2005); $^{40}Ar/^{39}Ar$ age on Raddatz dike of 39.4 ± 0.34 Ma (Kennecott, unpublished date in Krahulec, 2005).

Tib **Basalt sill** (middle Eocene) – Dark-gray basalt sill intruding Oquirrh Group strata on South Mountain; may be related to unit Tvfo; K-Ar age of 40.1 ± 0.5 Ma (Moore and McKee, 1983); previously called a nepheline basalt (Gilluly, 1932; Moore and McKee, 1983); only largest sill mapped, about 50 feet (15 m) thick.

Volcanic Rocks of the Vernon Hills

Tbav, Tbav?

Basaltic andesite (Oligocene?, Eocene?) – Dark-gray basaltic andesite lava flow with olivine phenocrysts; weathered and poorly exposed; no direct age data but unit overlies and postdates map unit Trv; exposed thickness is 40 feet (13 m) (Kirby, 2010a, 2010b).

Trv **Rhyolite** (upper Eocene) – White to light-gray and locally dark-gray, rhyolitic ash-flow tuff; ranges from densely welded to unwelded and ashy; contains about 15% phenocrysts of quartz, also with angular and subangular lithic fragments of older volcanic rocks (to 10 mm) and black vitrophyre (to 20 mm); also includes pale-red to gray, porphyritic, densely welded tuff with 30% phenocrysts of plagioclase, biotite, and hornblende; forms low hills and small blocky outcrops; $^{40}Ar/^{39}Ar$ ages on sanidine of 35.33 ± 0.05 Ma and on plagioclase of 35.58 ± 0.29 Ma (UGS and NIGL, 2012a); exposed thickness is 40 to 100 feet (12–30 m) (Kirby, 2010a, 2010b).

Tdv **Dacite** (upper Eocene) – Light-gray to reddish-brown porphyritic dacite and trachydacite lava flows that contain phenocrysts (30%) of plagioclase and minor hornblende; forms low hills and small blocky outcrops; $^{40}Ar/^{39}Ar$ age on plagioclase of 36.63 ± 0.16 Ma (UGS and NIGL, 2012a); maximum exposed thickness is 30 feet (10 m) (Kirby, 2010a, 2010b).

Volcanic Rocks of the Northern East Tintic Mountains

Tb **Mosida Basalt** (Miocene) – Medium-dark-gray, porphyritic, trachybasalt lava flow with phenocrysts (10%–20%) of olivine, plagioclase, and clinopyroxene; forms blocky exposures; vent is not exposed, but is located near Soldiers Pass at southern Lake Mountains (east of map area) (Christiansen and others, 2007; Biek and others, 2009); $^{40}Ar/^{39}Ar$ ages of 19.47 ± 0.17 and 19.65 ± 0.15 Ma (Christiansen and others, 2007), and 19.74 ± 0.05 Ma (Christiansen and others, 2013); likely associated with the onset of initial Basin and Range-type extension (Christiansen and others, 2007); 0 to 40 feet (12 m) thick (McKean, 2011, 2020; McKean and others, 2020); thicker to east of map area.

Tfb **Shoshonite of Broad Canyon** (upper Oligocene) – Light-gray to black, vesicular to dense, porphyritic to aphanitic, shoshonitic lava flow with 10% megacrysts of anorthoclase, and 15%–20% phenocrysts of highly altered amphibole (replaced with Fe-Ti oxides), clinopyroxene, olivine, magnetite, and apatite; forms blocky exposures; $^{40}Ar/^{39}Ar$ age of 25.33 ± 0.03 Ma (Christiansen and others, 2013); thickness is 30 to 130 feet (10–40 m) (Allen, 2012).

Tdm **Mafic dikes** (late Oligocene) – Gray to black, dense, aphanitic intrusions of basalt and trachybasalt with 10%–20% phenocrysts of plagioclase, pyroxene, altered olivine, apatite, and Fe-Ti oxides; forms three small exposures in the Boulter Peak quadrangle; $^{40}Ar/^{39}Ar$ age of 25.40 ± 0.20 Ma from dike at Gardison Ridge (Allen, 2012; Christiansen and others, 2013); exposed thickness less than 15 feet (5 m) (Allen, 2012).

Tvm **Minette of Black Rock Canyon** (Oligocene) – Yellow to dark-brown, deeply weathered intrusion with minette-like characteristics in a few small exposures near Black Rock Canyon, Boulter Peak quadrangle; contains 30%–40% phenocrysts of brassy hexagonal phlogopite; in thin section includes phenocrysts of clinopyroxene, apatite, and magnetite; secondary calcite occurs in veins and fractures; $^{40}Ar/^{39}Ar$ age on phlogopite of 28.72 ± 0.06 Ma (Allen, 2012; Christiansen and others, 2013); exposed width less than 6 feet (2 m) (Allen, 2012).

Tpc **Pinyon Creek Conglomerate** (Oligocene) – Volcanic conglomerate with reddish-brown to gray clasts up to boulder size probably derived from the Laguna Springs Volcanic Group; distinctly bedded (beds 1.5 to 10 feet [0.5–3 m] thick) with some beds of nearly all fine ash and small volcanic fragments and others with both fine and coarse volcanic fragments (Morris and Lovering, 1979); unit appears to include a dark-gray pillow lava breccia (shoshonite) and a basaltic dike in two small exposures near Chimney Rock Pass (unit Tpcb of McKean and others, 2020); forms rubble-strewn exposures; field relations indicate unit Tpc is younger than Laguna Spring Volcanic Group units and older than the Mosida Basalt, but no direct age data; may have a thin lacustrine and alluvial cover below the Bonneville shoreline; thickness is greater than 150 feet (50 m) (McKean, 2011; McKean and others, 2020).

Laguna Springs Volcanic Group includes several units after Morris and Lovering (1979), not all present in the map area. Divided into the following informal members after McKean (2011) and McKean and others (2020):

Tlsl **Laguna Springs Volcanic Group, lava flow unit** (lower Oligocene) – Reddish-brown, purplish-gray and gray andesite to trachyandesite lava flows; lavas are dense and commonly vitrophyric, with large phenocrysts (30%–40%) of plagioclase, sanidine, biotite, hornblende, and clinopyroxene; ledge to cliff former;

$^{40}Ar/^{39}Ar$ sanidine age of 32.66 ± 0.03 Ma (Christiansen and others, 2013; McKean and others, 2020;); exposed thickness to 650 feet (200 m) (McKean and others, 2020; this study).

Tlsa **Laguna Springs Volcanic Group, tuff unit** (lower Oligocene) – A heterogeneous unit composed mostly of ash and tuffaceous sediment of varying grain and clast sizes; dark-reddish-brown andesite to trachyandesite tuffs contain phenocrysts (10%–20%) of plagioclase, biotite, and hornblende; typically forms poorly exposed rubbly exposures; no age data but underlies unit Tlsl; exposed thickness to 300 feet (100 m) (McKean and others, 2020; this study).

Soldiers Pass Formation divided into the following members after Christiansen and others (2007), Biek and others (2009), McKean (2011, 2020), Allen (2012), and McKean and others (2020):

Tsw **Soldiers Pass Formation, White Knoll Member** (lower Oligocene to upper Eocene) – White and pale-yellowish-orange limestone that weathers yellowish gray, with interbedded very pale orange, white, and pale-red claystone; ledge and slope former; partly coeval with map unit Tsb, but probably spans a relatively large age range (Biek and others, 2009); thickness is as much as 80 feet (25 m) (McKean, 2020; McKean and others, 2020), but much thicker in adjacent areas.

Tsb **Soldiers Pass Formation, breccia member** (lower Oligocene to upper Eocene) – Gray, white, brown, and pale-red shoshonite lava flow; exposed mostly as distinctive, carbonate-impregnated lava breccia, but also occurs as gray and pale-red, locally vesicular lava flow; interfingers with and partly overlain by the White Knoll Member (Tsw) (Biek and others, 2009); forms ledges and rounded knobs; $^{40}Ar/^{39}Ar$ age of 33.73 ± 0.65 Ma from east of map area (Christiansen and others, 2007); exposed thickness as much as 170 feet (50 m) (McKean, 2020).

Tsa **Soldiers Pass Formation, andesite member** (lower Oligocene to upper Eocene) – Medium-gray vesicular andesitic lava flow with no phenocrysts (see Biek and others, 2009); locally contains lithic clasts of rounded sandstone; mapped in one location where only weathered clasts of the flow remain; geochemically is andesite (table A6); $^{40}Ar/^{39}Ar$ 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 from east of map area; thickness estimated at over 10 feet (3 m) (McKean, 2020), and thicker to east.

Tstp, Tstp?

Soldiers Pass Formation, tuff of Twelvemile Pass member (upper Eocene) – Reddish-brown to dark-reddish-brown, densely welded, dacitic to trachydacitic tuff with phenocrysts (10%–20%) of plagioclase, biotite, hornblende, and clinopyroxene, and flattened pumice lapilli (5%–10%) (lapilli typically 1–2 cm in diameter, locally 6–20 cm); Allen (2012) included this unit in the Laguna Springs Volcanic Group, but is older and geochemically more similar to the Soldiers Pass Formation (A.P. McKean, UGS, verbal communication, May 2013); forms rounded knobs; $^{40}Ar/^{39}Ar$ age of 34.62 ± 0.17 Ma from west of Chimney Rock Pass (Christiansen and others, 2013; McKean and others, 2020); exposed thickness to 50 feet (15 m) (Allen, 2012; McKean and others, 2020).

Tsc **Soldiers Pass Formation, Chimney Rock Pass Tuff Member** (upper Eocene) –Gray to light-gray, porphyritic, rhyolitic ash-flow tuff; contains about 10% small phenocrysts of quartz, plagioclase, sanidine, biotite, and Fe-Ti oxides; also contains conspicuous pumice (~15%, 1–5 cm) and lithic fragments (<5%, 1.0–4.5 cm); vent unknown, but may be near Black Point at southern Lake Mountains (east of map area) (Biek and others, 2009); forms ledgy exposures; $^{40}Ar/^{39}Ar$ ages of 34.70 ± 0.07 and 34.73 ± 0.08 Ma (Christiansen and others, 2007; Biek and others, 2009) and 34.61 ± 0.02 Ma (Christiansen and others, 2013; McKean and others, 2020); exposed thickness to 80 feet (25 m) (Allen, 2012; McKean and others, 2020).

Tintic Mountain Volcanic Group includes several units after Morris and Lovering (1979) and Keith and others (2009); only one unit is present in the map area:

Ttlr **Tintic Mountain Volcanic Group, Latite Ridge Latite** (upper Eocene) – Dark-reddish-brown to brown, densely welded, trachytic tuff with phenocrysts (15%–20%) of plagioclase, biotite, and clinopyroxene; tuff is rich in lithic fragments (15%–20%, ~1 cm), pumice (10%–15%), and black flattened nonvesicular cognate clasts (5–15 cm); crops out as ledges and knobs; $^{40}Ar/^{39}Ar$ biotite age of 34.64 ± 0.17 Ma (UGS and NMGRL, 2007) from Tintic Mountain quadrangle (south of map area); exposed thickness up to 65 feet (20 m) (McKean and others, 2020).

Packard Quartz Latite subdivided by Morris and Lovering (1979) into several units that are not all present in the map area; informal units of McKean (2011), Allen (2012) and McKean and others (2020) are combined as follows:

Tp **Packard Quartz Latite, undivided** (upper Eocene) – Combined unit includes several volcanic lithofacies, informally subdivided by McKean and others (2020) into three members: (1) tuff of Rattlesnake Pass (ignimbrite), (2) tuff of Tintic Davis Canyon (vitrophyric rhyolite tuff), and (3) lava flow and tuff member; the latter member is equivalent to the rhyolite lava member of Allen (2012); tuff of Rattlesnake Pass member predominantly light-gray to pink, non-welded to welded rhyolite ignimbrite with large and abundant phenocrysts (30%–40%) of quartz, sanidine, plagioclase, and biotite; bi-pyramidal quartz phenocrysts are the distinguishing characteristic of this lithofacies; also contains pumice (1%–5%, 1–4 cm) and lithic fragments (1%–5%, 1–4 cm) that are not as abundant as in unit Tsc; $^{40}Ar/^{39}Ar$ sanidine age of 35.08 ± 0.03 Ma on ignimbrite (tuff of Rattlesnake Pass; Christiansen and others, 2013; McKean and others, 2020); tuff of Tintic Davis Canyon member includes small area of dark-brown, densely welded, ash-flow tuff (vitrophyre) with an $^{40}Ar/^{39}Ar$ age of 35.21 ± 0.03 Ma (tuff of Tintic Davis Canyon; Christiansen and others, 2013; McKean and others, 2020); lava flow and tuff member locally consists of rhyolite lava flows and related flow breccia (southern border of Boulter Peak and Allens Ranch quadrangles) with an $^{40}Ar/^{39}Ar$ age of 35.25 ± 0.04 Ma (Allen, 2012; Christiansen and others, 2013) (lava flow and tuff member; rhyolite lava member); in Broad Canyon, unit includes small exposure of tuff of Hot Stuff mine (Allen, 2012) underlying tuff of Rattlesnake Pass member; unit Tp exposed thickness to 425 feet (130 m) (Allen, 2012; McKean and others, 2020).

TRIASSIC TO NEOPROTEROZOIC ROCK UNITS IN MAIN PART OF MAP AREA

Triassic and Permian stratigraphy in the Martin Fork area of the eastern Stansbury Mountains was reinterpreted from Jordan and Allmendinger (1979) by modifying some formation contacts.

ŦRtw **Thaynes Formation and Woodside Formation, undivided** (Lower Triassic) – ***Thaynes*** is light- to medium-gray and brown, gastropod- and pelecypod-bearing limestone, sandstone, and siltstone; the unit is resistant, bioturbated, and irregularly medium bedded; regionally contains *Meekoceras* beds (ammonite) at base of unit (Kummel, 1954); underlying ***Woodside*** is pale-red and brown siltstone and calcareous sandstone, greenish-brown shale, and minor light-gray laminated limestone that is poorly exposed and forms slopes; present only at core of Martin Fork syncline; unconformity between unit ŦRtw and underlying unit Ppfm; incomplete thickness of Thaynes is 590 feet (180 m) and complete Woodside is 210 feet (65 m), with a combined unit thickness of 800 feet (245 m).

Pz Paleozoic rocks, undivided – Cross sections only.

Pz-Z Paleozoic and Neoproterozoic rocks, undivided – Cross sections only.

Ppfm **Park City Formation, Franson Member and Phosphoria Formation, Meade Peak Member, undivided** (middle to lower Permian) – ***Franson*** is moderate-brown and gray limestone, sandy limestone, and calcareous sandstone that is medium bedded, with minor shale; underlying ***Meade Peak*** is pale-red, brown, and dark-gray shale, with lesser bedded chert and phosphorite; forms a distinct red-brown-weathering slope or saddle; crops out at Martin Fork syncline; Franson is 280 feet (85 m) and Meade Peak is 230 feet (70 m) thick, and combined unit thickness is 510 feet (155 m).

Ppg **Park City Formation, Grandeur Member** (lower Permian) – Gray cherty and bioclastic limestone, sandy and cherty dolomite, calcareous sandstone, quartzite, and bedded chert; medium- to thick-bedded ledge former present only in the Martin Fork syncline; thickness is 500 feet (150 m).

Psl **Permian sandstone, limestone and dolomite** (lower Permian, Leonardian) – Gray to light-brown sandstone, limestone, and lesser dolomite; sandstone is fine to medium grained with calcareous cement and tabular cross-beds; carbonate rocks are finely crystalline, locally with chert and calcite nodules, and locally with brachiopods and gastropods; medium to thick bedded forming steep, ledgy slopes at Cedar Mountains; Leonardian age is from bracketing strata and fusulinids in the Cedar Mountains (sample D-77; Clark and others, 2016); may correlate with the Pequop Formation (west) and Diamond Creek Sandstone and Kirkman Formation (east); present in two small outcrops at northwest corner of map; complete thickness at Cedar Mountains is 3953 feet (1205 m) (Maurer, 1970).

Pdk, Pdk?

Diamond Creek Sandstone and Kirkman Formation, undivided (lower Permian, Leonardian? to Wolfcampian) – Mapped as combined unit in South Mountain and Martin Fork syncline, eastern Stansbury Mountains; ***Diamond Creek*** is gray to tan, weathering to red brown and light brown, fine-grained sandstone and quartzite to calcareous sandstone (at Martin Fork) that is thin to medium bedded; typically slope-forming unit weathers to chips and blocks; ***Kirkman*** at South Mountain is atypical and may be represented by a 30-foot-thick (10 m) sandy limestone at base of unit and some overlying sandstone (Welsh and James, 1998), or may be attenuated; at Martin Fork area, Kirkman is moderate-gray to light-brown limestone, calcareous sandstone, fossiliferous carbonate-clast conglomerate, and oncolitic limestone; limestone is locally bioclastic and cherty, and laminated with chert stringers and nodules; thin to thick bedded forming ledges and cliffs; the Kirkman is regionally a weak, intensely deformed interval (refer to descriptions of this unit in the Oquirrh Mountains [Tooker and Roberts, 1970; Swenson, 1975; Laes and others, 1997] and Wasatch Range [Constenius and others, 2011]); limited fossil age data (Jordan, 1979a, 1979b; table A8); top not exposed, incomplete thicknesses are 2600 feet (790 m) at South Mountain and about 750 feet (225 m) at Martin Fork area.

Oquirrh Group strata includes five lower Permian and Pennsylvanian formations of the Bingham mine area (Oquirrh Mountains) after Laes and others (1997) (figures 4 and 5), and one unit of the Cedar thrust sheet (see Clark and others, 2020b).

Pofc **Oquirrh Group, Freeman Peak and Curry Peak Formations, undivided** (lower Permian, Wolfcampian) – Combined unit at Cedar Mountains and Stansbury Mountains; see unit descriptions below; fossil age data in table A8; figure 4 shows reinterpretation from prior mapping at Cedar Mountains; maximum exposed thickness is about 3500 feet (1070 m) (Clark and others, 2016).

Pofp, Pofp?

Oquirrh Group, Freeman Peak Formation (lower Permian, Wolfcampian) – Light-brown, weathering to red brown, fine-grained sandstone and quartzite; medium to thick bedded, resistant, and jointed, forming blocky ledges and talus-covered slopes; age from Welsh and James (1961), Jordan (1979a, 1979b), and Armin and Moore (1981) (table A7); thickness is 2900 feet (880 m) in South Mountain, and 2400 feet (730 m) thick on Freeman Peak at the Bingham district (Swenson, 1975), north of map area.

Pocp **Oquirrh Group, Curry Peak Formation** (lower Permian, Wolfcampian) – Dark-gray, weathering to light gray and tan, very fine grained calcareous sandstone and siltstone that is poorly bedded (thin) and includes some minor quartzite and limestone intervals; sparsely fossiliferous, but worm tracks and trails are abundant on bedding planes; quartzite lacks fine banding; forms chippy slopes with few ledges; unconformity between Curry Peak Formation and Bingham Mine Formation in the Bingham district (Welsh and James, 1961), but not observed to the west; age from Welsh and James (1961), Jordan (1979a, 1979b), and Armin and Moore (1981) (table A7); thickness is 1800 feet (550 m) at South Mountain, and 2450 feet (750 m) thick in reference section on Curry Peak at the Bingham district (Swenson, 1975), north of map area.

ℙob, ℙob?

Oquirrh Group, Bingham Mine and Butterfield Peaks Formations, undivided (Upper to Lower Pennsylvanian) – Combined unit in a few exposures of southern Oquirrh Mountains, western Traverse Mountains, and southern Cedar Mountains.

ℙobm, ℙobm?

Oquirrh Group, Bingham Mine Formation, undivided (Upper Pennsylvanian, Virgilian-Missourian) – Brown-weathering, fine-grained quartzitic sandstone, quartzite, and calcareous sandstone with interbeds of medium- to dark-gray, fine-grained sandy and cherty limestone; light-brown to pale-red sandstones are very fine grained, feldspathic, and cross-laminated; limestone can be poorly bedded; overall, sandstone predominates over limestone; forms talus-covered slopes with some intervening ledges; age data in Welsh and James (1961), Tooker and Roberts (1970), Douglass and others (1974), Jordan (1979a, 1979b), and Armin and Moore (1981) (table A8); complete thickness is 5300 to 6500 feet (1600–2000 m) at the Bingham district (Welsh and James, 1961; Swenson, 1975) north of map area, 6400 feet (1950 m) at South Mountain (Welsh and James, 1998), 8000 feet (2450 m) at southern Stansbury Mountains, and 2800 feet (850 m) at southern Cedar Mountains (Clark and others, 2016); incomplete section at Vernon Hills is about 1850 to 3200 feet (560–980 m) thick (Kirby, 2010a, 2010b).

Bingham Mine Formation in southern Oquirrh Mountains locally divided into upper and lower members after Swenson (1975):

ℙobmu

Oquirrh Group, Bingham Mine Formation, upper member (Upper Pennsylvanian, Virgilian?) – Light-gray to brownish-tan, thinly color-banded, locally cross-bedded, calcareous quartzite with interbedded thin, light- to medium-gray, calcareous, fine-grained sandstone, limestone, and siltstone; several of the thin calcareous units are locally important as marker beds; unit is very similar to the lower member above the Commercial Limestone; 2200 feet (670 m) thick at the Oquirrh Mountains (Swenson, 1975).

ℙobml

Oquirrh Group, Bingham Mine Formation, lower member (Upper Pennsylvanian, Missourian) – Unit includes the Commercial and basal Jordan Limestone marker beds (important Bingham ore hosts); most of the unit consists of light-gray to brownish-tan, banded orthoquartzite and calcareous quartzite with thin, interbedded, light- to medium-gray, calcareous, fine-grained sandstone, limestone, siltstone, and minor shale; the Commercial consists of thin-bedded, dark-gray to black, argillaceous, silty and cherty limestone, whereas the Jordan is thin-bedded, dark-gray, argillaceous and silty, cherty limestone and arenaceous limestone; Missourian-age conodont fauna was recovered from the Jordan Limestone east of Tooele (S.M. Ritter, Brigham Young University, written communication, October 27, 2009); thickness is about 3100 feet (945 m) near Middle Canyon (Swenson, 1975).

ℙobw **Oquirrh Group, Butterfield Peaks Formation and West Canyon Limestone, undivided** (Middle to Lower Pennsylvanian, Desmoinesian-Morrowan) – Combined unit mapped in small exposures of southern Cedar Mountains and Onaqui Mountains where subdivision is difficult due to similar lithofacies in faulted sections.

ℙobp, ℙobp?

Oquirrh Group, Butterfield Peaks Formation (Middle to Lower Pennsylvanian, Desmoinesian-Morrowan) – Typically cyclically interbedded limestone and clastic 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; diagnostic black chert weathers brown and locally occurs as spherical nodules and laterally linked masses; light-brown calcareous quartzite, orthoquartzite, and calcareous sandstone is thin to medium bedded and locally cross-bedded; includes some poorly exposed light-gray siltstone and mudstone interbeds; limestone is similar in abundance to quartzite and sandstone, with clastic percentages increasing somewhat upsection; unit forms ledges and cliffs with regularly intervening slopes; age data in Tooker and Roberts (1970), Douglass and others (1974), and Armin and Moore (1981) (table A8); complete thickness is 9000 feet (2765 m) on Butterfield Peaks at the Oquirrh Mountains (Tooker and Roberts, 1970) north of map area, and 5400 feet (1650) thick at southern Cedar Mountains (Clark and others, 2016); incomplete thickness is 6000 feet (1800 m) at southern Stansbury Mountains (Armin and Moore, 1981; Copfer and Evans, 2005), 6842 feet (2086 m) at Manning Canyon, Oquirrh Mountains (Konopka, 1999), 1100 to 1250 feet (340–380 m) at Vernon Hills (Kirby, 2010a, 2010b), and about 3650 feet (1110 m) at northern East Tintic Mountains, where it corresponds to Oquirrh formation units 2 through 5 of Disbrow (1957).

ℙowc, ℙowc?

Oquirrh Group, West Canyon Limestone (Lower Pennsylvanian, Morrowan to Upper Mississippian?, Chesterian?) – Medium-gray to dark-gray limestone, sandy limestone, and fossiliferous limestone that is thin to medium bedded; locally laminated with silt and sand and contains some sparse chert; locally includes minor thin sandstone and quartzite in middle and near upper and lower contacts; fossils include crinoid columnals, brachiopods, bryozoans, rugose corals, and fusulinids; forms ledgy exposures; ledge and slope-forming unit is the basal carbonate package of Oquirrh Group, however, there are uncertainties about researchers picking a consistent lithologic and fossil datum at the lower contact with unit Mmc; age data in Tooker and Roberts (1970), Douglass and others (1974), Webster and others (1984), and Davis and others (1994) (table A8); thickness is 1456 feet (444 m) at type section (West Canyon in southern Oquirrh Mountains) (Nygreen, 1958), and 1007 to 1053 feet (307–321 m) at reference section (Soldier Canyon) (Tooker and Roberts, 1970; Davis and others, 1994); complete thicknesses of 500 to 800 feet (150–245 m) at southern Cedar Mountains (Clark and others, 2016), up to 800 feet (250 m) at Onaqui Mountains (Croft, 2004; this study), and about 750 feet (230 m) at northern East Tintic Mountains where it corresponds to Oquirrh formation unit 1 of Disbrow (1957, 1961); incomplete thickness about 1150 to 1650 feet (350–500 m) at Vernon Hills (Kirby, 2010a, 2010b).

ℙolc **Oquirrh Group, limestone unit, Cedar thrust sheet** (Middle Pennsylvanian?) – Moderate-gray limestone and cherty limestone with minor interbedded light-brown calcareous sandstone; typically medium to thick bedded, forming cliffs and ledges; no fossils were found for biostratigraphic control; Maurer (1970) mapped as Oquirrh Formation unit 3 and Clark and others (2016) mapped as unit ℙobp, but Oquirrh Group facies change westward across the Cedar and Calcite thrust faults (see figure 3; Clark and others, 2020a, 2020b); incomplete thickness is roughly 1900 feet (580 m).

M Mississippian rocks, undivided – Cross section only.

M-D Mississippian and Devonian rocks, undivided – Cross section only.

Mmc, Mmc?

Manning Canyon Formation (Lower Pennsylvanian?, Morrowan? to Upper Mississippian, Chesterian) – Lithologically diverse unit of predominantly shale with lesser sandstone, quartzite, and limestone; black to grayish-purple calcareous and carbonaceous shale and siltstone; light-brown, fine-grained calcareous sandstone with cross-bedding; brown-weathering, medium- to thick-bedded orthoquartzite with vitreous luster; and medium-gray to bluish-gray, thin- to thick-bedded, fossiliferous and argillaceous limestone; weak, slope-forming unit; fossils include brachiopods, bryozoans, rare trilobites, and leaves; in Soldier Canyon, conodont age data from Webster and others (1984) (note discrepancy with Davis and others, 1994), and palynomorph data (C. Morgan, UGS, verbal communication, April 13, 2009) suggest a late to middle Chesterian age (table A9); unit is an interval of regional decollement, commonly exhibiting substantial deformation, but Soldier Canyon in the Oquirrh Mountains and the Lake Mountains (east of map area) contain relatively intact sections; thickness at Soldier Canyon is 1140 feet (347 m) (Gilluly, 1932) to 1559 feet (475 m) (Moyle, 1959), and 1176 feet (359 m) thick at Lake Mountains (Biek and others, 2009) (east of map area); incomplete sections are as much as 1050 feet (320 m) at northern East Tintic Mountains (Disbrow, 1957), up to 1300 feet (400 m) at Vernon Hills, Stansbury Mountains, Onaqui Mountains, northern Sheeprock Mountains, Davis–Little Davis Mountains area (Kirby, 2010a, 2010b; this study), and about 1500 to 2000 feet (450–600 m) thick at southern Cedar Mountains (Maurer, 1970).

Mgb, Mgb?

Great Blue Limestone, undivided (Upper Mississippian) – Mapped as combined unit in the southern Cedar Mountains, Davis–Little Davis Mountains area, southernmost Stansbury Mountains, Onaqui Mountains, northern Sheeprock Mountains, and northern East Tintic Mountains, where the medial Long Trail Shale is not well exposed or absent; we did not use the members in the East Tintic Mountains previously used by Disbrow (1957, 1961) and Morris and Lovering (1961); see descriptions for units Mgbu and Mgbl; thickness about 1600 feet (490 m) at the Stansbury Mountains southward to Davis Mountain area; incomplete thicknesses of 2440 feet (745 m) at the southern Cedar Mountains (Maurer, 1970), 440 to 820 feet (130–250 m) at Vernon Hills (Kirby, 2010a, 2010b), and as much as 1080 feet (330 m) at the northern East Tintic Mountains (Disbrow, 1961; this study).

Great Blue Limestone divided into three members in the southern Oquirrh Mountains and locally in the Stansbury Mountains (after Gilluly, 1932), and an additional member (Mgbus) near Fivemile Pass (this study):

Mgbus **Great Blue Limestone, upper limestone and shale member** (Upper Mississippian) – Interbedded, silty and arenaceous, blue-gray, medium-bedded, sparsely fossiliferous limestone and a thick section of fissile, greenish-black shale with interspersed thin chert and quartzite lenses; crops out as ledges and slopes; unit is a different facies of the upper limestone member with more shale at the southern end of the Oquirrh Mountains near Fivemile Pass, which Tooker (1999) called a separate structural block, whereas Laes and others (1997) mapped an upper shale unit within their upper limestone unit; following Tooker, we map the unit as an informal member of the Great Blue Limestone; Mgbus may in part be transitional with the overlying Manning Canyon Formation and/or the upper limestone member of the Great Blue Limestone; source of brick clay deposits and local variscite deposits north of Fivemile Pass; exposed thickness is roughly 2000 feet (610 m).

Mgbu, Mgbu?

Great Blue Limestone, upper limestone member (Upper Mississippian) – Blue-gray limestone, cherty and argillaceous limestone, and calcareous shale; sparsely fossiliferous and thin to medium bedded forming ledges, cliffs, and slopes; also informally called Mercur limestone member (Gordon and others, 2000); unit transitions to Mgbus southward across Wells–Clay Canyon fault near Fivemile Pass, southern Oquirrh Mountains; Great Blue age data from Gordon and others (2000); thickness is 3000 feet (915 m) at southern Oquirrh Mountains (Gilluly, 1932), and north of Mercur Canyon is between 2500 and 2800 feet (760–850 m) (Kirby, 2012); 800 feet (240 m) thick at southern Stansbury Mountains (Copfer and Evans, 2005).

Mgbs, Mgbs?

Great Blue Limestone, shale member (Upper Mississippian) – Black to dark-green calcareous and carbonaceous shale in upper part, fossiliferous argillaceous limestone and silty limestone in lower part; forms a thin-bedded, slope-forming interval between enclosing limestone members; maximum thickness is 110 feet (34 m) at southern Oquirrh Mountains where it has been called the Long Trail Shale Member (Gilluly, 1932; Kirby, 2012); 30 to 80 feet (10–25 m) thick at the southern Stansbury Mountains (Copfer and Evans, 2005).

Mgbl, Mgbl?

Great Blue Limestone, lower limestone member (Upper Mississippian) – Blue-gray limestone and argillaceous limestone, interbedded with calcareous sandstone and sandy limestone; thin to medium bedded, locally silicified (jasperoid of Laes and others, 1997), and locally fossiliferous (brachipods, corals, bryozoans), forming ledges, slopes, and cliffs; also informally called Silveropolis limestone member (Gordon and others, 2000); upper part of lower limestone member (mineralized interval) was called the Mercur series (Laes and others, 1997) and Mercur member (Mako, 1999); thickness is 460 to 560 feet (140–170 m) at southern Oquirrh Mountains (Gilluly, 1932), 700 feet (210 m) at southern Stansbury Mountains (Copfer and Evans, 2005).

Mhd? **Humbug Formation and Deseret Limestone, undivided?** (Upper to Lower Mississippian) – Queried unit in one area of southern Stansbury Mountains where probable Humbug and Deseret are poorly exposed; see descriptions for units Mh and Md.

Mh, Mh?

Humbug Formation (Upper Mississippian) – Interbedded calcareous quartz sandstone, orthoquartzite, and limestone that weather to ledgy slopes; limestone is medium to dark gray, medium to very thick bedded, locally cross-bedded, with uncommon brachiopod, coral, and bryozoa fauna; locally contains light-gray sublithographic limestone in uppermost part; sandstone and quartzite is brown weathering and commonly lenticular, medium to very thick bedded, locally cross-bedded; in isolated exposures can be confused with Oquirrh Group strata; about 600 feet (180 m) thick at the northern East Tintic Mountains (Disbrow, 1957); 650 feet (200 m) thick at the southern Oquirrh Mountains (Gilluly, 1932); 700 feet (210 m) thick at southern Stansbury Mountains (Teichert, 1958), up to 1240 feet (380 m) thick at the Onaqui Mountains, 850 feet (260 m) thick at the Sheeprock Mountains, 1400 feet (425 m) thick in Davis Mountain (Harrill, 1962; this study), and 850 to 1250 feet (260–380 m) at the Vernon Hills (Kirby, 2010a, 2010b); incomplete thickness of 1014 feet (310 m) at southern Cedar Mountains (Maurer, 1970).

Md **Deseret Limestone** (Upper to Lower Mississippian) – Blue-gray limestone that is medium to very thick bedded and locally sandy, fossiliferous, and cherty, forming ledges and cliffs; basal part contains slope-forming black shale and chert (red weathering) of the Delle Phosphatic Member (up to 30 feet [10 m] thick) (see Sandberg and Gutschick, 1984); in the 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 these members are not mapped regionally; thickness is about 650 feet (200 m) at the southern Oquirrh Mountains (Gilluly, 1932); about 700 feet (215 m) at the northern East Tintic Mountains (Disbrow, 1957); 525 feet (160 m) at southern Stansbury Mountains; 450 feet (140 m) at the Onaqui Mountains; about 200 feet (60 m) at northern Sheeprock Mountains and Davis Mountain; attenuated thickness is about 200 feet (60 m) at Vernon Hills (Kirby, 2010a, 2010b).

MDgs **Gardison Limestone, Fitchville Formation, Pinyon Peak Limestone, Stansbury Formation, undivided** (Lower Mississippian to Upper Devonian) – Combined unit north of head of Dry Canyon in southern Stansbury Mountains, but to the south this interval is mapped as units MDfs and Mg; see individual unit descriptions below; Stansbury Formation thins northward to zero near head of Indian Hickman Canyon, and northward the Pinyon Peak and Fitchville pinch out; thickness is about 1200 feet (370 m).

Mg, Mg?

Gardison Limestone (Lower Mississippian) – Medium- to dark-gray limestone and cherty limestone that is very fossiliferous and well bedded; upper part is thicker bedded (medium to very thick), sandy and cherty, forming cliffs and ledges, whereas lower part is thinner bedded (thin and medium) and less resistant forming ledges and slopes; black chert occurs as nodules and thin beds; fossils include rugose and colonial corals, brachiopods, gastropods, and bryozoans, and some fossils are replaced by white calcite; unconformity between Gardison and Fitchville–Pinyon Peak Formations; 450 feet (140 m) thick at the northern East Tintic Mountains (Disbrow, 1961); 460 feet (140 m) thick at the southern Oquirrh Mountains (Gilluly, 1932); 700 feet (210 m) thick at southern Stansbury Mountains; 780 feet (240 m) thick at the Onaqui Mountains; 840 feet (260 m) thick at Vernon Hills (Kirby, 2010a, 2010b); about 400 feet (120 m) thick at northern Sheeprock Mountains and Davis Mountain; queried at Skull Valley where more than 600 feet (180 m) is exposed.

MDfs **Fitchville Formation, Pinyon Peak Limestone, Stansbury Formation, undivided** (Lower Mississippian to Upper Devonian) – Combined unit south of Dry Canyon in southern Stansbury Mountains; refer to descriptions below; Fitchville-Pinyon Peak thickness is about 450 feet (140 m), Stansbury thickness is 0 to about 60 feet (0–20 m), and combined unit thickness is about 500 feet (150 m).

MDfp **Fitchville Formation and Pinyon Peak Limestone, undivided** (Lower Mississippian to Upper Devonian) – Lithologically complex unit with interbedded gray dolomite and limestone (coarse to fine grained) with intraformational breccia; upper part (Fitchville) is gray carbonate rock that is typically thicker bedded; lower part (Pinyon Peak) consists of gray to tan sandy and silty limestone and dolomite that is locally bioclastic and irregularly bedded, with interbeds of light-brown to pale-red sandstone and quartzite; in southern Oquirrh Mountains, within upper cliffy part of unit is one massive bed that contains conspicuous white calcite blebs up to a few inches in diameter, called the "eye bed" (Gilluly, 1932); Gilluly (1932) originally mapped this unit as Jefferson(?) dolomite and Tooker (1987) subsequently used Fitchville–Pinyon Peak; thickness is 130 feet (40 m) at the southern Oquirrh Mountains (Kirby, 2012); about 200 feet (60 m) thick at southern Stansbury Mountains; about 300 feet (90 m) thick at the Onaqui Mountains, northern Sheeprock Mountains, and Davis Mountain; 60 feet (20 m) thick at the Vernon Hills (Kirby, 2010a, 2010b).

D Devonian rocks, undivided – Cross sections only.

Dst **Stansbury Formation** (Upper Devonian) – Typically consists of distinctive conglomerate with gray carbonate clasts in a dolomite matrix that varies from matrix to clast supported; clasts are subrounded to subangular typically from pebble to boulder size; includes white quartzite that weathers to tan and pale red, is locally cross-bedded and is thin to medium bedded forming resistant ledges and knobs (unit Dst exposures near Box Elder Canyon, Stansbury Mountains); type area at Flux of northern Stansbury Mountains; formation previously described by Rigby (1958), Stokes and Arnold (1958), Trexler (1992), and Clark and others (2017, 2020b); our mapping follows Trexler (1992) except for reassigning the uppermost part (commonly covered) to the Pinyon Peak Limestone (see Rigby, 1958; Sandberg and Gutschick, 1979); fossil data indicate the formation is Famennian in age (Sandberg and Gutschick, 1979; Mamet, in Trexler, 1992); Hollis (2015) reported U-Pb detrital zircon provenance data, but no maximum depositional age; major unconformity at base of formation associated with the Stansbury uplift, locally removing Devonian through Middle Cambrian strata (Rigby, 1959a; Morris and Lovering, 1961; Trexler, 1992); the formation extends to Stansbury Island and the Wasatch Range (Rigby, 1959a; Bryant, 1990; Trexler, 1992); incomplete thickness is 0 to 200 feet (0–60 m) in map area, and complete thickness as much as 1710 feet (520 m) at northern Stansbury Mountains (Trexler, 1992).

DOu **Guilmette Formation?, Simonson, Sevy, Laketown, and Ely Springs Dolomites, undivided** (Upper Devonian? to Upper Ordovician) – Combined unit at the southern Stansbury Mountains; ***Guilmette?*** includes dark-gray, well-bedded limestone; ***Simonson*** is dark-gray, coarsely to medium crystalline dolomite; ***Sevy*** is very light gray, finely crystalline dolomite with laminated surface appearance; ***Laketown*** is gray, medium- to thick-bedded, locally cherty, coarsely to medium crystalline dolomite; ***Ely Springs*** is dark-gray and mottled, medium crystalline dolomite; Guilmette? newly recognized and Ely Springs previously mapped as the Fish Haven Dolomite; thickness is as much as about 2000 feet (600 m) where not missing under the Devonian unconformity.

Dg, Dg?

Guilmette Formation (Upper to Middle Devonian) – Moderate- to dark-gray, medium- to fine-grained, thin- to thick-bedded (moderately to weakly bedded), sparsely fossiliferous dolomite with a few thin, dark-gray, fine-grained limestone beds near the top of unit; forms slopes and ledges; thickness is 180 feet (55 m) at Vernon Hills (Kirby, 2010a, 2010b), but unit is absent at northern Sheeprock Mountains and Davis Mountain; queried west of Camels Back Ridge due to structure and incomplete section, but exposed thickness there is about 500 feet (150 m) (Clark and others, 2016).

Dsi, Dsi?

Simonson Dolomite (Middle Devonian) – Light-brownish-gray to pale- and medium-gray, locally weathers brownish gray, fine- to medium-grained, very thick or thin-bedded dolomite that forms cliffs and ledges; local zones of chert; generally more lithologically variable and less well bedded than the underlying Sevy; thickness is 750 feet (225 m) at Davis Mountain; 640 to 1150 feet (195–350 m) thick at northern Sheeprock Mountains; 670 to 930 feet (200–280 m) in Vernon Hills (Kirby, 2010a, 2010b), and incomplete thickness is about 500 feet (150 m) at Camels Back Ridge area (Clark and others, 2016)

Dsy, Dsy?

Sevy Dolomite (Lower Devonian) – Medium-gray, weathering to white and very light gray, fine- to medium-grained dolomite; displays well-developed fine-scale planar lamination on weathered surface; rarely fossiliferous; contains uncommon thin beds of sandy dolomite; thin to medium bedded, forms ledges and float-covered hills; unconformity between Sevy and underlying Laketown; thickness is 590 feet (180 m) at

Davis Mountain; 1200 to 1480 feet (360–450 m) thick at northern Sheeprock Mountains; 1310 feet (400 m) thick at Vernon Hills (Kirby, 2010a, 2010b); incomplete thickness is about 250 feet (75 m) at Camels Back Ridge area (Clark and others, 2016).

S-O Silurian and Ordovician rocks, undivided – Cross sections only.

SOu, SOu?

Laketown Dolomite and Ely Springs Dolomite, undivided (Silurian to Upper Ordovician) – Dark- to medium-gray, granular to fine-grained, moderately or poorly bedded cherty dolomite; contains common pink to dark-gray chert bands or nodules; fossils include rugose corals and rare stromatolites in lower part of unit and chain corals near upper contact; poorly bedded parts of this unit appear bioturbated; forms small blocky outcrops and steep slopes; thickness is 1420 feet (430 m) at Davis Mountain and 1070 to 1690 feet (325–510 m) at northern Sheeprock Mountains; incomplete thickness is 1060 to 1280 feet (320–390 m) at Vernon Hills (Kirby, 2010a, 2010b).

Sl **Laketown Dolomite** (Silurian) – Moderate- to dark-gray, finely to moderately crystalline dolomite that locally weathers to light and moderate brown and light gray and that contains some intervals of light-gray dolomite; contains gray and red chert in beds, masses and nodules, and rust-colored, case-hardened surfaces; mostly very thick bedded, forming cliffs and ledges; to the southwest, Hintze (1980) separated into several members corresponding to formations of Staatz and Carr (1964) (see Hintze and Kowallis, 2009); incomplete thickness is about 500 feet (150 m) at the Camels Back Ridge area (Clark and others, 2016).

Ou **Ordovician strata, undivided** (Upper to Lower Ordovician?) – Dark- to medium-gray calcitic dolomite breccia (75% of exposures), light-gray silicic limestone breccia, and light-reddish-brown, strongly recrystallized limestone with abundant reddish-brown chert (Geomatrix, 2001); exposed at Hickman Knolls on the Skull Valley Indian Reservation, which was not accessed for this map; previously mapped by Moore and Sorensen (1979) as Ordovician carbonate rocks and quartzite; may include all or parts of the Ely Springs Dolomite and Pogonip Group; exposed thickness roughly 200 feet (60 m).

Oes, Oes?

Ely Springs Dolomite (Upper Ordovician) – Locally upper part is very light gray, finely crystalline dolomite with indistinct to medium bedding (Floride Member of Hintze, 1980); lower part is cherty, resistant, moderate-gray dolomite (at top) underlain by brown-weathering, less resistant, thin-bedded dolomite; both parts are thin to thick bedded, forming ledges, cliffs and slopes; locally unconformable on unit Op; incomplete thickness is 250 feet (75 m) at Camels Back Ridge area (Clark and others, 2016).

O€u **Lower Ordovician and Upper-Middle Cambrian strata, undivided** (Lower Ordovician? to Upper-Middle Cambrian?) – Carbonate rocks at Simpson Buttes; gray-, brown-, and pink-weathering dolomite and limestone, thin to very thick bedded; further subdivision precluded due to lack of access, but may correspond to parts of Pogonip Group?, Notch Peak Formation, Orr Formation, Lamb Dolomite, and Trippe Limestone; incomplete thickness about 2300 feet (700 m) (Clark and others, 2016).

O **Ordovician rocks, undivided** – Eureka Quartzite and Pogonip Group rocks, cross sections only.

Oe **Eureka Quartzite** (Upper Ordovician) – Grayish-tan to light-gray, medium- to thick-bedded, medium-grained, vitreous orthoquartzite; commonly displays well-developed trough cross-bedding and planar bedding; crops out as resistant ledges and cliffs with some intervening slopes; locally the Eureka and uppermost part of the Pogonip Group are absent over the Tooele arch (Hintze, 1959); variable in thickness, 420 feet (125 m) thick at Davis Mountain and 260 to 1000 feet (80–300 m) thick at northern Sheeprock Mountains; incomplete thickness of 40 to 80 feet (12–24 m) at the Vernon Hills (Groff, 1957; Kirby, 2010a, 2010b); absent at southern Stansbury Mountains (Copfer and Evans, 2005) and probably Camels Back Ridge area (Clark and others, 2016).

Opk **Pogonip Group, Kanosh Shale** (Middle Ordovician) – Black to dark-brown shale and lesser siltstone and sandstone; slope-forming unit; locally mapped (where thicker) as separate unit in northern Sheeprock Mountains, elsewhere mapped with unit Op; variable thickness, up to 250 feet (75 m) at northern Sheeprock Mountains, Davis Mountain, and southern Stansbury Mountains (Cohenour, 1957, 1959; Teichert, 1958, 1959; this study).

Op, Op?

Pogonip Group, undivided (Middle to Lower Ordovician) – Moderate-gray, weathering to blue gray and reddish tan, limestone and silty limestone with lesser intraformational conglomerate, siltstone, and minor shale; thin to medium bedded in typically ledgy exposures; upper part locally includes Kanosh Shale (see unit Opk), and the underlying formations are described by Hintze (1980); previously mapped as Kanosh Shale and Garden City Formation at the Stansbury Mountains (Rigby, 1958; Teichert, 1958, 1959); locally upper or all Pogonip Group rocks are absent over the Tooele arch (Hintze, 1959) and Stansbury uplift (Rigby, 1959a); thickness is 0 to 1350 feet (410 m) at southern Stansbury Mountains (Copfer and Evans, 2005) and 800 to 2130 feet (240–650 m) at northern Sheeprock Mountains and Davis Mountain (Cohenour, 1957, 1959; this study); incomplete thickness up to 150 feet (45 m) at Camels Back Ridge area (Clark and others, 2016).

Ꞓ Cambrian rocks, undivided – Cross sections only.

Ꞓ-Z Cambrian and Neoproterozoic rocks, undivided – Cross sections only.

Ꞓu, Ꞓu?

Upper Cambrian strata, undivided (lowermost Ordovician to Upper Cambrian) – Combined Notch Peak Formation and Orr Formation at eastern Davis Mountain where poorly exposed and structurally disturbed; thickness roughly 1600 feet (490 m).

Ꞓum, Ꞓum?

Upper and Middle Cambrian strata, undivided (lowermost Ordovician, Upper to Middle Cambrian) – Combined unit of several formations at the southern Stansbury Mountains and locally northern Sheeprock Mountains where structural complexities and lithofacies similarities make subdivision difficult at this map scale; includes carbonate rocks and shale from all or parts of the following formations: Orr, Lamb, Trippe, Pierson Cove, Wheeler, Swasey, Whirlwind, Dome, Chisholm, and Howell; in the southern Stansbury Mountains the Devonian unconformity (Rigby, 1959a) cuts down section to middle Cambrian rocks (increasing northward); variable thickness (north to south) from 600 to 6700 feet (185–2045 m).

Ꞓnp, Ꞓnp?

Notch Peak Formation (lowermost Ordovician? to Upper Cambrian) – Moderate to dark-gray, finely to moderately crystalline dolomite with some intervals that are light gray, tan, and light pink (some up to several feet [meters] thick); medium to very thick bedded, cliff and ledge forming; locally includes chert nodules, pisolites, twiggy bodies, and *Girvanella* (algae); corresponds to Dugway Ridge Formation of Staatz and Carr (1964); thickness is about 700 feet (215 m) at northern Sheeprock Mountains (Cohenour, 1957, 1959); incomplete thicknesses about 500 feet (150 m) at Camels Back Ridge (Clark and others, 2016), greater than 500 feet (150 m) at Davis Mountain, and about 1000 feet (330 m) at southern Stansbury Mountains.

Ꞓo, Ꞓo?

Orr Formation (Upper Cambrian) – Moderate-gray silty limestone that is thin to medium bedded; typically faulted with some slopes and ledges, but not well exposed; incomplete thickness greater than 1200 feet (365 m) at the northern Sheeprock Mountains, and greater than 470 feet (140 m) at Davis Mountain.

Orr Formation locally separated into two units at Camels Back Ridge:

Ꞓou, Ꞓou?

Orr Formation, upper part (Upper Cambrian) – Very light gray to light-gray, finely to moderately crystalline dolomite and limestone, and green and light-brown shale; commonly medium to thick bedded; forms less-resistant and lighter-colored interval between Notch Peak Formation and Big Horse Limestone that likely includes (in descending order) Sneakover Limestone Member, Corset Spring Shale Member, Johns Wash Limestone Member, and Candland Shale Member; corresponds to Fera Limestone of Staatz and Carr (1964); 200 feet (60 m) thick (Clark and others, 2016).

Ꞓob **Orr Formation, Big Horse Limestone Member** (Upper Cambrian) – Moderate-gray to tan-gray, finely to moderately crystalline limestone, with some intervals weathering to light tan, pink, and mottled; medium- to very thick bedded, resistant interval forming cliffs and ledges; locally dolomitized; corresponds to Straight Canyon Formation of Staatz and Carr (1964); 425 feet (130 m) thick (Clark and others, 2016).

Ꞓl **Lamb Dolomite** (Upper to Middle Cambrian) – Upper part is less resistant, mostly very thin to thin bedded and commonly rusty and pink weathering, and consists of ledges of moderate-gray oolitic and silty limestone and flat-pebble conglomerate, underlain by moderate-gray dolomite and limestone with rusty-colored blebs and layers; lower part of more resistant gray dolomite that locally weathers to mottled gray, pink gray, and light brown, is moderate to coarsely crystalline, contains intervals of *Girvanella* (algae), and forms a thin- to very thick bedded ledgy interval; thickness is 900 feet (275 m) at Camels Back Ridge (Clark and others, 2016).

Ꞓm **Middle Cambrian strata, undivided** (Middle Cambrian) – Several carbonate and shale units composing the upper plate of a low-angle normal fault (Dry Canyon fault) on the southwest margin of the Stansbury Mountains; formations may include the lower Trippe, Pierson Cove, and Wheeler; thickness is roughly 1500 feet (450 m).

Ꞓtl **Trippe Limestone** (Middle Cambrian) – Upper part is moderate-gray, laminated and nodular limestone, shale, intraformational conglomerate, and light-tan-weathering dolomite that is laminated to medium bedded; lower part is light- to moderate-gray, locally mottled, laminated to very thick bedded limestone; unit forms generally less resistant and ledgy interval between Lamb Dolomite and Pierson Cove Formation; thickness is 700 feet (215 m) at Camels Back Ridge (Clark and others, 2016); incomplete thickness is 450 feet (140 m) at the northern Sheeprock Mountains.

Ꞓpc, Ꞓpc?

Pierson Cove Formation (Middle Cambrian) – Moderate-gray limestone and silty limestone with some light-gray dolomite interbeds; thin to very thick bedded forming ledges to cliffs; unit locally dolomitized; 870 feet (265 m) thick at the northern Sheeprock Mountains; incomplete thicknesses are about 800 feet (245 m) at Camels Back Ridge and greater than 400 feet (120 m) thick at the northern Simpson Mountains.

Ꞓww **Wheeler Formation, Swasey Limestone, Whirlwind Formation, undivided** (Middle Cambrian) – Combined unit at northern Simpson and northern Sheeprock Mountains; ***Wheeler*** is red-brown to medium- or dark-gray, thin- to medium-bedded calcareous shale and limestone that generally forms slopes; contains *Peronopsis* trilobite fauna (Hintze and Davis, 2003); ***Swasey*** is medium-gray, medium- to thin-bedded, blocky, cliff- and ledge-forming limestone; includes intervals of silty ribbon limestone and wackestone; contains *Elrathia* trilobite fauna (Hintze and Davis, 2003); ***Whirlwind*** is light-olive-gray to red or brown shale and argillite interbedded with thin-bedded limestone; contains *Ehmaniella* trilobite fauna (Hintze and Davis, 2003); combined unit thickness is 900 feet (275 m).

Ꞓdh **Dome Limestone, Chisholm Formation, Howell Limestone, undivided** (Middle Cambrian) – Combined unit at northern Simpson and northern Sheeprock Mountains; ***Dome*** is medium-gray, medium- to thin-bedded, blocky limestone that forms ledges; ***Chisholm*** is brown to red-brown shale and some dark-gray pisolitic limestone, and contains *Glossopleura* trilobite fauna (Hintze and Davis, 2003); ***Howell*** is light- to dark-gray limestone that forms ledges; combined unit thickness is 770 feet (235 m).

Ꞓp, Ꞓp?

Pioche Formation (Middle to Lower Cambrian) – Red-brown and green-brown shale and phyllitic shale with interbedded quartzite; upper part contains red-brown limestone that is irregularly bedded and some gray limestone and shale; thin to medium bedded unit forms ledges and slopes; as much as 400 feet (120 m) thick at southern Stansbury Mountains, northern Sheeprock Mountains, and northern Simpson Mountains.

Ꞓpm, Ꞓpm?

Prospect Mountain Quartzite (Lower Cambrian to Neoproterozoic?) – Light-gray, light-brownish-gray, and pinkish-gray, commonly reddish-brown-weathering quartzite that is thin to thick bedded and medium to coarse grained; locally contains a few beds of sandy phyllitic argillite near top and lenses of quartzite conglomerate in lower half; forms resistant ledges and cliffs; complete thicknesses of 4260 feet (1290 m) at northern Sheeprock Mountains, and 2700 feet (825 m) at northern Simpson Mountains; incomplete thicknesses of about 4200 feet (1280 m) at southern Stansbury Mountains (Rigby, 1958) and 2800 feet (850 m) at Davis Mountain.

Z Neoproterozoic rocks, undivided – Cross sections only.

Zm, Zm?

Mutual Formation (Neoproterozoic) – Maroon, pink, and purple quartzite that is feldspathic, medium to coarse grained, commonly gritty or pebbly with zones of reddish and white quartzite pebbles; locally contains trough cross-beds; forms resistant ledges and cliffs; contact with overlying Prospect Mountain is transitional and marked by color change and increase in feldspar and lithic content (Moore and Sorensen, 1977); complete thickness is 1700 feet (520 m) at northern Sheeprock Mountains, and incomplete thickness is greater than 950 feet (290 m) at northern Simpson Mountains.

Zi **Inkom Formation** (Neoproterozoic) – Olive-green and maroon slate and argillite that is locally micaceous with subordinate interbeds of moderate-brown quartzite and pebbly quartzite; slope and ledge-forming unit present in hanging wall of Government Canyon thrust fault at northern Sheeprock Mountains; at northern Simpson Mountains previously mapped as Inkom Formation? by Morris and Kopf (1986) and part of undivided siltstone and quartzite unit by Moore and Sorensen (1977); incomplete thicknesses are 600 feet (180 m) at northern Sheeprock Mountains, and greater than 790 feet (240 m) at northern Simpson Mountains.

Zcc, Zcc?

Caddy Canyon Quartzite (Neoproterozoic) – White to very pale pink and medium- to dark-brown, medium-bedded, medium-grained quartzite, with scattered lenses of white quartz-pebble conglomerate that forms resistant ledges and cliffs; similar to Prospect Mountain Quartzite but generally darker in color; queried in one large area of incomplete exposure at northern Simpson Mountains where neither top nor bottom contacts are exposed (Morris and Kopf, 1986); incomplete thickness is greater than 3800 feet (1160 m).

CAMBRIAN ROCK UNITS OF SOUTHERN OQUIRRH MOUNTAINS

A major disconformity occurs between the Fitchville–Pinyon Peak Formations (unit MDfp) and the underlying Cambrian strata at the southern Oquirrh Mountains.

Ꞓly **Lynch Dolomite** (Upper? to Middle? Cambrian) – Light-gray dolomite with a few limestone beds in lower half; lower part also includes dark-gray dolomite containing twiggy bodies (short white carbonate rods less than 1 inch [3 cm] in length); thick-bedded, prominent cliff-forming unit in Ophir Canyon; may correlate with Opex Formation? and Cole Canyon and Bluebird Dolomites at the East Tintic Mountains (Gilluly, 1932; Morris and Lovering, 1961); thickness from 810 to 1050 feet (245–320 m) (Gilluly, 1932; Kirby, 2012).

Ꞓb **Bowman Limestone** (Middle? Cambrian) – Mottled shaley limestone, intraformational conglomerate, and oolitic limestone; includes a shaley/hornfels unit about 40 feet (12 m) thick at base; forms ledgy slopes and small cliffs; sparse trilobite fauna; may correlate with upper part of Herkimer Limestone at East Tintic Mountains (Gilluly, 1932; Morris and Lovering, 1961); thickness is 310 to 345 feet (95–105 m) (Gilluly, 1932; Kirby, 2012).

Ꞓh **Hartmann Limestone** (Middle? Cambrian) – Gray, banded, mottled, thin-bedded, silty and shaley limestone; oolitic toward the top, and contains sparse trilobite fauna; forms slopes and small ledges; may correlate to the lower part of Herkimer Limestone and Teutonic Limestone at East Tintics (Gilluly, 1932; Morris and Lovering, 1961); thickness is 590 to 630 feet (180–190 m) (Gilluly, 1932; Kirby, 2012).

Ꞓop **Ophir Formation** (Middle Cambrian) – Gray shale and micaceous shale, with several beds of mottled shaley limestone in middle of unit, and sandy shale and quartzite near base; slope-forming unit with few ledges; contains brachiopod and trilobite (*Olenellus*) fauna; thickness in core of Ophir anticline is 280 to 310 feet (85–95 m) (Gilluly, 1932; Kirby, 2012).

Ꞓt **Tintic Quartzite** (Middle? to Lower? Cambrian) – White quartzite that weathers to reddish brown; bedding is thick and locally irregular and cross-bedded, forms ledges and slopes; only upper part exposed in core of Ophir anticline, where it is gradational with the overlying Ophir Formation; exposed thickness as much as 300 feet (90 m) (Gilluly, 1932; Kirby, 2012).

MISSISSIPPIAN TO NEOPROTEROZOIC ROCK UNITS OF NORTHERN EAST TINTIC MOUNTAINS

The Gardison Limestone (unit Mg) conformably overlies the Fitchville Formation (unit MDf) at the northern East Tintic Mountains (Greenhalgh, 1980), but is shown as unconformable in Hintze and Kowallis (2009).

MDf **Fitchville Formation** (Lower Mississippian to Upper Devonian) – Commonly divided into three parts; upper part consists of very thick bedded pink sublithographic limestone capped by a bed of laminated light- and dark-gray stromatolitic limestone (the "Curley" limestone; see Proctor and Clark, 1956) that is as much as 3 feet (1 m) thick; middle part is black dolomite or limestone with scattered pods of chert or coarsely crystalline white dolomite; lower part is light- to medium-gray shaley limestone; fossils include corals and brachiopods; forms cliffs and ledges; thickness about 300 feet (90 m) (Disbrow, 1961).

Dpv **Pinyon Peak Limestone and Victoria Formation, undivided** (Upper Devonian) – ***Pinyon Peak*** is thin- and very thick bedded, medium-gray to light-blue-gray limestone; sandy at the top and contains a brown sandstone and a tan shaley limestone unit near the base; fossils include crinoids, brachiopods and bryozoans; 125 to 175 feet (40–55 m) thick (Disbrow, 1961); separated by a disconformity from the underlying Victoria Formation (Morris and Lovering, 1979); ***Victoria*** is medium- to light-gray dolomite that is fine to medium grained with a minor amount of light-brown, rusty weathering quartzite and quartzite breccia; locally a 4-foot-thick (1 m) bed of dark-gray dolomite crowded with ¼-inch white dolomite crystals is present a few feet above base of formation; Victoria is 125 feet (40 m) thick (Disbrow, 1961); unit Dpv forms slopes and ledges; unconformity present between the Victoria and underlying Bluebell; combined unit thickness is 250 to 300 feet (75–90 m).

DOb **Bluebell Dolomite** (Upper Devonian to Upper Ordovician) – Light- and dark-gray dolomite, thick and thin bedded, generally banded and mottled in appearance, locally cherty at base and sandy near top; sparsely fossiliferous with crinoids, corals, and pentamerid brachipods; locally, distinctive 10-foot-thick (3 m) bed of laminated light- and dark-gray dolomite is in middle of formation (Colorado Chief marker bed of Morris and Lovering, 1961); ledge former; unit contains two unconformities (Budge and Sheehan, 1980); thickness is about 600 feet (180 m) (Disbrow, 1961).

Od **Ordovician dolomite** (Upper Ordovician) – Medium- and light-gray dolomite in very thick and thin beds that weather to a rough surface texture; nodular chert-bearing and mottled beds common in upper one-third of formation; fossils include crinoids, corals, and brachiopods; distinctive dark-gray and white mottled dolomite, the Leopard Skin marker bed (50 to 100 feet [15–30 m] thick), is at top of formation; forms cliffs and slopes; may be equivalent to the Ely Springs Dolomite; previously mapped as Fish Haven Dolomite by Disbrow (1961); unconformity exists between the formation and underlying Opohonga Limestone; thickness is 270 feet (80 m) thick (Disbrow, 1961).

Oo **Opohonga Limestone** (Lower Ordovician) – Distinctive unit of light-blue-gray, thin-bedded limestone with seams and beds of yellow, pink, and red mudstone that impart a striped, mottled or mosaic appearance; flat-pebble conglomerate beds common throughout; pods of white chert typical in lower one-third of formation; basal beds are brown sandstone; slope forming unit with flaggy outcrops; thickness is about 800 feet (245 m) (Disbrow, 1961).

Ꞓao **Ajax Dolomite and Opex Formation, undivided** (lowermost Ordovician? to Upper Cambrian) – ***Ajax*** is light- to dark-blue-gray, cherty dolomite with a medial interval of creamy white dolomite (Emerald Member) that is 15 to 30 feet (5–10 m) thick; chert is less common in lower part; well bedded (thin to thick) forming cliffs and ledges; Ajax thickness is 600 feet (180 m) (Disbrow, 1961); ***Opex*** is light- and dark-gray limestone mottled and streaked with yellow and red mudstone; thin beds of sand-streaked limestone and flat-pebble conglomerate interlayered throughout; 10 feet (3 m) of greenish-gray shale near top and light-gray oolitic dolomite 40 to 70 feet (12–20 m) thick near base; thin bedded and forms slopes; Opex thickness is 250 feet (75 m) (Disbrow, 1961); combined unit thickness is 850 feet (260 m).

Ꞓc **Cole Canyon Dolomite** (Middle Cambrian) – Upper part (about 625 feet [190 m]) of alternating light- and dark-gray dolomite beds; light-gray beds are mottled or laminated; dark-gray beds are locally mottled, laminated, or with white twig-like dolomite-calcite bodies (twiggy bodies); lower part (about 200 feet [60 m]) is blue-gray limestone streaked and mottled with yellow and red mudstone interlayered with light-colored laminated dolomite and with lenses of intraformational conglomerate; well stratified (medium to thick bedded) forming ridges and steps; thickness is 825 feet (250 m) (Disbrow, 1961).

Ꞓbh **Bluebird Dolomite and Herkimer Limestone, undivided** (Middle Cambrian) – ***Bluebird*** is dusky blue-gray dolomite or limestone with twiggy bodies and is very thick bedded forming ridges and ledges; Bluebird thickness is about 200 feet (60 m) (Disbow, 1961); ***Herkimer*** is light-blue-gray limestone mottled and striped with yellow and red mudstone that is thin to medium bedded; unit of 20-foot-thick (6 m) green to tan shale exists about 180 feet (55 m) above base; oolitic and pisolitic near top; moderately resistant forming slopes and low cliffs; Herkimer thickness is 400 feet (120 m) (Disbrow, 1961); combined unit thickness is 600 feet (180 m).

Ꞓdt **Dagmar Dolomite and Teutonic Limestone, undivided** (Middle Cambrian) – ***Dagmar*** is medium-gray, fine-grained, laminated dolomite with minor interbedded light-gray limestone; distinctive unit is thin-bedded and weathers to creamy white color with a blocky fracture; Dagmar is about 75 feet (20 m) thick (Disbrow, 1961); ***Teutonic*** is light- and dark-gray limestone generally mottled and streaked with yellow-brown argillaceous lenses; oolite and pisolite beds common in lower and middle parts; locally contains *Girvanella* spherules; medium bedded, forming smooth cliffs and ledges; Teutonic thickness is 420 feet (130 m) (Disbrow, 1961); combined unit thickness is about 500 feet (150 m).

Ꞓop **Ophir Formation** (Middle Cambrian) – Upper part is gray-green micaceous shale overlying a medial limestone interval of dark-gray limestone mottled and streaked with yellow-brown mudstone; lower part is gray-green shale with minor interlayered limestone, and near base is brown and purple sandstone; slope-forming unit; thickness is about 430 feet (130 m) (Disbrow, 1961).

Ꞓt **Tintic Quartzite** (Middle? to Lower? Cambrian) – Pink, white, brown, and greenish-gray quartzite that is medium- to very thick bedded, cross-bedded, and fractured, containing shaley and conglomeratic zones; a thin, altered diabase flow is locally interbedded about 980 feet (300 m) above base; lower part is marked by a purple conglomerate unit 300 feet (90

m) thick; forms resistant ridges and rounded hills; unconformity present between Tintic Quartzite and underlying Big Cottonwood Formation; approximately 2500 feet (760 m) thick (Disbrow, 1961; this study).

Zbc **Big Cottonwood Formation** (Neoproterozoic?) – Olive-green to brownish-green phyllitic shale, argillite, quartzite, and quartzite conglomerate assigned to the Big Cottonwood Formation by Morris and Lovering (1961); well bedded and slightly metamorphosed; no age control at East Tintic Mountains, but at Wasatch Range likely Neoproterozoic in age and possibly correlative with the <770 Ma Uinta Mountain Group based on U-Pb detrital zircon data (Mueller and others, 2007; Dehler and others, 2010); only about 200 feet (60 m) exposed in the map area at the core of the North Tintic anticline of the East Tintic Mountains; maximum exposed thickness south of the map area at the East Tintic district is 1675 feet (510 m) (Morris and Lovering, 1961; Morris, 1964).

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APPENDICES

APPENDIX A: Tables

Table A1. *Selected drill hole and well log data from the Rush Valley 30'x 60' quadrangle.*

Map ID[1]	Source[2]	Location	Location Data UTM 27-12E	Location Data UTM 27-12 N	Total Depth (feet)	Basin fill Thickness (feet)[3]	Log Description[4]	Notes	ID[5]
W1	UDWRI	Cedar Valley	414051	4468259	554	225	Q 0-225, Tv 225-385, PIPo 385-554	UGS Eagle Mountain monitoring well	N110 W475 S4 24 5S 2W SL
W2	UDWRI	Cedar Valley	406472	4461733	466	462	Q 0-462, PIPo? 462-466		S1035 W38 NE 18 6S 2W SL
W3	UDOGM	Rush Valley	388243	4451362	7132	4217	Tsl 0-2460, Oligocene? 2460-4217, PIPo 4217-7132 TD in IPowc	Oligocene? noted on log, lithology and geophysics look like Tsl	4304530017
W4	UDOGM	Rush Valley	392113	4451317	4046	3530	Tsl 0-3530, PIPo 3530-4046		4304530019
W5	UDOGM	Rush Valley	386084	4450589	3250	2780	Tsl 0-2780, PIPo 2780-3250		4304530020
W6	UDWRI	Skull Valley	354804	4464190	601	601+	Q 0-157, Tsl 157-601		N20 W826 SE 02 6S 8W SL
W7	UDWRI	Skull Valley	361834	4464688	480	368	Q 0-368, Tv 368-385, Md? or Mmc? (black shale) 385-480	Tv noted as red colored on log	S528 E968 W4 03 6S 7W SL
W8	UDWRI	Skull Valley	351789	4484012	542	493+	Q 0-493, Ts? or Tsl? conglomerate 493-542	TD in Ts or Tsl conglomerate	N1300 W1725 SE 04 4S 8W SL
W9	UDWRI	Government Creek	338556	4447463	405	405+	Q only	Deepest well log along Government Creek	S804 W786 NE 06 8S 9W SL
W10	UDWRI	Rush Valley	391851	4440725	298	298+	Q 0-285, Tsl 285-298		S1050 W108 NE 22 8S 4W SL
W11	UDWRI	Rush Valley	376816	4475837	900	517	Q 0-517, PIPo 517-900		N2100 E2600 SW 31 4S 5W SL
W12	UDWRI	Rush Valley	376135	4443679	510	420	Q 0-250, Tsl 250-420, PIPo 420-510		N0 E1320 W4 7 8S 5W SL
W13	UDWRI	Rush Valley	376320	4437212	1165	1140	Q 0-1140, PIPo1140-1165		S2600 W410 S4 30 8S 5W SL
W14	Kennecott	Rush Valley	383421	4474808	3015	1394	Q 0-1394, Tv (tuff) 1394-1601, Tv (latite) 1601-3015	Core is available in the UGS core research center	04RDYR01
W15	Kennecott	Rush Valley	383688	4478968	770	436	Q 0-436, Tv (andesite) 436-770	Just south of Stockton Bar	97RCTKO33
W16	Kennecott	Rush Valley	386120	4475916	2202	1400	Q 0-1400, Tv (latite) 1400-2202		68RCSTK02A
W17	Kennecott	Rush Valley	386942	4475096	1500	1290	Q 0-1290, PIPo (mostly limestone) 1290-1500		68RCSTK004

Notes:
[1] Map ID on plate 1.
[2] Data sources: UDWRI is the Utah Division of Water Rights; UDOGM is the Utah Division of Oil, Gas and Mining; Kennecott data are unpublished mineral exploration drill holes.
[3] Basin fill thickness including unconsolidated deposits (Q) and Salt Lake Formation (Tsl). Plus indicates a minimum thickness.
[4] Depth ranges for geologic units. Q = unconsolidated deposits, Tv = Tertiary-age volcanic rocks undivided, Tsl = Salt Lake Formation, Ts = Tertiary conglomerates undivided, PIPo = Oquirrh Group undivided, Md = Deseret Limestone, Mmc = Manning Canyon Formation. Well picks for UDWRI and UDOGM data by Kirby, and for Kennecott data by K. Krahulec (UGS retired).
[5] ID is the PLS location for water wells, API number for oil and gas wells, and drill hole number for Kennecott data.

Table A2. *Ages and elevations of major shorelines of Lake Bonneville and related lakes in the Rush Valley 30' x 60' quadrangle***.**

Lake Cycle and Phase	Shoreline (map symbol)	Age (Rounded to 1000 years)		Skull Valley	Government Creek Basin	Southern Tooele Valley	Rush Valley	Cedar Valley	Goshen Valley
		radiocarbon years B.P.	calibrated years B.P.[1]	Elevation feet (meters)	Elevation feet (meters)	Elevation feet (meters)	Elevation feet (meters)	Elevation feet (meters)	Elevation feet (meters)
Transgressive Phase	Stansbury (S)	22–20 [2]	26–24	4470 (1363)	4460 (1360)	not in map area	not present	not present	not present
	Bonneville (B)	~15[3]	~18	5260–5280 (1604–1610)	5240–5260 (1598–1604)	5235–5245 (1596–1599)	5175–5260 (1578–1603)	5165–5180 (1575–1579)	5125–5150 (1563–1570)
flood									
Overflowing Phase	Cedar Valley (CV)	unknown[4]	unknown					~4900 (~1494)	
	Provo (P)	15–12.6 [5]	18–15	4800–4880 (1463–1488)	4850–4880 (1479–1488)	4845–4880 (1477–1487)	see below	4800 (1463)	not in map area
	Shambip (Sh)[6]	14–13[7]	17–16				5045–5060 (1538–1542)		
Regressive Phase	Smelter (Sm)[6]	no data	no data				5010 (1527)		

Notes:
[1] Calendar calibration using OxCal ^{14}C calibration and analysis software (v. 4.3.2) (Bronk Ramsey, 2009) using the IntCal13 calibration curve (Reimer and others, 2013), rounded to the nearest 1000 years.
[2] Oviatt and others (1990). Stansbury high and low.
[3] Oviatt (2015), Miller (2016) and references therein.
[4] McKean (2020)
[5] Miller and others (2013), Godsey and others (2005, 2011), Oviatt (2015).
[6] Burr and Currey (1988, 1992) reported that regressive-phase shorelines in Rush Valley fluctuated independently from the main body of Lake Bonneville subsequent to construction of the Stockton Bar. They reported these shorelines may be equivalent in age to the Provo and Gilbert shorelines.
[7] Nelson (2012)

Table A3. *Summary of radiocarbon ages from the Rush Valley 30' x 60' quadrangle and adjacent areas.*

Lab code	^{14}C age (yr)	^{14}C error 1- sigma (yr)	Material	Collection elevation (m)	Stratigraphic interpretation	Method - Conventional or AMS	Latitude °N (NAD83)	Longitude °W (NAD83)	Reference	Location
Beta- 156660	11,940	130	gastropod shells	1460	"Barrier beach composed of marl-rich very fine sand with abundant gastropods, sharp contact with overlying gravels that grade into cobbles" (Godsey and others, 2005); "gastropods collected from sand about 24 m below Provo shoreline (in "P7 offshore" position)" (H.S. Godsey, 2008, personal communication); *Stagnicola*	conventional	40.51	112.37	Godsey and others, 2005	Stockton Bar; Tooele Army Depot water main trench
Beta- 159810	13,580	40	gastropod shells	1468	"Cobbles encrusted with thin tufa layer on crest of spit about 14 m below the Provo shoreline" (Godsey and others, 2005); "*Pyrgulopsis* collected from interstices of tufa" (H.S. Godsey, 2008, personal communication); *Pyrgulopsis*	conventional	40.51	112.36	Godsey and others, 2005	Stockton Bar; Tooele Army Depot quarry
Beta-50770	14,420	370	gastropod shells *Stagnicola*	1575	"Sample take from interstices of tufa on gravel beach crest about 5 m below the B1 shoreline" (Godsey and others, 2005)	conventional	40.47	112.36	Godsey and others, 2005	Stockton Bar railroad cut
Beta- 146004	14,730	140	gastropod shells	1572	"Laminated medium to fine sand overlain by coarse sand and gravel in embayment of the west side of the Stockton Bar about 30 m below Bonneville shoreline" (Godsey and others, 2005); "Gravel and rippled sand about 5 m below spit crest ("armpit" sand)" (H.S. Godsey, 2008, personal communication); *Stagnicola*	conventional	40.47	112.36	Godsey and others, 2005	Stockton bar sand pit
SI-4227C	14,730	100	tufa	1579	"innermost 18%, C13/C12 adjusted" . . . "Youngest occupation of Bonneville shoreline" (Currey and Oviatt, 1985); "Tufa on gravel beach crest about 5 m below the B1 shoreline at the Stockton Bar" (Godsey and others, 2005); collected by D.R. Currey from the railroad cut through the Stockton bar; from the part of the Bonneville shoreline referred to by Burr and Currey (1988) as the "B8" shoreline. This age (SI-4227C) was reported as 14730 +/- 100 by Currey and Oviatt (1985) and Godsey and others (2005), and as 14260 +/- 100 by Currey and James (1982); Currey and others (1983) and Burr and Currey (1992).	conventional	40.46	112.36	Robert Stuckenrath, personal communication to Currey, 1979, reported in Currey and James, 1982; Currey and others, 1983; Currey and Oviatt, 1985; Burr and Currey, 1992	Stockton Bar
Beta- 156660	11,940	130	gastropod shells	1460	"Barrier beach composed of marl-rich very fine sand with abundant gastropods, sharp contact with overlying gravels that grade into cobbles" (Godsey and others, 2005); "gastropods collected from sand about 24 m below Provo shoreline (in "P7 offshore" position)" (H.S. Godsey, 2008, personal communication); *Stagnicola*	conventional	40.51	112.37	Godsey and others, 2005	Stockton Bar; Tooele Army Depot water main trench
Beta- 159810	13,580	40	gastropod shells	1468	"Cobbles encrusted with thin tufa layer on crest of spit about 14 m below the Provo shoreline" (Godsey and others, 2005); "*Pyrgulopsis* collected from interstices of tufa" (H.S. Godsey, 2008, personal communication); *Pyrgulopsis*	conventional	40.51	112.36	Godsey and others, 2005	Stockton Bar; Tooele Army Depot quarry
Beta-50770	14,420	370	gastropod shells *Stagnicola*	1575	"Sample take from interstices of tufa on gravel beach crest about 5 m below the B1 shoreline" (Godsey and others, 2005)	conventional	40.47	112.36	Godsey and others, 2005	Stockton Bar railroad cut
Beta- 146004	14,730	140	gastropod shells	1572	"Laminated medium to fine sand overlain by coarse sand and gravel in embayment of the west side of the Stockton Bar about 30 m below Bonneville shoreline" (Godsey and others, 2005); "Gravel and rippled sand about 5 m below spit crest ("armpit" sand)" (H.S. Godsey, 2008, personal communication); *Stagnicola*	conventional	40.47	112.36	Godsey and others, 2005	Stockton bar sand pit
SI-4227C	14,730	100	tufa	1579	"innermost 18%, C13/C12 adjusted" . . . "Youngest occupation of Bonneville shoreline" (Currey and Oviatt, 1985); "Tufa on gravel beach crest about 5 m below the B1 shoreline at the Stockton Bar" (Godsey and others, 2005); collected by D.R. Currey from the railroad cut through the Stockton bar; from the part of the Bonneville shoreline referred to by Burr and Currey (1988) as the "B8" shoreline. This age (SI-4227C) was reported as 14730 +/- 100 by Currey and Oviatt (1985) and Godsey and others (2005), and as 14260 +/- 100 by Currey and James (1982); Currey and others (1983) and Burr and Currey (1992).	conventional	40.46	112.36	Robert Stuckenrath, personal communication to Currey, 1979, reported in Currey and James, 1982; Currey and others, 1983; Currey and Oviatt, 1985; Burr and Currey, 1992	Stockton Bar
Beta- 156660	11,940	130	gastropod shells	1460	"Barrier beach composed of marl-rich very fine sand with abundant gastropods, sharp contact with overlying gravels that grade into cobbles" (Godsey and others, 2005); "gastropods collected from sand about 24 m below Provo shoreline (in "P7 offshore" position)" (H.S. Godsey, 2008, personal communication); *Stagnicola*	conventional	40.51	112.37	Godsey and others, 2005	Stockton Bar; Tooele Army Depot water main trench
Beta- 159810	13,580	40	gastropod shells	1468	"Cobbles encrusted with thin tufa layer on crest of spit about 14 m below the Provo shoreline" (Godsey and others, 2005); "*Pyrgulopsis* collected from interstices of tufa" (H.S. Godsey, 2008, personal communication); *Pyrgulopsis*	conventional	40.51	112.36	Godsey and others, 2005	Stockton Bar; Tooele Army Depot quarry
Beta-50770	14,420	370	gastropod shells *Stagnicola*	1575	"Sample take from interstices of tufa on gravel beach crest about 5 m below the B1 shoreline" (Godsey and others, 2005)	conventional	40.47	112.36	Godsey and others, 2005	Stockton Bar railroad cut
Beta- 146004	14,730	140	gastropod shells	1572	"Laminated medium to fine sand overlain by coarse sand and gravel in embayment of the west side of the Stockton Bar about 30 m below Bonneville shoreline" (Godsey and others, 2005); "Gravel and rippled sand about 5 m below spit crest ("armpit" sand)" (H.S. Godsey, 2008, personal communication); *Stagnicola*	conventional	40.47	112.36	Godsey and others, 2005	Stockton bar sand pit
SI-4227C	14,730	100	tufa	1579	"innermost 18%, C13/C12 adjusted" . . . "Youngest occupation of Bonneville shoreline" (Currey and Oviatt, 1985); "Tufa on gravel beach crest about 5 m below the B1 shoreline at the Stockton Bar" (Godsey and others, 2005); collected by D.R. Currey from the railroad cut through the Stockton bar; from the part of the Bonneville shoreline referred to by Burr and Currey (1988) as the "B8" shoreline. This age (SI-4227C) was reported as 14730 +/- 100 by Currey and Oviatt (1985) and Godsey and others (2005), and as 14260 +/- 100 by Currey and James (1982); Currey and others (1983) and Burr and Currey (1992).	conventional	40.46	112.36	Robert Stuckenrath, personal communication to Currey, 1979, reported in Currey and James, 1982; Currey and others, 1983; Currey and Oviatt, 1985; Burr and Currey, 1992	Stockton Bar
							UTM NAD? Zone 12	**UTM NAD? Zone 12**		
Beta- 307253	13,360	50	gastropod shells *Valvata utahensis*	nd	Shambip paleoshoreline, over wash gravels behind a small beach barrier	AMS	378750 E	4472300 N	Nelson, 2012; D. Nelson, unpublished data	Rush Valley
Beta- 307252	13,300	50	gastropod shellsS *tagnicola bonnevillensis*	nd	Shambip paleoshoreline, over wash gravels behind a small beach barrier	AMS	378750 E	4472300 N	Nelson, 2012; D. Nelson, unpublished data	Rush Valley
Beta- 307254	13,990*	50	gastropod shells *Valvata utahensis*	nd	Shambip paleoshoreline, offshore beach sands just below shoreline	AMS	380000 E	4476000 N	Nelson, 2012; D. Nelson, unpublished data	Rush Valley
Beta- 457941	14,100	50	shells	nd	nd	AMS	380000 E	4476000 N	D. Nelson, unpublished data	Rush Valley

Notes:
AMS is Accelerator Mass Spectrometry.
UTM datum for Nelson samples is presently unknown.
*Age is 14,290 in Nelson (2012).
nd is no data.

Table A4. Summary of tephrochronology data from the Rush Valley 30' x 60' quadrangle.

Map ID	Sample ID	7.5' Quadrangle	Location Data	Location Data	Tephra Name	Age (Ma)	Error (Ma)	Age Type	Comments	Reference
Skull Valley										
TR1-4 (8')		Hickman Knolls	*	*	unknown (SE California tephra?)	~3-4	-	interpolation?	ash analysis by M.E. Perkins	Geomatrix, 2001; Perkins, pers. comm, 2009
ctb-1-80		Hickman Knolls	*	*	unknown	~6?	-	-	ash analysis by M.E. Perkins	Geomatrix, 2001; Perkins, pers. comm, 2009
ctb-5-75		Hickman Knolls	*	*	unknown	~6?	-	-	ash analysis by M.E. Perkins	Geomatrix, 2001; Perkins, pers. comm, 2009
ctb-8-70		Hickman Knolls	*	*	unknown	~6?	-	-	ash analysis by M.E. Perkins	Geomatrix, 2001; Perkins, pers. comm, 2009
ctb-1-155		Hickman Knolls	*	*	Walcott	6.31	0.04	correlation	ash analysis by M.E. Perkins	Geomatrix, 2001; Perkins, pers. comm, 2009
A-1 (85')		Hickman Knolls	*	*	Walcott	6.4	0.2	correlation	ash analysis by W.P. Nash	Stone & Webster Engineering Corp., 1997
A-1 (90')		Hickman Knolls	*	*	Walcott	6.4	0.2	correlation	ash analysis by W.P. Nash	Stone & Webster Engineering Corp., 1997
TR1-1 (8')		Hickman Knolls	*	*	unknown	~4 to 16	-	-	ash analysis by M.E. Perkins	Geomatrix, 2001; Perkins, pers. comm, 2009
TR1-2 (10')		Hickman Knolls	*	*	unknown	~4 to 16	-	-	ash analysis by M.E. Perkins	Geomatrix, 2001; Perkins, pers. comm, 2009
TR1-3 (5')		Hickman Knolls	*	*	unknown	~4 to 16	-	-	ash analysis by M.E. Perkins	Geomatrix, 2001; Perkins, pers. comm, 2009
South Willow Canyon			**Latitude (N) NAD83**	**Longitude (W) NAD83**						
T1	sb87-11	Deseret Peak East	40.497440°	112.562570°	Cougar Point Tuff unit XIII	10.94	0.03	correlation - Ar/Ar	in steep, narrow gully	Perkins, unpub data
Rush Valley			**UTM 27-12 E**	**UTM 27-12 N**						
T2	412	Lofgreen	388219	4431831	Walcott	6.33		correlation	ash analysis by M.E. Perkins	Kirby, in preparation
T3	1751	Lofgreen	391989	4431499	Walcott	6.33		correlation	ash analysis by M.E. Perkins	Kirby, in preparation
T4	396	Lofgreen	386445	4434257	Blacktail Creek	6.69		correlation	ash analysis by M.E. Perkins	Kirby, in preparation
			Latitude (N) NAD83	**Longitude (W) NAD83**						
T5	rv88-18	Faust	40.176270°	112.392160°	Blacktail Creek	6.66	0.03	correlation - Ar/Ar	exposed on east side of UP tracks	Perkins and others, 1998; Perkins, unpub data
T6	rv93-553	Vernon NE	40.180940°	112.372580°	Blacktail Creek	6.66	0.03	correlation - Ar/Ar		Perkins, unpub data
T7	rv88-2	Vernon NE	40.179060°	112.372000°	Cub River	7.05	0.03	interpolation		Perkins and others, 1998; Perkins, unpub data
T8	rv88-15a	Faust	40.176267°	112.390580°	Faust	7.54	0.04	correlation - Ar/Ar	a number of short adits into this tephra	Perkins and others, 1998; Perkins, unpub data
T9	rv88-12b	Faust	40.179310°	112.386932°	Rush Valley	8.39	0.24	correlation - Pb/U	very thick tephra mined for light weight aggregate	Perkins and others, 1998; Perkins, unpub data
T10	rv89-11	Faust	40.176381°	112.384817°	Inkom	8.59	0.18	interpolation		Perkins and others, 1998; Perkins, unpub data
T11	rv89-240	Vernon NE	40.169460°	112.371400°	McMullan Cr. Tuff unit 1	9.22	0.04	correlation - Ar/Ar	Hill 5333 section; location approximate	Perkins, unpub data
T12	rv88-10	Faust	40.178043°	112.380614°	Schmidt Ranch?	9.3	0.17	interpolation	sample collected at/near this location; possible correlative of Great Plains tephra	Perkins and others, 1998; Perkins, unpub data
T13	rv88-5	Vernon NE	40.175920°	112.375670°	Section 26	9.61	0.15	interpolation		Perkins and others, 1998; Perkins, unpub data
T14	rv88-0	Vernon NE	40.177010°	112.373170°	-	9.82	0.23	interpolation	fault between this sample and rv88-2	Perkins, unpub data
Tickville Gulch										
T15	TS9903-2	Tickville Spring	40°25'29.2"	112°02'09.0"	Walcott	6.4	0.2	correlation	ash analysis by M.E. Perkins	Biek and others, 2005
T16	TS101904-1	Tickville Spring	40°25'18.0"	112°01'55.0"	Walcott	6.4	0.2	correlation	ash analysis by M.E. Perkins	Biek and others, 2005

Notes:

* Skull Valley area samples were from the subsurface, depths in feet indicated in parentheses; location coordinates were not provided in sources, sample locations are shown on maps in references.

Age type (correlation) are based on correlation to the database of analyses/stratigraphic data/age dates for late Cenozoic vitric tephra layers in the Western U.S. assembled by M.E. Perkins and several colleagues at the University of Utah, Dept. of Geology and Geophysics. Some of the key tephra layers in this database are described in Perkins and others (1995, 1998). Refer to Perkins and others (1995) for procedures on sample preparation and analyses.

Age type (correlation - Ar/Ar, - Pb/U) are based on correlation to tephra with isotopic age measurement. All Ar/Ar ages are relative to an age of 28.02 Ma for the Fish Canyon Rhyolite sanidine Ar monitor.

Age type (interpolation) are interpolated age estimates relative to isotopic ages.

Table A5. *Summary of U-Pb zircon age analyses from the Rush Valley 30' x 60' quadrangle.*

Map ID	Sample ID	Map Unit	Rock Name	7.5' Quadrangle	Location Data UTM 27-12E	Location Data UTM 27-12N	Preferred Age (Ma)	Material Dated	Laboratory	Comments	Reference
Zr1	1835	Tsl	Sandstone	Faust	379883	4448263	6.49 ± 0.38	detrital zircon	AtoZ	weighted mean age, 1 grain	UGS and AtoZ, 2013
Zr2	1831	Tir	Rhyolite	Ophir	392571	4468991	36.46 ± 1.40	primary zircon	AtoZ	weighted mean age, 15 grains	Kirby, 2012; UGS and AtoZ, 2013
Zr3	RV-48	Tso	Sandstone	Vernon	383931	4436403	38.70 +0.28 -0.62	detrital zircon	AtoZ	TuffZirc age, 10 grains	UGS and AtoZ, 2013
Zr4	RV-46	Tso	Sandstone	Davis Knolls	362036	4447797	46.77 ± 1.28	detrital zircon	AtoZ	weighted mean age, 4 grains	UGS and AtoZ, 2013

Notes:

AtoZ is Apatite to Zircon Inc., Viola, Idaho.

TuffZirc program of Ludwig (2003).

For complete data, see UGS and AtoZ (2013).

Table A6. *Selected major- and trace-element whole-rock analyses from the Rush Valley 30′ x 60′ quadrangle.*

https://ugspub.nr.utah.gov/publications/maps/m-294/m-294A.xlsx

Table A7. *Selected radiometric age analyses from the Rush Valley 30' x 60' quadrangle.*

Map ID	Sample ID	Map Unit[1]	Rock Name	7.5' Quadrangle	Location[2]	Location Data UTM 27-12 E	Location Data UTM 27-12 N	Age (Ma)	Material Dated	Laboratory[3]	Analysis Type	Comments	Reference
R1	TS102103-5	Tido	Dacite	Tickville Spring	Northeastern-Bingham	409609	4474471	32.05 ± 0.13	biotite	NMGRL	Ar/Ar	furnace step-heat, somewhat disturbed	Biek and others, 2005; NMGRL and UGS, 2006
	Tick 28	Tvlb	Dacite	Tickville Spring	Northeastern-Bingham	407485	4477079	32.12 ± 0.14	plagioclase	Berkeley	Ar/Ar	plateau age	Deino and Keith, 1997
R2	TS33104-7	Tvfa	Basaltic andesite lava flow	Tickville Spring	Northeastern-Bingham	409562	4474433	32.86 ± 0.48	groundmass concentrate	NMGRL	Ar/Ar	furnace step-heat, disturbed	Biek and others, 2005; NMGRL and UGS, 2006
R3	TS33104-4	Tir	Rhyolite	Tickville Spring	Northeastern-Bingham	408141	4483153	35.49 ± 0.13	sanidine	NMGRL	Ar/Ar	laser total fusion	Biek and others, 2005; NMGRL and UGS, 2006
R4	TS32904-3	Tia	Andesite	Tickville Spring	Northeastern-Bingham	409619	4480719	36.26 ± 0.18	biotite	NMGRL	Ar/Ar	furnace step-heat	Biek and others, 2005; NMGRL and UGS, 2006
	Tick 43	Tvfo	Minette	Tickville Spring	Northeastern-Bingham	406009	4477714	37.82 ± 0.14	whole rock	Berkeley	Ar/Ar	plateau age	Deino and Keith, 1997
	Tick-113	Tvlo	Waterlain tuff	Tickville Spring	Northeastern-Bingham	406618	4477536	38.68 ± 0.13	sanidine	Berkeley	Ar/Ar	plateau age	Maughan, 2001
	Bing-6	Til	Latite	Tickville Spring	Northeastern-Bingham	404805	4483095	38.84 ± 0.19	plagioclase	Berkeley	Ar/Ar	plateau age	Deino and Keith, 1997
	Tick 23	Tvlo	Latite clast	Tickville Spring	Northeastern-Bingham	405090	4481395	39.18 ± 0.11	biotite	Berkeley	Ar/Ar	plateau age	Deino and Keith, 1997
R5	D-17	Tac	Andesite	Tabbys Peak SW	Western-Cedar Mountains	334856	4463878	38.17 ± 0.47	groundmass concentrate	NMGRL	Ar/Ar	furnace step-heat	Clark and others, 2016: UGS and NMGRL, 2009b
R6	D-4	Tid	Dacite	Tabbys Peak SW	Western-Cedar Mountains	338545	4464979	38.69 ± 0.10	sanidine	NMGRL	Ar/Ar	laser total fusion	Clark and others, 2016: UGS and NMGRL, 2009b
R7	D-48	Trr	Rhyolite	Tabbys Peak	Western-Cedar Mountains	332246	4476004	39.18 ± 0.06	sanidine	NIGL	Ar/Ar	laser total fusion	UGS and NIGL, 2012b
R10	FM083105-1	Tid	Dacite	Camels Back Ridge NE	Western-Cedar Mountains	343583	4451611	39.56 ± 0.10	biotite	NMGRL	Ar/Ar	integrated age, low K_2O%	Clark and others, 2016; UGS and NMGRL, 2009a
R9	D-40	Tiac	Andesite	Tabbys Peak	Western-Cedar Mountains	331518	4480861	40.61 ± 0.78	groundmass concentrate	NMGRL	Ar/Ar	furnace step-heat	Clark and others, 2016: UGS and NMGRL, 2009b
R10	FM083105-1	Tid	Dacite	Camels Back Ridge NE	Western-Cedar Mountains	343583	4451611	40.95 + 0.32	hornblende	NMGRL	Ar/Ar	step-heating, plateau age	Clark and others, 2016; UGS and NMGRL, 2009a
R11	RV-24	Tir	Rhyolite	Mercur	Northeastern-Mercur	396473	4462674	32.38 ± 0.10	biotite	NIGL	Ar/Ar	isochron age	UGS and NIGL, 2012b
R12	RV-30	Tim	Granodiorite	Stockton	Northeastern-Stockton	387157	4478428	41.06 + 0.21	sanidine	NIGL	Ar/Ar	laser total fusion	UGS and NIGL, 2012b
R13	879	Trv	Rhyolite	Vernon	Vernon Hills	380034	4434853	35.33 ± 0.05	sanidine	NIGL	Ar/Ar	laser fusion ages, weighted mean	Kirby, 2010b; UGS and NIGL, 2012a
R14	873	Trv	Rhyolite	Vernon	Vernon Hills	381537	4430359	35.58 ± 0.29	plagioclase	NIGL	Ar/Ar	plateau age	Kirby, 2010b; UGS and NIGL, 2012a
R15	920	Tdv	Trachydacite	Lofgreen	Vernon Hills	382814	4437572	36.63 + 0.16	plagioclase	NIGL	Ar/Ar	isochron age	Kirby, 2010a; UGS and NIGL, 2012a
R16	AR-608	Tb	Trachybasalt	Allens Ranch	East Tintic Mtns	412938	4440242	19.74 ± 0.05	groundmass	NMGRL	Ar/Ar	step heat, weighted mean	McKean, 2011; Christiansen and others, 2013
R17	BOULTPK-1509	Tfb	Shoshonite	Boulter Peak	East Tintic Mtns	401201	4432828	25.33 ± 0.03	anorthoclase	NMGRL	Ar/Ar	step heat, weighted mean	Allen, 2012; Christiansen and others, 2013
R18	BOULTPK-409	Tdm	Basalt	Boulter Peak	East Tintic Mtns	403293	4433755	25.40 ± 0.20	groundmass	NMGRL	Ar/Ar	plateau of age spectrum	Allen, 2012; Christiansen and others, 2013
R19	BOULTPK-209	Tvm	Shoshonite	Boulter Peak	East Tintic Mtns	395377	4432026	28.72 ± 0.06	biotite	NMGRL	Ar/Ar	step heat, weighted mean	Allen, 2012; Christiansen and others, 2013
R20	AR-1608	Tlsl	Trachyandesite	Allens Ranch	East Tintic Mtns	412630	4428811	32.66 ± 0.03	sanidine	NMGRL	Ar/Ar	laser fusion single crystals	McKean, 2011; Christiansen and others, 2013
R21	AR-1108	Tsc	Rhyolite	Allens Ranch	East Tintic Mtns	411684	4434924	34.61 ± 0.02	sanidine	NMGRL	Ar/Ar	laser fusion single crystals	McKean, 2011; Christiansen and others, 2013
R22	AR-2606	Tstp	Dacite	Allens Ranch	East Tintic Mtns	410555	4435119	34.62 ± 0.17	plagioclase	NMGRL	Ar/Ar	step heat, weighted mean	McKean, 2011; Christiansen and others, 2013
R23	AR-908	Tp	Rhyolite?	Allens Ranch	East Tintic Mtns	414391	4440196	35.08 ± 0.03	sanidine	NMGRL	Ar/Ar	laser fusion single crystals	McKean, 2011; Christiansen and others, 2013
R24	AR-1708	Tp	Rhyolite	Allens Ranch	East Tintic Mtns	406519	4429195	35.21 ± 0.03	sanidine	NMGRL	Ar/Ar	laser fusion single crystals	McKean, 2011; Christiansen and others, 2013
R25	BOULTPK-309	Tp	Rhyolite	Boulter Peak	East Tintic Mtns	403829	4428375	35.25 + 0.04	sanidine	NMGRL	Ar/Ar	laser fusion single crystals	Allen, 2012; Christiansen and others, 2013
	74-KA-1	Tb	Olivine basalt	Goshen Pass	East Tintic Mtns	414002	4445147	21.4 ± 2.5	whole rock	USGS	K-Ar	Goshen Pass area	Moore and McKee, 1983
	9	Tvbs	Hornblende latite tuff-breccia	Tickville Spring	Northeastern-Bingham	411830	4479863	30.7 ± 0.9	biotite	USGS	K-Ar	W Traverse Mtns - South Mountain	Moore, 1973a
	11	Trf	Biotite rhyolite vitrophyre	Tickville Spring	Northeastern-Bingham	413466	4474663	31.2 ± 0.9	biotite	USGS	K-Ar	W Traverse Mtns - Tickville Gulch rhyolite flow	Moore, 1973a
	12	Tir	Fine-grained biotite rhyolite	Mercur	Northeastern-Mercur	397741	4462279	31.6 ± 0.9	biotite	USGS	K-Ar	Oquirrh Mtns - Mercur district, Eagle Hill rhyolite plug	Moore, 1973a
	10	Tir	Biotite rhyolite vitrophyre	Tickville Spring	Northeastern-Bingham	408197	4483237	33.0 ± 1.0	biotite	USGS	K-Ar	W Traverse Mtns - Shaggy Peak plug	Moore, 1973a
	WT-41	Tipqm	Biotite granodiorite porphyry	Mercur	Northeastern-Mercur	396196	4466649	36.7 ± 0.5	biotite	USGS	K-Ar	Oquirrh Mtns - Porphyry Hill at Ophir	Moore and McKee, 1983
	6	Til	Quartz latite porphyry dike	Lowe Peak	Northeastern-Bingham	397740	4483003	37.1 ± 1.1	biotite	USGS	K-Ar	Oquirrh Mtns - Middle Canyon area	Moore, 1973a
	7	Tim	Monzonite porphyry stock	Stockton	Northeastern-Stockton	387210	4477973	38.0 ± 1.1	biotite	USGS	K-Ar	Oquirrh Mtns - Stockton District, Calument Mine area	Moore, 1973a
	74-KA-2	Trv	Biotite-hornblende rhyolite	Vernon	Vernon Hills	398020	4461998	38.0 ± 0.5	biotite	USGS	K-Ar	Vernon Hills	Moore and McKee, 1983
	69-TS-32	Tvfo	Basalt	Tickville Spring	Northeastern-Bingham	407043	4475604	38.5 ± 0.3	whole rock	USGS	K-Ar	Oquirrh Mtns - South of Bingham mine	Moore and McKee, 1983
	5	Tiql	Quartz monzonite porphyry sill	Stockton	Northeastern-Stockton	388429	4483876	38.6 ± 1.1	biotite	USGS	K-Ar	Oquirrh Mtns - Selkirk Canyon area	Moore, 1973a
	69-SM-2	Tib	Basalt	South Mountain	Northeastern-Stockton	377774	4480188	40.1 + 0.5	whole rock	USGS	K-Ar	South Mountain dike	Moore and McKee, 1983

Notes:

[1] Map unit corresponds with those on plate 1.

[2] General unit location corresponds to figure 7.

[3] Laboratory: NMGRL is New Mexico Geochronology Research Laboratory, Socorro, New Mexico; NIGL is Nevada Isotope Geochronology Laboratory, Las Vegas, Nevada.

Data is selected to be representative for the various rock units. It is not intended to be a comprehensive list of geochronology data.

Table A8. *Fossil identifications and ages from the Rush Valley 30' x 60' quadrangle.*

Map ID	Sample ID	Map Unit	Rock Type	7.5' Quadrangle	Location Data	Location Data	Fossil Type	Fauna	Preservation & Abrasion	Calcareous Algae Present	Age
Data from southern Cedar Mountains by Clark and others (2016)											
					UTM 27-12 E	**UTM 27-12 N**					
F1	D-69	Pofc	biomicrite: wackestone	Tabbys Peak	330675	4480889	fusulinid	*Triticites* cf. *T. meeki*	Good	None	early Wolfcampian
F2	D-75	Pofc	biomicrite: mudstone	Tabbys Peak	332168	4481562	fusulinid	*Triticites* cf. *T. meeki*	Fair	None	early Wolfcampian
F3	D-76	IPobm	biomicrite: wackestone	Tabbys Peak	335200	4484669	fusulinid	*Triticites*	Fair	None	Virgilian
F4	D-68	IPobm	biomicrite: wackestone	Tabbys Peak	330601	4473150	fusulinid	*Triticites*	Fair	None	Virgilian
F5	D-52	IPobm	biomicrite: wackestone	Tabbys Peak SW	331231	4468857	fusulinid	*Pseudofusulinella, Triticites*	Fair	None	early Virgilian
F6	D-57	IPobm	biosparite: packstone	Tabbys Peak SW	332609	4465513	fusulinid	*Triticites cullomensis*	Good	None	early Virgilian
F7	D-71	IPobm	biomicrite: mudstone	Tabbys Peak	331523	4472158	fusulinid	*Triticites*	Good	None	Missourian
F8	D-78	IPobm	biomicrite: wackestone	Tabbys Peak SW	332115	4466551	fusulinid	*Triticites*	Fair	None	Missourian
F9	D-70	IPobp	biomicrite: wackestone	Tabbys Peak	332246	4472228	fusulinid	*Beedeina*	Fair	Fragments	early Desmoinesian
F10	D-50	IPowc	crinoidal packstone	Tabbys Peak	333106	4471299	conodont	*Adetognathus lautus*	-	-	latest Mississippian to early Permian

Note:
Fusulinids identified by A.J. Wells (independent). Also see Utah Geological Survey and Wells (2017).
Conodonts identified by S.R. Ritter (Brigham Young University).
Map number on plate 1.

Map ID	Sample ID	Map Unit	Rock Type	7.5' Quadrangle	Location Data	Location Data	Fossil Type	Fauna	Preservation & Abrasion	Calcareous Algae Present	Age
Data from Stansbury Mountains, South Mountain, Oquirrh Mountains (this study)											
					UTM 27-12 E	**UTM 27-12 N**					
F11	RV-17	Pofc	biosparite: packstone	Deseret Peak East	369232	4480292	fusulinid	*Triticites* cf. *T. meeki*	Good	None	early Wolfcampian
F12	RV-8	Pofc	biosparite: packstone	Deseret Peak East	370302	4476669	fusulinid	*Schwagerina, Triticites*	Poor	None	early Wolfcampian
F13	RV-11	IPobm	biosparite: packstone	Deseret Peak East	369812	4476473	fusulinid	*Triticites*	Poor	None	Virgilian
F14	RV-9	IPobm	biomicrite: wackestone	Deseret Peak East	369355	4476355	fusulinid	*Triticites* cf. *T. Cullomensis*	Fair	None	Virgilian
F15	RV-2	IPobm	biosparite: packstone	Deseret Peak East	368510	4481907	fusulinid	*Triticites*	Fair	None	Virgilian
F16	RV-5	IPobm	wackestone	Deseret Peak East	368234	4481041	fusulinid	*Triticites*	Good	None	Missourian
F17	RV-4	IPobm	biomicrite: wackestone	Deseret Peak East	368084	4481089	fusulinid	*Propseudofusulinella*	Fair	None	Missourian
F18	RV-6	IPobm	sandstone	Deseret Peak East	367964	4480377	fusulinid	*Propseudofusulinella*	Good	None	Missourian
F19	RV-14	Pdk	biosparite: grainstone	South Mountain	376615	4480605	fusulinid	*Schwagerina*	Fair-Poor	None	late-early Wolfcampian
F20	RV-15	Pocp	biomicrite: mudstone	South Mountain	380540	4481840	fusulinid	*Triticites, Schwagerina*	Poor	None	Wolfcampian
F21	970	IPobm	biomicrite: mudstone	South Mountain	379150	4481088	fusulinid	*Triticites*	Fair	None	late Missourian to Virgilian
F22	1199	IPobm	calcareous sandstone	South Mountain	378298	4473296	fusulinid	*Triticites*	Poor	None	Missourian
F23	RV-20	IPobm	calcareous sandstone	South Mountain	380660	4478875	fusulinid	*Triticites*	Poor	None	early Missourian
F24	RV-18	IPobm	wackestone	South Mountain	381603	4479643	fusulinid	*Propseudofusulinella*	Good	None	Missourian
F25	RV-28	IPobm	limestone	South Mountain	382228	4479232	conodont	ideognathodids and/or adetognathids	-	-	Pennsylvanian
F26	RV-27	IPobm	limestone	South Mountain	382399	4479227	conodont	ideognathodids and/or adetognathids	-	-	Pennsylvanian
F27	969	IPobp	biomicrite: wackestone	South Mountain	382403	4478628	fusulinid	*Fusulina*	Poor	None	early Desmoinesian
F28	RV-23	IPobp	calcareous sandstone	Stockton	388761	4480243	fusulinid	*Fusulinella*	Fair	None	late Atokan
F29	RV-22	IPobp	mudstone	Stockton	389008	4479246	fusulinid	*Fusulinella*	Poor	None	late Atokan
F30	RV-31	IPowc	limestone	Lowe Peak	395986	4471439	conodont	ideognathodids and/or adetognathids	-	-	Pennsylvanian
Data from Vernon Hills and Onaqui Mountains by Kirby (2010a, b; 2013b) and this study.											
					UTM 27-12 E	**UTM 27-12 N**					
F31	447	IPobm	biomicrite: wackestone	Faust	381857	4443049	fusulinid	*Triticites* cf. *T. cullomensis*	Good	None	middle-early Virgilian
F32	720	IPobm	biomicrite: wackestone	Lofgreen	383405	4441220	fusulinid	*Psuedofusulinella*	Fair	None	late Missourian through Virgilian
F33	726	IPobm	biomicrite: wackestone	Lofgreen	383688	4440907	fusulinid	*Psuedofusulinella: P.* cf. *fergusonensis*	Fair	None	Missourian through earliest Wolfcampian
F34	1600	IPobm	wackestone	Faust	382450	4443329	fusulinid	*Triticites*	Good	None	early Missourian
F35	1341	IPobp	mudstone	Onaqui Mountains South	371105	4453230	fusulinid	*Wedekindellina*	Fair	None	early Desmoinesian
F36	1641	IPobp	wackestone	Faust	372987	4452702	fusulinid	*Profusulinella*	Poor	None	early Atokan
F37	245	IPobp	biomicrite: mudstone	Lofgreen	383170	4440190	fusulinid	*Profusulinella*	Good	None	early Atokan
F38	586	IPowc	biomicrite: wackestone	Vernon	382346	4439325	fusulinid	-	Poor	None	Morrowan?

Note:
Fusulinids identified by A.J. Wells (independent). Also see UGS and Wells (2017).
Conodonts identified by S.M. Ritter (Brigham Young University).

Data from Stansbury Mountains by Jordan (1979a)

Map ID	Sample ID	Map Unit	Township, Range, Section	7.5' Quadrangle	Approximate UTM 27-12 E	Approximate UTM 27-12 N	Fossil Type	Fauna	Age
SJ1	8f53	Pofc	4S., 6W., NW1/4 NE1/4 28	Deseret Peak East	370554	4478264	fusulinid	*Triticites* sp., *Schwagerina* sp.	Wolfcampian
SJ2	8f104B	Pofc	4S., 6W., SE1/4 SE1/4 17	Deseret Peak East	369365	4480176	fusulinid	*Pseudofusulinella* sp., *Triticites* sp., *Pseudofusulina?*	Wolfcampian

Note:
Map unit designations from this study.
Fusulinids identified by R.C. Douglass (USGS).

Table A8. *Continued*

Map ID	Sample ID	Map Unit	Township, Range, Section	7.5' Quadrangle	Approximate UTM 27-12 E	Approximate UTM 27-12 N	Fossil Type	Fauna	Age
S18	77-AF-46	Pofc	4S., 6W., 28	Deseret Peak East	370517	4477951	fusulinid	*Schwagerina* sp.	Wolfcampian
S19	77-AF-48	Pofc	4S., 6W., 29	Deseret Peak East	369432	4478292	fusulinid	*Triticites* sp., *Schwageria?* sp.	Wolfcampian
S14	77-AF-30	IPobm	4S., 6W., 29	Deseret Peak East	368569	4476962	fusulinid	*Pseudofusulinella* sp., *Triticites* sp.	Virgilian or Wolfcampian
S22	77-AF-80	IPobm	5S., 6W., 4	Deseret Peak East	370790	4473903	fusulinid	*Pseudofusulinella* sp.	Late Pennsylvanian or Early Permian
S16	77-AF-40	IPobm	5S., 6W., 5	Deseret Peak East	369375	4474957	fusulinid	*Triticites* sp.	Late Pennsylvanian or Early Permian
S17	77-AF-42	IPobm	5S., 6W., 4	Deseret Peak East	370118	4475006	fusulinid	*Triticites?* sp.	Late Pennsylvanian or Early Permian
S12	77-AF-20	IPobm	4S., 6W., 20	Deseret Peak East	366545	4479751	fusulinid	*Pseudofusulinella* sp.	Late Pennsylvanian
S23	77-AF-82	IPobm	5S., 6W., 4	Deseret Peak East	369704	4473721	fusulinid	*Triticites?* sp.	Late Pennsylvanian
S15	77-AF-36	IPobm	5S., 6W., 5	Deseret Peak East	368664	4474538	fusulinid	*Triticites* sp.	Late Pennsylvanian
S11	77-AF-19	IPobp	4S., 6W., 19	Deseret Peak East	367241	4479434	fusulinid	*Triticites* sp.	Late Pennsylvanian
S20	77-AF-51	IPobm	4S., 6W., 19	Deseret Peak East	368047	4478729	fusulinid	*Pseudofusulinella* sp., *Triticites* sp.	Virgilian(?)
S24	78-AF-7	IPobm	4S., 6W., 30	Deseret Peak East	367882	4478458	fusulinid	*Triticites* sp.	Virgilian(?)
S13	77-AF-25	IPobm	4S., 6W., 30	Deseret Peak East	637529	4477456	fusulinid	*Triticites* sp.	Virgilian(?)
S21	77-AF-55	IPobm	4S., 6W., 19	Deseret Peak East	367413	4479546	fusulinid	*Triticites* sp.	Virgilian
S25	78-AF-16	IPobm	5S., 6W., 16	Deseret Peak East	370974	4471546	fusulinid	*Pseudofusulinella* sp., *Triticites* sp.	Missourian (?)
S26	78-AF-22	IPobm	4S., 6W., 19	Deseret Peak East	366728	4478670	fusulinid	*Pseudofusulinella* sp., *Triticites* sp.	Missourian (?)
S27	78-AF-23	IPobm	4S., 6W., 31	Deseret Peak East	367562	4476708	fusulinid	*Pseudofusulinella* sp., *Triticites?* sp.	Missourian (?)
S4	77-AF-35	IPobm	5S., 6 W., 6	Deseret Peak East	367782	4474128	fusulinid	*Pseudofusulinella* sp., *Triticites* sp.	early Missourian?
S5	77-AF-45	IPobm	5S., 6W., 16	Deseret Peak East	369798	4471544	fusulinid	*Pseudofusulinella* sp., *Triticites* sp.	early Missourian?
S2	77-AF-18	IPobp	4S., 7W., -	Deseret Peak East	366423	4478244	fusulinid	*Beedeina* ? sp.	Desmoinesian?
S3	77-AF-21	IPobp	4S., 7W., -	Deseret Peak East	365855	4479450	fusulinid	*Beedeina* ? sp.	Desmoinesian?
S7	77-AF-88	IPobp	5S., 6 W., 17	Deseret Peak East	368509	4470762	brachiopod	*Mesolobus* cf. *M euampygus* (Girty)	Desmoinesian
S8	78-AF-8	IPobp	5S., 6W., 20	Johnson Pass	368811	4470140	brachiopod	*Mesolobus* sp.	Middle Pennsylvanian
S10	Seq 6-6	IPobp	4S., 7 W., -	Deseret Peak East	366052	4477001	fusulinid	*Beedeina* sp.	Desmoinesian
S1	77-AF-13	IPobp	5S., 6W., 7	Deseret Peak East	367253	4472644	fusulinid	*Fusulinella* sp.	Atokan
S6	77-AF-87	IPobp	5S., 6W, 17	Deseret Peak East	368390	4470612	fusulinid	*Fusulinella* sp.	Atokan
S9	Seq 5-6	IPobp	5S., 6 W., 18	Deseret Peak East	367896	4472019	fusulinid	*Fusulinella* sp.	Atokan
O26	13672	IPobm	7S., 6W., 30	Onaqui Mountains South	367239	4447746	fusulinid	*Triticites* sp.	Virgilian
O18	77-AF-56	IPobm	7S., 7W., 36	Onaqui Mountains South	365999	4447413	fusulinid	*Triticites* sp.	Virgilian?
O19	77-AF-57	IPobm	7S, 7W., 36	Onaqui Mountains South	366087	4447559	fusulinid	*Triticites* sp.	Virgilian?
O21	77-AF-59	IPobm	7S., 6W., 31	Onaqui Mountains South	367239	4447746	fusulinid	*Triticites* sp.	Virgilian?
O20	77-AF-58	IPobm	7S., 6W., 31	Onaqui Mountains South	366264	4447738	fusulinid	*Triticites* sp.	Late Pennsylvanian
O22	77-AF-61	IPobm	7S., 6W., 30	Onaqui Mountains South	367776	4448701	fusulinid	*Triticites* sp.	Late Pennsylvanian
O23	13671	IPobm	7S., 7W., 13	Onaqui Mountains South	365601	4451182	fusulinid	*Triticites* sp.	Late Pennsylvanian
O24	24544	IPobm	7S., 6W., 19	Onaqui Mountains South	366834	4450409	fusulinid	*Triticites* sp.	Late Pennsylvanian
O25	13682	IPobm	7S., 7W., 26	Onaqui Mountains South	365703	4448311	fusulinid	*Triticites* sp.	Late Pennsylvanian
O27	13683	IPobm	7S., 7W., 36	Onaqui Mountains South	365921	4447313	fusulinid	*Triticites* sp., *Pseudofusulinella* sp.	Late Pennsylvanian
O28	24543	IPobm	7S., 6W., 31	Onaqui Mountains South	367616	4447561	fusulinid	*Triticites* sp.	Late Pennsylvanian
O16	77-AF-1	IPobm	7S., 6W., 29	Onaqui Mountains South	367883	4448099	fusulinid	*Kansanella* sp.	Missourian
O17	77-AF-12	IPobm	7S., 6W., 19	Onaqui Mountains South	366595	4450316	fusulinid	*Triticites* sp.	Missourian
O1	77-AF-13	IPobp	7S., 6W., 29	Onaqui Mountains South	369166	4448468	fusulinid	*Beedeina* sp.	Desmoinesian
O2	77-AF-14	IPobp	7S., 6W., 7	Onaqui Mountains South	367097	4453396	fusulinid	*Beedeina* sp.	Desmoinesian
O3	77-AF-15	IPobp	7S., 6W., 19	Onaqui Mountains South	367305	4450233	fusulinid	*Beedeina* sp.	Desmoinesian
O4	77-AF-16	IPobp	7S., 6W., 32	Onaqui Mountains South	368070	4446947	fusulinid	*Beedeina* sp.	Desmoinesian
O5	77-AF-62	IPobp	7S., 6W., 19	Onaqui Mountains South	366322	4451056	fusulinid	*Beedeina* sp.	Desmoinesian
O6	77-AF-65	IPobp	7S., 6W., 18	Onaqui Mountains South	366331	4451981	fusulinid	*Beedeina* sp.	Desmoinesian
O7	77-AF-68	IPobp	7S., 6W., 18	Onaqui Mountains South	366715	4452457	fusulinid	*Beedeina* sp.	Desmoinesian
O8	77-AF-71	IPobp	7S., 6W., 29	Onaqui Mountains South	368289	4449166	fusulinid	*Beedeina* sp.	Desmoinesian
O9	77-AF-72	IPobp	7S., 6W., 29	Onaqui Mountains South	368955	4448653	fusulinid	*Beedeina* sp.	Desmoinesian
O11	Seq 2-8	IPobp	7S., 6W., 29	Onaqui Mountains South	368675	4447887	fusulinid	*Beedeina* sp.	Desmoinesian
O12	f13673	IPobp	7S., 6W., 6	Onaqui Mountains South	367517	4454372	fusulinid	*Beedeina* sp.	Desmoinesian
O13	f13674	IPobp	7S., 7W., 12	Onaqui Mountains South	365961	4452982	fusulinid	*Beedeina* sp.	Desmoinesian
O14	f13681	IPobp	7S., 6W., 7	Onaqui Mountains South	366891	4453221	fusulinid	*Beedeina* sp.	Desmoinesian
O15	f24545	IPobp	7S., 6W., 8	Onaqui Mountains South	368210	4453462	fusulinid	*Beedeina* sp.	Desmoinesian
O10	77-AF-73	IPobp	7S., 7W., 12	Onaqui Mountains South	365855	4453741	fusulinid	*Beedeina* sp.	Atokan

Note:
Sample locations were obtained from Armin and Moore's (1981) geologic map.
Map unit designations are modified from Armin and Moore (1981).
Fossil identification by C.H. Stevens (USGS).
Wright (1961) also reported fossil data from measured sections in the Stansbury Mountains, but is not included since it lacks detailed location information.

Table A8. *Continued*

Data from South Mountain by Jordan (1979a)

Map ID	Sample ID	Map Unit	Township, Range, Section	7.5' Quadrangle	Approximate UTM 27-12 E	Approximate UTM 27-12 N	Fossil Type	Fauna	Age
SM1	SI33	Pdk	4S., 5W., NW1/4 SW1/4 18	South Mountain	376451	4480780	fusulinid	*Psuedofusulina* sp., *Schwagerina* sp., *Psuedoschwagerina?*	Wolfcampian
SM2	SI30	Pofp	4S., 5W., north edge SE1/4 SW1/4 18	South Mountain	376749	4480431	fusulinid	*Triticites?, Schwagerina* sp.	Wolfcampian
SM3	SI28	Pofp	4S., 5W., north edge SE1/4 SW1/4 18	South Mountain	376654	4480427	fusulinid	*Schwagerina* sp.	Wolfcampian
SM4	SI23	Pofp	4S., 5W., SW1/4 SE1/4 18	South Mountain	377074	4480268	fusulinid	*Schwagerina* sp.	Wolfcampian
SM5	SI18	Pofp	4S., 5W., south boundary NE1/4 SW1/4 18?	South Mountain	376597	4480429	fusulinid	*Triticites?, Schwagerina?*	Wolfcampian
SM6	SI17	Pofp	4S., 5W., south boundary NE1/4 SW1/4 18?	South Mountain	376597	4480429	fusulinid	*Pseudofusulina?, Schwagerina* sp., *Pseudoschwagerina*	Wolfcampian
SM7	SI13a, SI14	Pofp	4S., 5W., south edge NE1/4 SE1/4 18	South Mountain	377458	4480325	fusulinid	*Schwagerina* sp.	Wolfcampian
SM8	SI5	Pocp	4S., 5W., SE1/4 SW1/4 17	South Mountain	378271	4480266	fusulinid	*Triticites* sp.	late Virgilian/early Wolfcampian
SM9	61F84ab	IPobm	4S., 5W., NW1/4 21	South Mountain	379693	4479651	fusulinid	*Triticites* sp.	Missourian/earliest Virgilian
SM10	61F77a, 61F78a, 61F79, 61F84	IPobm	4S., 5W., NW1/4 21	South Mountain	379782	4479638	fusulinid	*Tetrataxis* sp., *Bradyina* sp., *Millerella* sp., *Fusulinella* sp., *Oketaella?, Kansanella* sp., *Triticites* sp.	Missourian with intermixed Middle Pennsylvanian
SM11	61F74, 61F75abc	IPobm	4S., 5W., SE1/4 NE1/4 21	South Mountain	380648	4479399	fusulinid	*Bradyina* sp., *Climacammina* sp., *Pseudofusulinella* sp., *Triticites* sp.	Missourian
SM12	61F73	IPobm	4S., 5W., center N edge SW1/4 22	South Mountain	381331	4479272	fusulinid	*Bradyina* sp., *Eowaeringella* sp.	Missourian

Note:
Map unit designations from this study.
Fusulinids identified by R.C. Douglass (USGS).
MacKenzie and Duncan in Tooker and Roberts (1970) report on megafauna of the Butterfield Peaks Formation of the Oquirrh Mountains in the West Canyon type and reference sections and the Soldier Canyon reference section (see their table 6).

Data from Western Traverse Mountains by Douglass and others (1974)

Map ID	Sample ID (Map Locality Number)	Map Unit	7.5' Quadrangle	Approximate UTM 27-12 E	Approximate UTM 27-12 N	Fossil Type	Fauna	Age
WT1	f24507 (11)	IPobm	Tickville Spring	414925	4477544	fusulinid	*Triticites* sp. aff. *T. pygmaeus*	Missourian
WT2	f24417 (7)	IPobp	Tickville Spring	411807	4473741	fusulinid	*Fusulinella* sp. undet.	latest Atokan to early Desmoinesian
WT3	f24416 (6)	IPobp	Tickville Spring	413111	4470559	fusulinid	*Fusulinella* sp. undet.	latest Atokan to early Desmoinesian
WT4	f24415 (5)	IPobp	Tickville Spring	407266	4474453	fusulinid	*Wedekindellina* sp. 4, *Beedeina* sp. 1	late Desmoinesian
WT5	f24506 (4)	IPobp	Tickville Spring	405037	4477907	fusulinid	*Beedeina* sp. aff. *B. rockymontana?*	middle Desmoinesian
WT6	f24505 (3)	IPobp	Tickville Spring	404920	4477719	fusulinid	*Beedeina* sp. aff. *B. pristina*	middle Desmoinesian
WT7	f24503 (2)	IPobp	Tickville Spring	404766	4476860	fusulinid	*B.* sp. aff. *B. rockymontana*	middle Desmoinesian
WT8	f24504 (1)	IPobp	Tickville Spring	404873	4476331	fusulinid	*F.* sp. aff. F. haywardi	latest Atokan to early Desmoinesian
WT9	f24540 (28)	IPobp	Tickville Spring	414983	4476198	fusulinid	*Beedeina* sp. 1*?*	late Desmoinesian
WT10	f24501 (10)	IPobp	Tickville Spring	414413	4476641	fusulinid	*Beedeina* sp. 1	late Desmoinesian
WT11	f24541 (29)	IPobp	Tickville Spring	414907	4474953	fusulinid	*Millerella* sp., *W.* sp. 3	late Desmoinesian
WT12	f24502 (9)	IPobp	Tickville Spring	413458	4476737	fusulinid	*M.* sp., *F.* sp. aff. *F. lounsberyi Streptognathodus anteeccentricus,*	latest Atokan to early Desmoinesian
WT13	24769-PC (8)	IPowc	Tickville Spring	414189	4473191	conodont	*Adetognathus gigantus, A. lautus, Hindeodella* sp.	Morrowan
WT14	25031-PC (33)	IPowc	Tickville Spring	413633	4475544	conodont	*A. lautus, Hindeodella* sp. *A. lautus, Hindeodella* sp., *Neognathodus*	Morrowan
WT15	25030-PC (32)	IPowc	Tickville Spring	414531	4474068	conodont	*bassleri symmetricus, Ozarkodina* sp., *Rhachistognathus muricatus*	Morrowan

Note:
Sample ID (map locality numbers) were obtained from Moore's (1973c) geologic map.
Map unit designations are modified from Moore (1973c).
Fossil identifications by R.C. Douglass (fusulinids) and J.W. Huddle (conodonts) (see Douglass and others, 1974).

Table A9. *Summary of palynology data from the Rush Valley 30' x 60' quadrangle.*

Map ID	Sample ID	Map Unit	7.5' Quadrangle	Location Data UTM 27-12 E	Location Data UTM 27-12 N	Waanders Report Date	Recovery	Age	Environment	Spores and Pollen	Reference
P1	1928	Mmc	Fivemile Pass	398926	4446425	12/29/2010	barren	Indeterminate	Restricted Marine/Lacustrine	-	this study
P2	1944	Mgbs	Ophir	392415	4467140	12/29/2010	barren	Indeterminate	Fluvial/Floodplain	-	this study
P3	2097	Mgbus	Fivemile Pass	399206	4454944	12/29/2010	yes	Namurian B-C? (Chesterian?)	Swamp/Deltaic	*Densosporites* sp. (R), *Lycospora* sp. (R)	this study
P4	2101	Mgbus	Mercur	400279	4457873	12/29/2010	yes	Namurian B-C? (Chesterian?)	Swamp/Lacustrine	*Densosporites* sp. (C), *Leiotriletes adnatus* (R), *Lycospora* sp. (C), *Punctatisporites* spp. (F)	this study
P5	SC-9	IPowc	Stockton	389971	4476460	4/13/2009	yes	Chesterian? (Namurian B-C?)	Swamp	*Densosporites* spp. (R), *Lycospora* spp. (R), *Punctatisporites* spp. (R)	Chidsey, 2016
P6	SC-8	Mmc	Stockton	390028	4476280	4/13/2009	yes	Chesterian? (Namurian B-C?)	Swamp	*Densosporites* spp. (R), *Lycospora* spp. (R), *Punctatisporites* spp. (R), *unidentifiable palynomorphs* (R), *Raistrickia nigra (R)*	Chidsey, 2016
	SC-7	Mmc	Stockton	-	-	4/13/2009	barren	Chesterian? (Namurian B-C?)	Swamp	-	Chidsey, 2016
P7	SC-5	Mmc	Stockton	389902	4476204	4/13/2009	yes	Chesterian? (Namurian B-C?)	Lacustrine	*Lycospora* spp. (R), root hairs and soil fungi (A)	Chidsey, 2016
P8	SC-3	Mmc	Stockton	389539	4476290	4/13/2009	yes	Chesterian? (Namurian B-C?)	Swamp	*Densosporites* spp. (R), *Lycospora* spp. (R), *Punctatisporites* spp. (R)	Chidsey, 2016
P9	SC-2	Mmc	Stockton	389632	4476260	4/13/2009	yes	Chesterian? (Namurian B-C?)	Lacustrine	*Densosporites* spp. (R), *Lycospora* spp. (R), *Punctatisporites* spp. (R)	Chidsey, 2016
P10	SC-1	Mmc	Stockton	389388	4476224	4/13/2009	yes	Chesterian? (Namurian B-C?)	Swamp	*Densosporites* spp. (R), *Lycospora* spp. (R), *Punctatisporites* spp. (R), *unidentifiable palynomorphs* (R)	Chidsey, 2016
	AR-1	Md	Allens Ranch	413473	4436379	10/5/2009	barren	Indeterminate	Restricted Marine/Lacustrine?	-	Chidsey, 2016
P11	AR-2	Mmc	Allens Ranch	406199	4429330	10/5/2009	yes	Chesterian?	Swamp	*Densosporites* spp. (A), *Lycospora* spp. (R), *Punctatisporites* spp. (R)	Chidsey, 2016
	AR-3	Mmc	Allens Ranch	406196	4429338	10/5/2009	barren	Indeterminate	Restricted Marine/Lacustrine?	-	Chidsey, 2016

Notes:

See Utah Geological Survey and Waanders (2020) for data reports.

Sample 1928 was previously mapped as the Poker Knoll Member of the Great Blue Formation.

SC-9 plots in our map unit IPowc.

SC-2 location was corrected.

Samples AR-2 and AR-3 were previously mapped as the Chiulos Member of the Great Blue Formation.

R=Rare <6 specimens/slide, F=Frequent 6-15 specimens/slide, C=Common 16-30 specimens/slide, A=Abundant >30 specimens/slide

APPENDIX B: Photo Gallery

Field review group examining Salt Lake Formation limestone in Rush Valley. Photo by Robert Biek.

Stefan Kirby explains geology of the Vernon Hills to the field review group. Photo by Robert Biek.

Close-up view of pisolitic limestone of the Dome Limestone of map unit Ꞓdh in the northern Sheeprock Mountains. Hammerhead for scale. Photo by Stefan Kirby.

Quartzite of the Pioche Formation in the northern Sheeprock Mountains. Hammer for scale. Photo by Stefan Kirby.

Close-up view of the Sevy Dolomite displaying wavy laminated bedding in the Vernon Hills. Hammer for scale. Photo by Stefan Kirby.

View southeast of the Hellhole Canyon area in the Onaqui Mountains. The high ground on the right side of the photo is composed of folded Oquirrh Group, Butterfield Peaks Formation. Photo by Donald Clark.

View south of the northern Simpson Mountains area. The high peak and much of the adjoining ridgelines are composed of Caddy Canyon Quartzite, Mutual Formation, and the Prospect Mountain Quartzite. Notch in right middle ground is Bonneville shoreline cut into older alluvial-fan deposits. Photo by Donald Clark.

View northeast of snow-capped Deseret Peak and the southern Stansbury Mountains and the floor of Skull Valley. Photo by Donald Clark.

View west of Government Creek basin, Simpson Buttes and northern Dugway Range (left) and Camels Back Ridge (right). In the background is Granite Peak (right) and the Deep Creek Mountains (center). Photo by Donald Clark.

View east of Red Pine Mountain in the northern Sheeprock Mountains. Photo shows north-dipping section of Cambrian strata that include the Prospect Mountain Quartzite through the Pierson Cove Formation. Photo by Donald Clark.

View south of the southern Cedar Mountains and Skull Valley. This part of the Cedar Mountains is composed primarily of folded and faulted Mississippian- through Permian-age sedimentary rocks and Tertiary igneous rocks. Photo by Donald Clark.

View east of Stockton Bar and spit complex and Oquirrh Mountains. Bedrock in this part of the Oquirrh Mountains consists of folded and faulted Oquirrh Group rocks. Photo by Donald Clark.

View north of the core of the Martin Fork syncline in the eastern Stansbury Mountains consisting of Thaynes Limestone. As mapped, the fold includes Triassic and Permian rocks of the Thaynes Limestone through Kirkman Formation. Photo by Donald Clark.

View of the Delle Phosphatic Member near the base of the Deseret Limestone. Located in Dry Canyon in the western Oquirrh Mountains near Ophir. Hammer for scale. Photo by Donald Clark.

View south of the Ophir anticline at the town of Ophir. The cliffs consist of folded upper? to middle? Cambrian carbonate rocks of the Lynch Dolomite. Upper forested part of ridge is Mississippian Humbug Formation strata. Photo by Donald Clark.

View west from the Oquirrh Mountains of Stockton Bar and northern Rush Valley, South Mountain, and the Stansbury Mountains. Photo by Donald Clark.

View south of the Mercur mine area in the southern Oquirrh Moutains. The East Tintic Mountains are in the distance on the right side of the photo. Photo by Donald Clark.

View north of Cedar Valley and the southern Oquirrh Mountains. Photo by Donald Clark.

View southwest up the South Willow Canyon drainage in the Stansbury Mountains. The high point is Deseret Peak, which is composed of folded Prospect Mountain Quartzite. Photo by Donald Clark.

View east of east-dipping exposure the Salt Lake Formation capped by alluvial gravel in South Willow Canyon, Stansbury Mountains. Photo by Donald Clark.

View north of the Deseret anticline in the Stansbury Mountains. The photo shows the gently dipping west limb and steep to overturned east limb composed of Prospect Mountain Quartzite. Photo by Donald Clark.

Tephra layer within the Salt Lake Formation. Age is about 6 to 7 Ma. Located in quarry on the Pony Express Road in Rush Valley. Pen for scale. Photo by Stefan Kirby.

Close-up view of rugose (horn) corals in the Great Blue Limestone in the Oquirrh Mountains. Hammertip for scale. Photo by Stefan Kirby.

View southwest of the southern part of Rush Valley near Vernon. The snow-capped Sheeprock Mountains lie in the distance. Photo by Stefan Kirby.

Close-up view of shale in the Pioche Formation in the Sheeprock Mountains. Hammer for scale. Photo by Stefan Kirby.

View to the north of the southern Stansbury Mountains, from the Onaqui Mountains. The slope in the foreground consists of gently west dipping, interbedded limestone and sandstone of the Humbug Formation. Photo by Stefan Kirby.

View of the Great Blue Limestone in the Onaqui Mountains. Photo by Stefan Kirby.

View from the top of the Vernon Hills, southern Rush Valley. The bedrock in the foreground is the Pennsylvanian-age West Canyon Limestone. The Sheeprock Mountains are in the distance. Photo by Stefan Kirby.

Close-up view of the conglomeratic red beds of the Older Tertiary strata (unit Tso) in the Vernon Hills. Hammer for scale. Photo by Stefan Kirby.

View to the east of west-tilted Salt Lake Formation strata capped by older alluvial-fan deposits in a railroad cut near the Vernon Hills. Photo by Stefan Kirby.

View of Upper and Middle Cambrian formations on the east flank of Camels Back Ridge, includes from top to bottom Notch Peak Formation, Orr Formation, Lamb Dolomite.

Southern Cedar Mountains with view to the east of lava flows and other volcanic rocks (unit Tac) in foreground and White Rock (unit Tid) in middle ground.

View southeast of Little Granite Mountain (unit Tid) with well developed Provo shoreline notch near middle and lower part of mountain.

Volcanic rocks above (unit Tac) and Oquirrh Group strata below, near Cane Springs, southern Cedar Mountains.

Beds of Oquirrh Group, Butterfield Peaks Formation in Wildcat Canyon, southern Cedar Mountains.