INTERIM 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]

[1] Utah Geological Survey, P.O. Box 146100, Salt Lake City, UT 84114-6100
[2] Department of Geology, Kansas State University, Manhattan, KS 66506-3201

Disclaimer

This open-file release provides information to the public during the review and production period necessary for a formal UGS publication. The map may be incomplete and inconsistencies, errors, and omissions have not been resolved. While the document is in the review process, it may not conform to UGS standards; therefore it may be premature for an individual or group to take actions based on its contents. Although this product represents the work of professional scientists, the Utah Department of Natural Resources, Utah Geological Survey, makes no warranty, expressed or implied, regarding its suitability for a particular use. The Utah Department of Natural Resources, Utah Geological Survey, shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to claims by users of this product.

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, G09AC00152, and G10AC00386. 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.

OPEN-FILE REPORT 593
UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources
2012

GEOLOGIC UNIT DESCRIPTIONS

QUATERNARY

Alluvial deposits

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

Qai **Alluvial silt deposits** (Holocene) – 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 some unexposed, thin, fine-grained lacustrine deposits; thickness less than about 20 feet (6 m).

Qat **Alluvial-terrace deposits** (Holocene to upper Pleistocene) – Sand, silt, clay, and gravel in terraces above floodplains; surfaces typically 10 feet (3 m) or more above adjacent drainages; thickness is 40 feet (12 m) or less.

Qafy **Younger alluvial-fan deposits, post-Bonneville** (Holocene) – 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 canyon and mountain valleys; may include small 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, Qafy spreads out along the wave-cut terraces and abuts Lake Bonneville shorelines, and Qafy also drapes over but does not completely conceal shorelines; thickness variable, to 100 feet (30 m) or more.

Qafb **Alluvial-fan deposits, 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; may include small areas of eolian and colluvial deposits; incised by younger alluvial deposits; thickness variable, to 100 feet (30 m) or more.

Qafo **Older alluvial-fan deposits, pre-Bonneville** (upper to middle? Pleistocene) – Poorly sorted gravel with sand, silt, and clay; forms higher level deposits that predate Lake Bonneville and that are incised by younger alluvial deposits; may locally include small areas of lacustrine or eolian deposits; Geomatrix (2001) reported on subsurface Quaternary deposits in Skull Valley that are of pre-Bonneville age (~28 to >160 ka); thickness variable, to 100 feet (30 m) or more.

Spring deposits

Qsm **Spring and marsh deposits** (Holocene) – Clay, silt, and sand that is variably organic-rich, calcareous, or saline; present in ephemeral or perennial saturated (marshy) areas near springs and seeps near the center of valleys; thickness 0 to 30 feet (0-10 m).

Eolian deposits

Qe **Eolian deposits** (Holocene) – Windblown sand and silt in sheet and dune forms; mapped in Skull Valley and Cedar Valley; 0 to 20 feet (0-6 m) thick.

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; 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; thickness to 50 feet (15 m).

Qei **Eolian silt** (Holocene) – Windblown silt and some fine sand; forms small dunes and sheet deposits; mapped in three areas near the Bonneville shoreline on the southeast side of Rush Valley; less than 20 feet (6 m) thick.

Lacustrine deposits (post Bonneville lake cycle)

Qpm **Playa mud** (Holocene) – Clay, silt, and small amounts of sand with local accumulations of gypsum, halite, and other salts; present within the playa lake bed of Rush Lake and one other area in Rush Valley; thickness is 10 feet (3 m) or less.

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)

Table 1 presents ages and elevations of Lake Bonneville shorelines in the map area. Shoreline elevation ranges 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. Crittenden (1963) and Currey (1982) provided regional data on shoreline elevations and rebound. Several prominent erosional and depositional landforms related to Lake Bonneville exist in the map area, described below.

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. 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, 2008); radiocarbon dating of the channels ranges from 8800 to 12,500 ^{14}C years B.P. (about 10,000 to 13,000 calendar years 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). Rush Valley contains the Bonneville-level shoreline and two sets of regressive-phase shorelines. These shorelines were initially described by Burr and Currey (1988, 1992) in conjunction with the Stockton Bar; co-author Oviatt also evaluated these shorelines in the field. 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 regressive shorelines present in Rush Valley (previously attributed to Lake Shambip, about 5050 feet [1540 m] in elevation, and Lake Smelter, about 5010 feet [1527 m] in elevation) do not coincide in elevation with the Provo or Gilbert levels of Lake Bonneville.

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).

Qlg **Lacustrine gravel** (upper Pleistocene) – Sandy gravel to boulders composed of locally derived rock fragments deposited in shore zones of Lake Bonneville; locally tufa-cemented (especially the Provo shoreline) 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; thickness to 100 feet (30 m) or more.

Qlf **Lacustrine fine-grained deposits** (upper Pleistocene) – Sand, silt, marl, and calcareous clay of Lake Bonneville; thinly to very thick bedded; locally includes the white marl of Gilbert (1890); thickness to 100 feet (30 m) or more.

Glacial deposits

Qg **Glacial deposits, undifferentiated** (upper to middle? Pleistocene) – Till present in terminal, lateral, valley-head, and end moraines, and outwash composed of

fine- to coarse-grained detritus derived from glaciated bedrock; present in several cirques and valleys near Deseret Peak in the Stansbury Mountains and Flat Top Mountain of the Oquirrh Mountains (also see Rigby, 1958; Valora, 1968; Sorensen, 1982; Mulvey, 1985; Osborn and Bevis, 2001; Laabs and others, in press); locally includes unmapped landslides and rotational slumps, particularly in cirque basins, as well as alluvial and colluvial deposits; Osborn and Bevis (2001) reported these deposits are primarily of Angel Lake age (Great Basin equivalent to Pinedale of Middle Rocky Mountains) and that some are also older; the Pinedale extended from about 12,000 to 24,000 years ago, while the older Bull Lake extended from about 128,000 to 186,000 years ago (Imbrie and others, 1984); up to 300 feet (90 m) thick.

Colluvial deposits

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

Mass-movement deposits

Qmtc **Talus and colluvial deposits** (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 **Landslide deposits** (Holocene to middle? Pleistocene) – Poorly sorted clay- to boulder-size material; generally characterized by hummocky topography, main and internal scarps, and chaotic bedding in displaced bedrock; undivided as to inferred age because new research shows 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 **Lacustrine and alluvial deposits** (Holocene to upper Pleistocene) – Mixed and reworked, gravelly lacustrine and alluvial deposits on piedmont slopes; includes pre-Bonneville alluvial fans etched by waves in Lake Bonneville, and thin alluvial-fan deposits overlying fine- to coarse-grained lake sediments; grades from pebbly sand and silt to sandy pebble gravel; 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** (Holocene to upper Pleistocene) – Primarily gravel, with sand, silt, and clay; forms aprons of small alluvial-fan and colluvial surfaces that spill out onto and grade into alluvial-fan deposits; also present within upland valleys; thickness generally less than 20 feet (6 m).

Qea **Eolian and alluvial deposits** (Holocene) – Included below solely as stacked unit Qea\Qlf.

Human-derived deposits

Qh **Human disturbance** (Historical) – Deposits and disturbed areas from human development; includes several disturbed areas on Dugway Proving Ground and Tooele Army Depot (South Area); also used for landfills on Skull Valley Indian Reservation and in Cedar Valley, several pits and quarries, tailings area north of Stockton Bar, and large mine areas (Mercur, Ophir, Bingham); thickness generally less than about 20 feet (6 m), but mine-dump deposits may exceed 200 feet (60 m) thick.

Stacked-unit deposits

Qei/Qal

Eolian silt over alluvial deposits (Holocene over Holocene) – Windblown silt overlying alluvial deposits of clay, silt, sand, and some gravel in one area west of Ditto (formerly Dog) area at Dugway Proving Ground; cover unit thickness typically less than 10 feet (3 m).

Qei/Qlf

Eolian silt over lacustrine fine-grained deposits (Holocene over upper Pleistocene) – Windblown silt overlying lacustrine silt, clay, marl, and some sand over a large area of Government Creek basin and smaller areas of southeastern Rush Valley; surface commonly contains distinctive vegetation stripes (characteristic landforms of sheetflow plains in arid to semiarid regions) (Oviatt and others, 2003); may locally include areas of thicker eolian deposits; cover unit thickness typically less than 3 feet (1 m).

Qea/Qlf

Eolian and alluvial deposits over lacustrine fine-grained deposits (Holocene over upper Pleistocene) – Windblown silt deposited in sheets adjacent to and locally covering alluvial sand and gravel in unmapped channels overlying lacustrine marl and fine-grained deposits; locally saline or gypsiferous; forms one exposure in Government Creek basin that is part of extensive mudflats of southern Great Salt Lake Desert; may locally include small areas of thicker eolian deposits; cover unit thickness typically less than 15 feet (5 m) thick.

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 in Skull and Cedar Valleys; cover unit thickness typically less than 10 feet (3 m) thick.

Qes/Qlf

Eolian sheet sand deposits over lacustrine fine-grained deposits (Holocene over upper Pleistocene) – Windblown sand and some silt deposited in sheets; overlies lacustrine silt, clay, marl, and some sand northeast of Little Granite Mountain; locally includes areas of thicker eolian deposits; cover unit thickness typically less than 6 feet (2 m).

Qed/Qlf

Eolian dune sand deposits over lacustrine fine-grained deposits (Holocene over upper Pleistocene) – Windblown dune sand and some silt overlying lacustrine sand, silt, marl, and clay; cover unit thickness typically less than 20 feet (6 m).

Qes/Qla

Eolian sheet sand deposits over lacustrine and alluvial deposits (Holocene over Holocene to upper Pleistocene) – Windblown sheet sand and silt overlying gravelly to fine-grained lacustrine and alluvial deposits; present at and northwest of Dugway and upland valley of White Rock-Post Hollow area; cover unit thickness typically less than 10 feet (3 m).

Qes/Qafy

Eolian sheet sand deposits over younger alluvial-fan deposits (Holocene over Holocene to upper Pleistocene) – Windblown sheet sand and silt covering younger alluvial fans west of Johnson Pass; cover unit thickness typically less than 10 feet (3 m).

Qes/Qafo

Eolian sheet sand deposits over older alluvial-fan deposits (Holocene over upper to middle? Pleistocene) – Windblown sheet sand and silt overlying older alluvial fans near Barlow Creek of the southwestern Stansbury Mountains; cover unit thickness typically less than 10 feet (3 m).

Qed/Qla

Eolian dune sand deposits over lacustrine and alluvial deposits (Holocene over Holocene to upper Pleistocene) – Windblown sand and some silt that forms well-developed dunes overlying gravelly to fine-grained lacustrine and alluvial deposits; locally well exposed in large gravel pit on southern margin of Cedar Mountains and north of the Dugway Proving Grounds airfield; cover unit thickness typically less than 20 feet (6 m).

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); exposures located on north side of

Hickman Knolls on the Skull Valley Indian Reservation; cover unit thickness to 6 feet (2 m) or more.

Qed/Tac
Eolian dune sand deposits over andesitic and dacitic rocks of southern Cedar Mountains (Holocene over middle Eocene) – Windblown dune sand and silt overlying bedrock unit; locally includes small bedrock exposures; cover unit thickness typically less than 10 feet (3 m).

Qlg/R **Lacustrine gravel over undifferentiated bedrock** (upper Pleistocene over Miocene? to Cambrian?) – Sandy and pebbly gravel overlying various bedrock units along western and southern margin of Cedar Mountains, on Camels Back Ridge, and in northern East Tintic Mountains; locally includes small bedrock exposures; cover unit thickness typically less than 15 feet (5 m).

QUATERNARY-TERTIARY

QTaf **High-level alluvial-fan deposits** (lower Pleistocene? to Pliocene?) – Poorly sorted gravel with sand, silt, and clay; 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.

TERTIARY

Taf **Tertiary alluvial-fan deposits** (Pliocene? to Oligocene?) – 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 deposition via extensional unroofing of Sheeprock Mountains; lower part of unit is partially lithified; unit overlies the rhyolite of Judd Creek, and is lapped onto and incised by younger alluvial deposits; exposed thickness is greater than 1200 feet (365 m).

Tsl **Salt Lake Formation** (Miocene) – Mapped in three areas: (1) Skull Valley (surface and subsurface), (2) South Willow Canyon area of the Stansbury Mountains, and (3) central Rush Valley. In ***Skull Valley***, a single outcrop of charophytic marl and limestone is mapped along State Road 196 north of Dugway, with an exposed thickness of 30 feet (10 m); trenching at the proposed Private Fuel Storage site (located on Skull Valley Indian Reservation north of Hickman Knolls) exposed predominantly claystone and tuffaceous siltstone with interbeds of siliceous vitric ash (tuff) and minor gravelly sandstone (Geomatrix, 2001); based on geochemical correlation of volcanic ashes, ages reported for this unit (table 2) were about 6 Ma (unknown tephra) and 6.31 $\pm$ 0.04 Ma (Walcott tuff) (SWEC, 1997; Geomatrix, 2001; M.E. Perkins, University of Utah, written communication, November 18, 2009); maximum subsurface thickness encountered in Skull Valley is about 90 feet (27 m), total thickness unknown.

Stansbury exposures are interbedded tuffaceous sandstone and conglomerate that weather rusty-orange with carbonate, igneous, and quartzite pebbles in a fine sandy calcareous matrix (Rigby, 1958; Copfer and Evans, 2005); Perkins and others (1998) geochemically correlated a tephra here to the Cougar Point Tuff unit XIII ash, which has an $^{40}Ar/^{39}Ar$ age of 10.94 $\pm$ 0.03 Ma (table 2); exposed thickness to about 1000 feet (300 m), total thickness 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 waterlain sandy ash in intervals 60 to 100 feet (23-30 m) thick; yielded five tephra interpolation and correlation ages from about 6.31 to 9.8 Ma (table 2) (Perkins and others, 1998); new U-Pb detrital zircon age from a sample in southern Rush Valley yielded an age of 6.49 $\pm$ 0.38 Ma (Kirby, in preparation; table 5); regional ages on the Salt Lake Formation extend from about 6 to 16.2 Ma (Perkins and Nash, 2002; M.E. Perkins, University of Utah, written communication, August 2, 2010); unit is up to 4200 feet (1280 m) thick (Kirby, 2010a, 2010c).

IGNEOUS AND SEDIMENTARY ROCKS OF THE SOUTHERN CEDAR MOUNTAINS, DAVIS KNOLLS, NORTHERN SIMPSON MOUNTAINS, NORTHERN SHEEPROCK MOUNTAINS, AND SOUTHERN STANSBURY MOUNTAINS

Geochemical and age data for Tertiary igneous rocks are presented in tables 3 and 4, NMGRL and UGS (2006), Clark (2008), UGS and NMGRL (2009a, 2009b), and UGS and NIGL (2012b). Rock names are generally from the total alkali-silica classification diagrams for volcanic rocks (Le Bas and others, 1986) and plutonic rocks (Middlemost, 1994). Descriptions and thickness data from Clark and others (2008) and this study.

Trr **Rhyolite of Rydalch Canyon area** (Eocene?) – Light-gray and very pale orange rhyolitic ash-flow tuff exposed south and east of Rydalch Canyon in southern Cedar Mountains; about 25% phenocrysts of feldspar, quartz, hornblende, and biotite; $^{40}Ar/^{39}Ar$ age of 39.18 $\pm$ 0.06 Ma (sanidine); exposed thickness to 650 feet (200 m).

Ts **Tertiary strata** (middle Eocene) – Grayish-orange, very pale orange, and moderate-orange-pink lacustrine limestone that is locally oncolitic, moderately crystalline, poorly to thin bedded, and underlain by moderate-reddish-orange tuffaceous sandstone in one area near Dugway; Little Valley exposure is moderate reddish orange micaceous mudstone and minor conglomerate; Davis Knolls area exposures include yellowish-brown to pale-red conglomerate and sandstone with rounded pebbles, cobbles, and boulders of quartzite and sandstone, locally these exposures are silicified to gray and red-brown colors; southern Stansbury Mountains exposure includes reddish-orange conglomerate with carbonate clasts in South Willow Canyon (queried there since no age control); U-Pb detrital zircon

age of 46.77 ± 1.28 Ma from Davis Knolls (table 5); 0 to about 200 feet thick (0-60 m) (Moore and Sorensen, 1977; Copfer and Evans, 2005; Clark and others, 2008).

Trdc **Rhyodacite of Cherry Springs** (upper Eocene) – Light-green dacitic ash-flow tuff with phenocrysts (~30%) of plagioclase, quartz, and biotite, and also pumice lapilli and volcanic rock fragments to 2 inches (5 cm) diameter; exposed near Simpson Springs, northwestern Simpson Mountains; outcrops correlated geochemically to rhyodacite of Cherry Springs (table 3; Yambrick, 1990); 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 near Simpson Springs; maximum exposed thickness is about 100 feet (30 m).

Trj **Rhyolite of Judd Creek** (upper Eocene) – Light-gray to light-pink and locally light-green rhyolitic ash-flow tuff; phenocrysts (~25%) of plagioclase, quartz, and biotite; exposed at Simpson Canyon, northwestern Simpson Mountains; correlated geochemically to rhyolite of Judd Creek (table 3; Yambrick, 1990); 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 **Latite of Government Creek** (upper-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; crops out near Government Creek between Davis Mountain and Simpson Mountains; does not appear to geochemically correlate to rocks of the eastern Simpson Mountains area (table 3; Yambrick, 1990); no age data, but may underlie Trj; exposed thickness is 40 feet (12 m) or less.

Tdi **Dacitic intrusions of White Rock and Little Granite Mountain** (middle Eocene) – Light-gray weathering to white and yellowish-gray porphyritic dacite; 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 (UGS and NMGRL, 2009a, 2009b); exposures to 9500 feet (2900 m) across.

Tac **Andesitic and dacitic rocks of southern Cedar Mountains** (middle Eocene) – Dark- to light-gray and pale-red lava flows interlayered with lahars and less common tuffs; lava flows are porphyritic to aphanitic, with phenocrysts of feldspar, quartz, and biotite; lahars contain clasts of intermediate volcanic rocks to 4 feet (1 m) across; variously welded ash-flow tuffs contain phenocrysts of feldspar, hornblende, and biotite; calc-alkaline affinities are similar to those of other Oligocene-Eocene rocks in the region (Clark, 2008); erupted from local vents mapped as Taci; $^{40}Ar/^{39}Ar$ age of 38.17 ± 0.47, and ages (from adjacent map

area) of 41.73 ± 0.24 Ma (hornblende) and 40.66 ± 0.45 (groundmass) (UGS and NMGRL, 2009b); exposed thickness to 1200 feet (370 m).

Taci **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 (Tac); phenocrysts of feldspar, 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.

Tvs **Intermediate volcanic rocks of Stansbury Mountains** (middle Eocene) – Interlayered lahars, debris flows, lava flows, and tuff described by Davis (1959); light-gray lahars are thin to very thick bedded with mostly cobble-size clasts, and gray to pale-red debris flows are indistinctly bedded with shattered clasts to boulder size; lahars and debris flows contain clasts of pale-red and moderate- to dark-gray intermediate volcanic rocks; latitic lava flows are moderate-gray weathering to light gray brown with small phenocrysts of plagioclase and biotite; tuff is pumice rich; exposures in South Willow Canyon area of Stansbury Mountains; Moore and McKee (1983) reported K-Ar ages of about 39 to 42 Ma north of the map area; exposed thickness to about 1400 feet (430 m).

IGNEOUS AND SEDIMENTARY ROCKS OF SOUTHERN OQUIRRH MOUNTAINS, SOUTH MOUNTAIN, AND WESTERN TRAVERSE MOUNTAINS

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. The terminology for the intrusive rocks of the Bingham district (after Lanier and others, 1978) is based on historic usage at Bingham mine (for the purpose of separating similar rock units); it is entrenched and does not necessarily reflect their geochemical compositions and newer geochemically-based rock classifications. For geochemical and age data, see Waite (1996), Waite and others (1997), Pulsifer (2000), Maughan (2001), Biek and others (2005), Biek (2006b); also refer to table 4. Unit thickness data is from Biek and others (2005) and this study.

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

Younger Extrusive and Sedimentary Rocks

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; 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 in the west Traverse Mountains; K-Ar age on clast of 30.7 ± 0.9 Ma (Moore, 1973); thickness to 300 feet (90 m).

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

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 Tvlb; exposed thickness may exceed 600 feet (180 m).

Tvlb **Lahars and debris flows 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 in 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).

Trf **Rhyolitic lava flows of Tickville Gulch** (lower Oligocene) – Rhyolite vitrophyre flows and lesser blocky flow breccia of green, pink, white, and black colors; 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, 1973); thickness may exceed 1500 feet (460 m).

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).

Younger Intrusive Rocks

Tdio **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 (Biek and others, 2005); 75 to 90 feet (23-27 m) thick.

Tri **Rhyolitic intrusions** (early Oligocene? to late Eocene) – Rhyolitic intrusions of Shaggy Peak (Rose-Butterfield Canyon area), Tickville Gulch area, Dry Mountain-Ophir area, and Eagle Hill-Mercur 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 (Biek and others, 2005) and prior K-Ar age of 33.0 ± 1.0 Ma (Moore, 1973). Tickville Gulch intrusion is white, altered and chalky weathering, with phenocrysts of quartz common. Eagle Hill Rhyolite is white, tan, and pink rhyolite and rhyolite porphyry; usually aphanitic with ~1% phenocrysts of quartz and rare biotite, locally flow banded; occurs as dikes and sills at Mercur (Mako, 1999) and Ophir (Laes and others, 1997); K-Ar age of 31.6 ± 0.9 Ma (Moore, 1973), and new $^{40}Ar/^{39}Ar$ isochron age on biotite of 32.38 ± 0.10 Ma (UGS & NIGL, 2012b); U-Pb age on zircon for a rhyolite dike near Ophir is 36.46 ± 1.40 Ma (Kirby, in preparation; table 5).

Tai **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).

Tpqmi **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 granodiorite (dacite) porphyry with abundant phenocrysts of plagioclase and biotite and lesser hornblende in fine-grained groundmass; typically weathers to grussy or clayey soils; present near mouth of Butterfield Canyon near former Lark townsite (Swenson, 1975; Biek and others, 2005); 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 on 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).

Older Volcanic and Intrusive Suite (middle Eocene, ~37-40 Ma) – Data indicate that the 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).

Older Extrusive and Sedimentary Rocks

Ts? **Tertiary strata?** (middle Eocene?) – White to rusty-brown and reddish orange, conglomerate, pebbly conglomerate, pebbly sandstone, and gritstone; clasts reflect local sources including quartzite, quartzitic sandstone, limestone, and black chert likely from Oquirrh Group and other Paleozoic units; medium- to very thick bedded (but commonly crudely so), and poorly to very resistant forming ledges, cliffs, and rounded knobs; present in western Traverse Mountains and Fivemile Pass; similar to other Ts exposures but queried since no direct age control; 0 to about 200 feet thick (0-60 m) (Disbrow, 1957; Biek and others, 2005).

Tvfo **Nepheline minette and shoshonite lava flows** (middle Eocene) – Dark-gray minette with abundant phenocrysts of olivine and minor phlogopite and pyroxene, and another minette with minor olivine and more abundant phlogopite and pyroxene; also includes red, aa-type, shoshonite and olivine latite lava flows with abundant small phenocrysts of olivine, pyroxene, and biotite (Pulsifer, 2000; Maughan, 2001; Biek and others, 2005); poorly exposed near the Rose-Butterfield Canyon area of Oquirrh Mountains; minette $^{40}Ar/^{39}Ar$ age of 37.82 $\pm$ 0.14 Ma (Deino and Keith, 1997) and prior K-Ar age of 38.5 $\pm$ 0.3 Ma (Moore and McKee, 1983); exposed thickness to 150 feet (45 m).

Tsu **Lacustrine strata** (middle Eocene) –Yellowish-brown, brownish–gray, and light-gray, typically thin-bedded and tuffaceous mudstone, siltstone, oncolitic limestone, and volcaniclastic sandstone; locally silicified; present in one area near Butterfield Canyon; interlayered with Tvfou and Tvlo; exposed thickness about 150 feet (45 m) (Biek and others, 2005; Biek, 2006a).

Tvfou **Older intermediate lava flows** (middle Eocene) – Dark-gray lava flows of intermediate composition derived from Bingham intrusive complex; interlayered with and difficult to differentiate from the older lahars and debris flows (Tvlo); present between Butterfield and Rose Canyons; no age data; exposed thickness likely exceeds 1000 feet (300 m).

Tvlo **Older lahars and debris flows** (middle Eocene) – 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 adjacent Oquirrh outcrops; contains some thin discontinuous lava flows of intermediate composition (Pulsifer, 2000; Maughan, 2001; Biek and others, 2005); generally forms rubbly slopes between Butterfield and Rose Canyons and along south flank of Bingham mine, and on northeast flank of South Mountain (western Traverse Mountains); Bingham area $^{40}Ar/^{39}Ar$ ages of 38.68 $\pm$ 0.13 Ma from waterlain tuff near top of unit (Maughan, 2001) and 39.18 $\pm$ 0.11 Ma from clast near base of unit (Deino and Keith, 1997); thickness may exceed 4000 feet (1200 m).

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; based on cross-cutting relations, Tdmo is older than Tri dikes; dikes are 1 to 4 feet (0.3 to 1 m) wide.

Tqmi **Quartz monzonite porphyry intrusion** (middle Eocene?) – Altered part of the Soldier Canyon stock with K-spar and quartz phenocrysts and limonite staining (Lufkin, 1965); Laes and others (1997) suggested intrusion may be related to Bingham stock, which has a K-Ar age of 37.6 $\pm$ 0.07 Ma (Moore, 1973).

Tmi **Monzonite intrusions** (middle Eocene) – Monzonite intrusions of Spring Gulch, Soldier Canyon, and Bingham (Last Chance) areas. Fine- to medium-grained, equigranular, containing augite, hornblende, biotite, and magnetite, and ranging compositionally from diorite to quartz monzonite; the Spring Gulch monzonite crops out just north of the Calumet mine east of Stockton (Krahulec, 2005); Tmi also present at the Soldier Canyon stock (Lufkin, 1965) and near the axis of Long Ridge anticline (Laes and others, 1997; Tooker, 1992); 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 prior K-Ar age of 38.6 $\pm$ 0.18 Ma (Moore, 1973), U-Pb age of 38.55 $\pm$ 0.19 Ma, and $^{40}Ar/^{39}Ar$ age of 38.40 $\pm$ 0.16 Ma (Parry and others, 2001); K-Ar age of 38.0 $\pm$ 1.1 Ma (Moore, 1973) from monzonite porphyry stock of the Calumet Mine area, and new $^{40}Ar/^{39}Ar$ age on sanidine of 41.06 $\pm$ 0.21 Ma (UGS & NIGL, 2012b).

Tli **Latite to dacite porphyry sills and dikes** (middle Eocene) – Greenish-gray to dark-gray latite to dacite porphyry with abundant phenocrysts of plagioclase and hornblende and lesser biotite; present north of Butterfield and Middle Canyons in Oquirrh Group strata of south flank of Bingham mine area; K-Ar age of 37.1 $\pm$ 1.1 Ma (Moore, 1973), $^{40}Ar/^{39}Ar$ age of 38.84 $\pm$ 0.19 Ma (Deino and Keith, 1997); 0 to about 400 feet (120 m) thick.

Tqli **Quartz latite porphyry dikes** (middle Eocene) – Fine-grained, biotite, quartz latite porphyry with large potassium feldspar phenocryts (to 1 inch [3 cm]) and some augite; named the Raddatz porphyry (along Continental fault) in the Stockton/Rush Valley district where it forms dikes (Krahulec, 2005), also may crop out on Bald Mountain (north of Ophir); K-Ar age of 38.6 $\pm$ 1.1 Ma (Moore, 1973), $^{40}Ar/^{39}Ar$ age on Raddatz dike of 39.4 $\pm$ 0.34 Ma (Kennecott, unpublished date in Krahulec, 2005).

Tbi **Basalt sill** (middle Eocene) – Dark-gray basalt sill intruding Oquirrh strata on South Mountain; may be related to unit Tvfo; K-Ar age of 40.1 $\pm$ 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.

IGNEOUS AND SEDIMENTARY ROCKS OF THE VERNON HILLS

Unit descriptions and thickness data from Kirby (2010a, 2010b).

TERTIARY

Tbav **Basaltic andesite** (Oligocene?, Eocene?) – Dark-gray basaltic andesite lava flow with 20% 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).

Ts **Tertiary strata** (middle Eocene) – Interbedded conglomerate, limestone, mudstone, siltstone, and tuffaceous sandstone; red and red-brown conglomerate includes clasts of quartzite, carbonate, and sandstone in a sandy, gritty calcareous matrix; limestone is tan to pale-gray micrite that is medium bedded in intervals 10 to 20 feet (3-6 m) thick; mudstone and siltstone are red, red-brown, and purple with sandy lenses and are crudely to finely bedded; includes small exposure of breccia with Oquirrh fragments; present adjacent to the Vernon Hills fault; U-Pb detrital zircon age of 38.70 + 0.28 and -0.62 Ma (table 5); exposed thickness is greater than 2200 feet (>670 m) (Kirby, 2010a, 2010b).

Tdv **Dacite** (upper Eocene) - Light-gray to reddish-brown porphyritic dacite and trachydacite lava flows; phenocrysts (30%) of plagioclase and minor hornblende, and dark-gray lithic fragments; $^{40}Ar/^{39}Ar$ isochron age on plagioclase of 36.63 $\pm$ 0.16 Ma (UGS and NIGL, 2012a); maximum exposed thickness is 30 feet (10 m).

Trv **Rhyolite** (upper Eocene) – White to light-gray and locally dark-gray, rhyolitic ash-flow tuff; ranges from densely welded and flow banded 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 pale-red to gray porphyritic welded tuff; with 30% phenocrysts of plagioclase, biotite, hornblende; densely welded with flow banding; prior K-Ar biotite age of 38 $\pm$ 0.5 Ma (Moore and McKee, 1983), $^{40}Ar/^{39}Ar$ fusion age on sanidine of 35.33 $\pm$ 0.05 Ma and plateau age on plagioclase of 35.58 $\pm$ 0.29 Ma (UGS and NIGL, 2012a); exposed thickness is 40 to 100 feet (12-30 m).

IGNEOUS AND SEDIMENTARY ROCKS OF THE NORTHERN EAST TINTIC MOUNTAINS

Unit descriptions, age and thickness data from Christiansen and others (2007), Biek and others (2009), McKean (2011), McKean and others (in preparation), Allen (in preparation), and this study.

Tb **Mosida Basalt** (Miocene) – Medium-dark-gray, porphyritic, trachybasalt lava flow; contains phenocrysts of olivine, plagioclase, and clinopyroxene; vent is not exposed, but is located near Soldiers Pass in southern Lake Mountains (east of

map area); represents one of the oldest basaltic magmas of the eastern Great Basin, with $^{40}Ar/^{39}Ar$ ages of 19.47 $\pm$ 0.17 and 19.65 $\pm$ 0.15 Ma (Christiansen and others, 2007), additional Ar age pending (E.H. Christiansen, Brigham Young University [BYU]); 0 to 120 feet (35 m) thick.

Unconformity

Tfb **Mafic lava of Broad Canyon** (upper Oligocene) – Light gray to black, vesicular, porphyritic to aphanitic, shoshonitic lava flow with 10% megacrysts of anorthoclase and 5-15% phenocrysts of augite and highly altered micas that are replaced with Fe-oxides and olivine; preliminary $^{40}Ar/^{39}Ar$ age of 25.36 $\pm$ 0.03 Ma (E.H. Christiansen, BYU, written communication, July 20, 2011); thickness is 30 to 100 feet (10-30 m).

Tdm **Mafic dikes** (late Oligocene) – Aphanitic, dense basaltic intrusions with 10-25% phenocrysts of olivine, pyroxenes, and altered micas; forms three small exposures in the Boulter Peak quadrangle; preliminary $^{40}Ar/^{39}Ar$ age of 26.3 $\pm$ 0.3 Ma (E.H. Christiansen, BYU, written communication, July 20, 2011); exposed thickness less than 30 feet (10 m).

Tvm **Minette intrusion** (Oligocene) – Poorly consolidated intrusion with minette-like characteristics in one exposure at mouth of Black Rock Canyon (Boulter Peak quadrangle); 30-40% phenocrysts of brassy hexagonal biotite, and Fe-Ti oxides, apatite, clustered olivine, and possible carbonate; preliminary $^{40}Ar/^{39}Ar$ age of 28.45 $\pm$ 0.13 Ma (E.H. Christiansen, BYU, written communication, July 20, 2011); exposed thickness less than 30 feet (10 m).

Tpc **Pinyon Creek Conglomerate** (Oligocene?) – Agglomerate 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, 1961); unit includes a dark-gray pillow lava breccia (shoshonite) in one small exposure near Chimney Rock Pass; no age data; thickness is greater than 150 feet (>50 m).

Tlsl **Laguna Springs Volcanic Group, lava flow unit** (lower? Oligocene) – Andesite to trachyandesite lava flows that are reddish-brown, purplish-gray and gray; lavas are dense and commonly vitrophyric, with large phenocrysts (30-40%) of plagioclase, sanidine, biotite, hornblende, and clinopyroxene; $^{40}Ar/^{39}Ar$ age pending (E.H. Christiansen, BYU); exposed thickness to 750 feet (230 m).

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; no age data, but underlies Tlsl; exposed thickness to 400 feet (120 m).

Tlst **Laguna Springs Volcanic Group, tuff of Twelvemile Pass unit** (lower Oligocene) – Intensely welded tuff that is reddish brown to dark reddish brown; trachyandesite to trachydacite with phenocrysts (10-20%) of plagioclase, biotite, hornblende, and clinopyroxene, and flattened pumice lapilli (5-10%) (lapilli 6-20 cm and pumice 1-2 cm diameter); preliminary $^{40}Ar/^{39}Ar$ age of 32.66 Ma (E.H. Christiansen, BYU, verbal communication, January 14, 2010); exposed thickness to 125 feet (40 m).

Tsw **Soldiers Pass Formation, White Knoll Member** (lower Oligocene) – White and pale-yellowish-orange limestone that weathers yellowish gray, with interbedded very pale orange, white, and pale-red claystone; partly coeval with map unit Tsb, but probably spans a relatively large age range; thickness is 0 to 10 feet (3 m).

Tsb **Soldiers Pass Formation, breccia member** (lower Oligocene) – Gray, white, brown, and pale-red shoshonite lava flow; exposed mostly as distinctive, brecciated, carbonate-impregnated lava, but also occurs as gray and pale-red, locally vesicular lava flow; interfingers with and partly overlain by the White Knoll Member (Tsw); forms ledges and rounded knobs; $^{40}Ar/^{39}Ar$ age of 33.73 $\pm$ 0.65 Ma (Christiansen and others, 2007); exposed thickness is less than 40 feet (12 m).

Tsc **Soldiers Pass Formation, Chimney Rock Pass Tuff Member** (upper Eocene) – Yellowish-gray, porphyritic, rhyolitic ash-flow tuff; contains about 10% phenocrysts of quartz, plagioclase, sanidine, biotite, and Fe-Ti oxides in a glassy groundmass; also contains conspicuous pumice (10-15%, 1-5 cm) and lithic (10-15%, 1-4.5 cm) fragments; vent unknown, but may be near Black Point in southern Lake Mountains (east of map area); $^{40}Ar/^{39}Ar$ sanidine age of 34.73 $\pm$ 0.08 Ma from Chimney Rock Pass (Christiansen and others, 2007; Biek and others, 2009) and preliminary $^{40}Ar/^{39}Ar$ ages of 34.61$\pm$ 0.2 and 34.82 $\pm$ 0.06 Ma (E.H. Christiansen, Brigham Young University, verbal communication, January 14, 2010, and written communication July 20, 2011, respectively); exposed thickness to 100 feet (30 m).

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 and biotite in a glassy groundmass; tuff is rich in lithic fragments (15-20%, ~1 cm), pumice (10-15%), and black flattened pumice lapilli (5-15 cm); $^{40}Ar/^{39}Ar$ biotite age of 34.64 $\pm$ 0.17 Ma (UGS and NMGRL, 2007) from Tintic Mountain quadrangle (south of map area); exposed thickness is to 150 feet (45 m).

Tp **Packard Quartz Latite, undivided** (upper Eocene) – 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; also contains pumice (1-5%, 1-4

cm) and lithic fragments (1-5%, 1-4 cm) that are not as abundant as in the Chimney Rock Pass Tuff Member of the Soldiers Pass Formation; preliminary $^{40}Ar/^{39}Ar$ age of 35.08 $\pm$ 0.03 Ma (E.H. Christiansen, BYU, verbal communication, January 14, 2010); locally consists of a flow breccia with a preliminary $^{40}Ar/^{39}Ar$ age of 35.27 $\pm$ 0.03 Ma (E.H. Christiansen, BYU, written communication, July 20, 2011); also includes one exposure of dark-brown, densely welded, ash-flow tuff (vitrophyre) with a preliminary $^{40}Ar/^{39}Ar$ age of 35.21 $\pm$ 0.03 Ma (E.H. Christiansen, BYU, verbal communication, January 14, 2010); unit includes one small exposure of rhyolitic tuff underlying Packard Quartz Latite in Broad Canyon (Allen, in preparation); Morris and Lovering (1979) subdivided the Packard into several units that are not all present in the map area; exposed thickness to 500 feet (150 m).

Ts? **Tertiary strata?** (middle Eocene?) – Moderate reddish orange conglomerate that is poorly bedded with subangular carbonate clasts; one exposure in Twelvemile Pass, northern East Tintic Mountains; 0 to about 50 feet thick (0-15 m) (Disbrow, 1961).

TERTIARY-CRETACEOUS

TKj **Jasperoid** (Tertiary? and Cretaceous?) – Silica breccia, commonly dark red to dark red brown or moderate gray; probably associated with Sevier orogenesis and Tertiary volcanism; only larger exposures mapped in Davis Mountain, northern Sheeprock Mountains, Vernon Hills, northern East Tintic Mountains, and southern Oquirrh Mountains; variable thickness.

DEVONIAN TO CAMBRIAN STRATA OF CAMELS BACK RIDGE AND SIMPSON BUTTES

We apply the regional stratigraphic names of Hintze and Robison (1975) and Hintze (1980) to Devonian through Cambrian strata of Camels Back Ridge rather than local names of the Dugway Range (Staatz and Carr, 1964; Staatz, 1972). Descriptions and thicknesses are from Clark and others (2008); age data are contained within several sources (see Hintze and Davis, 2003, for a comprehensive treatment).

Dg? **Guilmette Formation?** (Upper to Middle Devonian) – Moderate- to dark-gray, thin- to thick-bedded, finely to moderately crystalline dolomite; locally weathers brownish gray, and forms ledges; queried due to structure and incomplete section; exposed thickness about 500 feet (150 m).

Fault

Dsi **Simonson Dolomite** (Middle Devonian) – Light- to dark-gray, finely to moderately crystalline dolomite; locally weathers brownish gray; local zones of chert; thin- to very thick bedded unit forms cliffs and ledges; exposed thickness about 500 feet (150 m).

Dsy **Sevy Dolomite** (Lower Devonian) – Moderate-gray, finely crystalline dolomite that weathers light gray with laminated surface appearance; thin to medium bedded, forms ledges; thickness is about 250 feet (75 m).

Fault

Sl **Laketown Dolomite, undivided** (Silurian) – Moderate- to dark-gray, finely to moderately crystalline dolomite that locally weathers to light and moderate brown and light gray, and 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 south, separated into several members (Hintze, 1980) corresponding to formations of Staatz and Carr (1964); exposed thickness is about 500 feet (150 m).

Oes **Ely Springs Dolomite** (Upper Ordovician) – Includes upper part (Floride Member) and lower part (lower member) not mapped separately; upper part is very light gray, finely crystalline dolomite with indistinct to medium bedding; 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; thickness is 250 feet (75 m).

Unconformity – Tooele Arch (Hintze, 1959); Eureka Quartzite and uppermost part of Pogonip Group likely missing

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

Op **Pogonip Group, undivided** (Middle to Lower Ordovician) – Exposed in low hills west of Camels Back Ridge; may include part of Kanosh Shale and underlying formations of this group; upper part is dark-gray and moderate-gray, finely to moderately crystalline dolomite, underlain by moderate-gray intraformational conglomerate, siltstone, and limestone; thin to medium bedded, forming ledges and slopes; Hintze (1980) described the various formations; exposed thickness to 150 feet (45 m).

Fault – separating Camels Back Ridge from low hills to west

We have not applied the changes to the Ordovician-Cambrian boundary reported in Hintze and Kowallis (2009), considering the ongoing debate on this issue.

Cn **Notch Peak Formation** (lowermost Ordovician to Upper Cambrian) – Present on crest and west flank of Camels Back Ridge; moderate- and light-gray, finely to moderately crystalline dolomite and limey dolomite, containing intervals several feet thick that weather to tan and light pink; locally includes pisolites, twiggy bodies, and *Girvanella* (algae); medium to very thick bedded, cliff and ledge forming; Dugway Ridge Formation of Staatz and Carr (1964); exposed thickness about 500 feet (150 m).

Cou **Orr Formation, upper part** (Upper Cambrian) – Present on east flank and crest of Camels Back Ridge; likely includes (decending order) Sneakover Limestone Member, Corset Spring Shale Member, Johns Wash Limestone Member, and Candland Shale Member; forms less resistant and lighter-colored interval between Notch Peak Formation and Big Horse Limestone; very light gray to light-gray, finely to moderately crystalline dolomite and limestone, and green and light-brown shale; commonly medium to thick bedded; Fera Limestone of Staatz and Carr (1964); 200 feet (60 m) thick.

Cob **Orr Formation, Big Horse Limestone Member** (Upper Cambrian) – Crops out on east flank and north part of Camels Back Ridge; medium- to very thick bedded, resistant interval forming cliffs and ledges; locally dolomitized; moderate-gray to tan-gray, finely to moderately crystalline limestone, with some intervals weathering to light tan, pink, and mottled; Straight Canyon Formation of Staatz and Carr (1964); 425 feet (130 m) thick.

Cl **Lamb Dolomite** (Upper to Middle Cambrian) – Largely present on east flank of Camels Back Ridge; upper part less resistant, mostly very thin to thin bedded and commonly rusty and pink weathering, 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; 900 feet (275 m) thick.

Ctl **Trippe Limestone** (Middle Cambrian) – Present on northeast side of Camels Back Ridge; forms generally less resistant and ledgey interval between Lamb Dolomite and Pierson Cove Formation; 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; gradational contact with Pierson Cove Formation below; 700 feet (215 m) thick.

Cpc **Pierson Cove Formation** (Middle Cambrian) – Present on northeast side of Camels Back Ridge; moderate-gray limestone with some light-gray dolomite interbeds, thin to very thick bedded forming ledges to cliffs; unit locally dolomitized; exposed thickness about 800 feet (245 m).

PERMIAN TO ORDOVICIAN STRATA OF SOUTHERN CEDAR MOUNTAINS AND SKULL VALLEY

Clark and others (2008) provided unit descriptions and their fossil age data are included in table 6. The Oquirrh Group has been substantially remapped to conform to the similar stratigraphy of the Oquirrh Mountains; refer to figure 3 for a comparison of Oquirrh strata between this map and Maurer (1970). The total thickness of Oquirrh Group strata is roughly 12,350 feet (3770 m). Following Laes and others (1997) and Hintze and Kowallis (2009), we combine Lower Permian (Wolfcampian) and Pennsylvanian formations under the Oquirrh Group, although this nomenclature differs from existing terminology established in the Oquirrh Mountains (Welsh and James, 1961; Tooker and Roberts, 1970).

PIPo **Oquirrh Group strata, undivided** (Lower Permian to Lower Pennsylvanian) – One area of combined unit on south margin of Cedar Mountains; exposed thickness about 50 feet (15 m).

PIPofm
Oquirrh Group, Freeman Peak, Curry Peak, and Bingham Mine Formations, undivided (Lower Permian and Upper Pennsylvanian, Wolfcampian-Virgilian) – See unit description under Oquirrh Mountains; one area along Cedar thrust, north of Rydalch Canyon.

Pofc **Oquirrh Group, Freeman Peak and Curry Peak Formations, undivided** (Lower Permian, Wolfcampian) – See unit description under Oquirrh Mountains; contains *Schwagerina* and *Triticites* cf. *T. meeki* (fusulinids); corresponds to most of Maurer's (1970) Unit 4 and Unit 5; 3500 feet (1070 m) thick.

Unconformity?

IPobm **Oquirrh Group, Bingham Mine Formation** (Upper Pennsylvanian, Virgilian-Missourian) – See unit description under Oquirrh Mountains; includes fusulinids (*Triticites and Pseudofusulinella*); corresponds to upper part of Maurer's (1970) Unit 3 and lower part of Unit 4; upper contact mapped at uppermost substantial limestone bed; 2800 feet (850 m) thick.

IPobw **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.

IPobp **Oquirrh Group, Butterfield Peaks Formation** (Middle to Lower Pennsylvanian, Desmoinesian-Morrowan) – See unit description under Oquirrh Mountains; includes fusulinids (*Fusulina, Beedeina*); corresponds to Maurer's (1970) Unit 2 and most of Unit 3; 5400 feet (1650) thick.

IPMwm

Oquirrh Group, West Canyon Limestone, and Manning Canyon Shale, undivided (Lower Pennsylvanian to Upper Mississippian, Morrowan-Chesterian) – Combined unit in small exposures of southern Cedar Mountains.

IPowc

Oquirrh Group, West Canyon Limestone (Lower Pennsylvanian, Morrowan) – See unit description under Oquirrh Mountains; corresponds to Maurer's (1970) Unit 1; 500 to 800 feet (150-245 m) thick.

IPMmc

Manning Canyon Shale (Lower Pennsylvanian to Upper Mississippian, Morrowan-Chesterian) – See unit description under Oquirrh Mountains; probably 1500 to 2000 feet (450-600 m) thick.

Faults

Mgb **Great Blue Limestone** (Upper Mississippian) – See unit description under Oquirrh Mountains; no obvious shaley intervals; top not exposed; 2440+ feet (745+ m) thick.

Mh **Humbug Formation** (Upper Mississippian) – See unit description under Oquirrh Mountains; base not exposed; 1014+ feet (310+ m) thick (Maurer, 1970).

Fault

Mg? **Gardison Limestone?** (Lower Mississippian) – See unit description under Oquirrh Mountains; greater than 600 feet (180 m) exposed.

Faults

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 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 Fish Haven Dolomite and Pogonip Group; exposed thickness about 200 feet (60 m).

TRIASSIC TO NEOPROTEROZOIC STRATA OF DAVIS AND LITTLE DAVIS MOUNTAINS, NORTHERN SIMPSON MOUNTAINS, SOUTHERN STANSBURY MOUNTAINS, ONAQUI MOUNTAINS, NORTHERN SHEEPROCK MOUNTAINS, AND VERNON HILLS

Triassic to Permian stratigraphy of the Martin Fork syncline area was modified from Jordan and Allmendinger (1979).

Trtw **Thaynes Limestone and Woodside Formation, undivided** (Lower Triassic) – ***Thaynes*** consists of light- to medium-gray and brown gastropod- and pelecypod-bearing limestone, sandstone, and siltstone; the unit is resistant, bioturbated, and medium bedded (irregularly); regionally contains *Meekoceras* (ammonite) at base of unit (Kummel, 1954); underlying ***Woodside*** contains pale-red and brown siltstone and calcareous sandstone, greenish-brown shale, and minor light-gray laminated limestone that is poorly exposed and forms slopes; exposed thickness of Thaynes is 590 feet (180 m) and Woodside is 210 feet (65 m), and combined unit thickness is 800 feet (245 m).

Ppfm **Park City Formation, Franson Member, and Phosphoria Formation, Meade Peak Phosphatic Shale Tongue, undivided** (Middle to Lower Permian) – ***Franson*** consists of moderate-brown and gray limestone, sandy limestone, and calcareous sandstone that is medium bedded, with minor shale; underlying ***Meade Peak*** consists of pale-red, brown, and dark-gray shale, with lesser bedded chert and phosphorite; forms a distinct red-brown-weathering slope or saddle; 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; thickness is 500 feet (150 m).

Pdc **Diamond Creek Sandstone** (Lower Permian) – Moderate-gray, weathering to light-brown, fine-grained calcareous sandstone that is thin to medium bedded; thickness is about 350 feet (105 m).

Pk **Kirkman Formation** (Lower Permian) – Moderate-gray to light-brown limestone, calcareous sandstone, fossiliferous carbonate conglomerate, and oncolitic limestone; limestone is locally bioclastic and cherty, and laminated with chert stringers and nodules; thin to thick bedded; exposed thickness is about 400 feet (120 m).

Martin Fork thrust fault – upper Oquirrh Group omitted; Martins Fork Spring thrust (Tooker, 1983)

Oquirrh strata of the southern Stansbury Mountains were evaluated and described by Wright (1961), Armin (1979), Armin and Moore (1981), and Jordan (1979a, 1979b). New and earlier fossil data are presented in table 6. It appears that both the upper (Freeman Peak Formation) and lower (West Canyon Limestone) parts of the Oquirrh Group have been truncated and omitted by faults near their respective contacts with

enclosing units of regional decollement (Kirkman Formation above and Manning Canyon Shale below).

Pofc **Oquirrh Group, Freeman Peak and Curry Peak Formations** (Lower Permian, Wolfcampian) – See unit description under Oquirrh Mountains; maximum exposed thickness is about 3500 feet (1100 m).

Unconformity?

IPobm **Oquirrh Group, Bingham Mine Formation** (Upper Pennsylvanian, Virgilian-Missourian) – See unit description under Oquirrh Mountains; thickness is about 8000 feet (2450 m) in southern Stansbury Mountains and exposed thickness is about 1850 to 3200 feet (560-980 m) in Vernon Hills.

Fault in Vernon Hills

IPobp **Oquirrh Group, Butterfield Peaks Formation** (Middle to Lower Pennsylvanian, Desmoinesian-Morrowan) – See unit description under Oquirrh Mountains; exposed thickness to 6000 feet (1800 m) in southern Stansbury Mountains, and 1100 to 1250 feet (340-380 m) in Vernon Hills.

Broad Canyon and Big Hollow faults – West Canyon Limestone omitted in southern Stansbury Mountains. These faults have several names and interpretations: Broad Canyon fault (Rigby, 1958; Cashman, 1992), Broad Canyon thrust (Tooker and Roberts, 1971; Sorensen, 1982; Tooker, 1983), and Central Range fault (Copfer and Evans, 2005).

Fault in Vernon Hills

IPowc

Oquirrh Group, West Canyon Limestone (Lower Pennsylvanian, Morrowan) – See unit description under Oquirrh Mountains; exposed thickness about 1150 to 1650 feet (350-500 m) in Vernon Hills.

Onaqui fault

IPMmc

Manning Canyon Shale (Lower Pennsylvanian to Upper Mississippian, Morrowan-Chesterian) – See unit description under Oquirrh Mountains; exposed thickness 0 to 1300 feet (0-400 m).

Fault in Vernon Hills

Mgb **Great Blue Limestone, undivided** (Upper Mississippian) – See unit description under Oquirrh Mountains; mapped as combined unit in the southernmost

Stansbury Mountains and areas to the south where the Long Trail Shale is not well exposed or absent; thickness about 1600 feet (490 m).

Mgbu **Great Blue Limestone, upper limestone member** (Upper Mississippian) – See unit description under Oquirrh Mountains; thickness is 800 feet (240 m).

Mgbs **Great Blue Limestone, Long Trail Shale Member** (Upper Mississippian) – See unit description under Oquirrh Mountains; thickness is 30 to 80 feet (10-25 m).

Mgbl **Great Blue Limestone, lower limestone member** (Upper Mississippian) – See unit description under Oquirrh Mountains; thickness is 700 feet (210 m) in southern Stansbury Mountains and incomplete thickness is 440 to 820 feet (130-250 m) in Vernon Hills.

Mh **Humbug Formation** (Upper Mississippian) – See unit description under Oquirrh Mountains; thickness is 700 feet (210 m) in southern Stansbury Mountains, and 850 to 1250 feet (260-380 m) in Vernon Hills.

Fault in Vernon Hills

Md **Deseret Limestone** (Upper to Lower Mississippian) – See unit description under Oquirrh Mountains; thickness is 525 feet (160 m) in southern Stansbury Mountains and attenuated thickness is about 200 feet (60 m) in Vernon Hills.

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; 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 **Gardison Limestone** (Lower Mississippian) – See unit description under Oquirrh Mountains; thickness is 700 feet (210 m) in southern Stansbury Mountains and 840 feet (260 m) in Vernon Hills.

Unconformity

MDfs **Fitchville Formation, Pinyon Peak Limestone, Stansbury Formation, undivided** (Lower Mississippian to Upper Devonian) – Combined unit south of Dry Canyon; refer to Fitchville-Pinyon Peak description below; Stansbury Formation is distinctive carbonate-clast conglomerate with rounded and commonly oblate light- and dark-gray carbonate clasts from 0.5 to 4 inches (1-10 cm) in diameter in a tan, sandy, dolomite matrix; Fitchville-Pinyon Peak thickness is about 450 feet (140 m), Stansbury thickness is about 0 to 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) – Gray, medium-bedded limestone (Fitchville) overlying gray to tan sandy and silty limestone that is locally bioclastic and irregularly bedded (Pinyon Peak); thickness is about 200 feet (60 m) in southern Stansbury Mountains and 60 feet (20 m) in Vernon Hills.

Dst **Stansbury Formation** (Upper Devonian) – White quartzite that weathers to tan and pale red, is locally cross-bedded, thin to medium bedded; exposed in quarry and adjacent hills southeast of Box Elder Canyon, Stansbury Mountains; exposed thickness is 200 feet (60 m) in Stansbury Mountains, but is absent to south and east.

Major unconformity – Stansbury uplift (Rigby, 1959a; Morris and Lovering, 1961)

Descriptions and thicknesses for Devonian through Cambrian units from Kirby (2010a, b) and this study. Also refer to Hintze and Davis (2003) for age data.

DOu **Guilmette Formation, Simonson, Sevy, Laketown, and Ely Springs Dolomites, undivided** (Upper Devonian to Upper Ordovician) – Combined unit in 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; ***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 0 to about 2000 feet (600 m).

Dg **Guilmette Formation** (Upper to Middle Devonian) – Dark-gray, medium- to fine-grained, moderately to weakly bedded, sparsely fossiliferous dark-gray dolomite with a few thin, dark-gray, fine-grained limestone beds near the top of unit; forms slopes and ledges; thickness is 180 feet (50 m) in Vernon Hills, and absent in northern Sheeprock Mountains and Davis Mountain.

Dsi **Simonson Dolomite** (Middle Devonian) – Light-brownish to pale- and medium-gray, fine to medium-grained, very thick or thin-bedded dolomite; generally more lithologically variable and less well bedded than the underlying Sevy; 670 to 930 feet (200-280 m) thick in Vernon Hills, 640 to 1150 feet (195-350 m) in Sheeprocks, 750 feet (225 m) in Davis Mountain.

Dsy **Sevy Dolomite** (Lower Devonian) – White to very-light or medium-gray, medium- to fine-grained dolomite; displays well developed fine-scale planar lamination on surface; rarely fossiliferous; contains uncommon thin beds of sandy dolomite; forms ledges and float-covered hills; 1310 feet (400 m) thick in Vernon Hills, 1200 to 1480 feet (360-450 m) in Sheeprocks, 590 feet (180 m) in Davis Mountain.

Unconformity

SOu **Laketown and Ely Springs Dolomites, undivided** (Silurian and Upper Ordovician) – Dark- to medium-gray, granular to fine-grained, moderately or poorly bedded cherty dolomite; 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; exposed thickness is 1060 to 1280 feet (320-390 m) in Vernon Hills, 1070 to 1690 feet (325-510 m) in Sheeprocks, and 1420 feet (430 m) in Davis Mountain.

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; variable thickness from 40 to 80 feet (12-24 m) in Vernon Hills, 260 to 1000 feet (80-300 m) in Sheeprock Mountains, 420 feet (125 m) in Davis Mountain, and absent in southern Stansbury Mountains.

Ok **Pogonip Group, Kanosh Shale** (Middle Ordovician) – Black to dark brown shale and lesser siltstone and sandstone; slope-forming unit; where thicker, locally mapped as separate unit, elsewhere mapped with Op; variable thickness from 0 to 250 feet (0-75 m).

Unconformity – Tooele Arch (Hintze, 1959); Eureka Quartzite and Kanosh Shale locally missing

Op **Pogonip Group, undivided** (Middle to Lower Ordovician) –Blue-gray-weathering limestone and reddish-tan-weathering silty limestone with lesser intraformational conglomerate and minor shale; thin to medium bedded in ledgey exposures; upper part locally includes about 100 feet (30 m) of slope-forming black to dark-brown shale and lesser siltstone and sandstone (Kanosh Shale); previously mapped as Kanosh Shale and Garden City Formation (Rigby, 1958; Teichert, 1958); thickness is 0 to 1350 feet (410 m) in southern Stansbury Mountains.

Clark and Kirby (2009) reevaluated the Cambrian stratigraphy of the Stansbury and northern Sheeprock Mountains. These strata closely resemble the western Utah section (Hintze and Robison, 1975) rather than the East Tintic Mountains section as initially applied by Rigby (1958) and perpetuated by Sorensen (1982) and Copfer and Evans (2005). Our revised terminology includes the following units (descending order): Notch Peak Formation; Orr Formation, upper part, includes Sneakover Limestone Member, Corset Spring Shale Member, and Johns Wash Limestone Member?; Orr Formation, Big Horse Limestone Member; Lamb Dolomite; Trippe Limestone (Fish Springs Member and lower member); Pierson Cove Formation; Wheeler Formation; Swasey Limestone; Whirlwind Formation; Dome Limestone; Chisholm Formation; Howell Limestone;

Pioche Formation; Prospect Mountain Quartzite (figure 4). Locally some of these units are combined due to map scale limitations or where structurally complex.

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

Cum **Upper and Middle Cambrian strata, undivided** (lowermost Ordovician, Upper and Middle Cambrian) – Combined unit of several formations in the southern Stansbury Mountains and northern Sheeprock Mountains where structural complexities make subdivision difficult; includes carbonates and shales from all or parts of the following formations: Notch Peak, Orr, Lamb, Trippe, Pierson Cove, Wheeler, Swasey, Whirlwind, Dome, Chisholm, and Howell; northward, the upper part of the section was removed by erosion associated with the Stansbury uplift; thickness roughly 1500 to 5000 feet (450-1500 m).

Cn **Notch Peak Formation** (lowermost Ordovician and Upper Cambrian) – Moderate to dark-gray dolomite with some light-gray intervals; medium to very thick bedded; thickness is about 1000 feet (330 m) in Stansbury Mountains, about 700 feet (210 m) in Sheeprocks, and greater than 500 feet (150 m) in Davis Mountain.

Co **Orr Formation** (Middle Cambrian) – Moderate-gray silty limestone that is thin to medium bedded; primarily upper part of unit exposed; exposed thickness is greater than 1200 feet (365 m) in the Stansbury and Sheeprock Mountains, and greater than 470 feet (140 m) in Davis Mountain.

Cl **Lamb Dolomite** (Middle Cambrian) – See description under Camels Back Ridge; thickness is about 1290 feet (390 m) in the Stansbury Mountains.

Red Pine fault – Lamb Dolomite omitted in northern Sheeprock Mountains

Cm **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 roughly 1500 feet (450 m).

Ctl **Trippe Limestone** (Middle Cambrian) – See description under Camels Back Ridge; thickness is about 1000 feet (305 m) in the Stansburys, and 1600 feet (490 m) in the Sheeprock Mountains.

Cpc **Pierson Cove Formation** (Middle Cambrian) – See description under Camels Back Ridge; thickness is about 620 feet (190 m) in the Stansbury Mountains,

1970 feet (600 m) in the Sheeprock Mountains, and greater than 540 feet (165 m) in the Simpson Mountains.

Cws **Wheeler Formation and Swasey Limestone, undivided** (Middle Cambrian) – ***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 sections of silty ribbon limestone and wackestone; contains *Elrathia* trilobite fauna (Hintze and Davis, 2003); combined unit thickness is about 340 to 970 feet (100-295 m) in the Stansbury Mountains, 550 feet (167 m) in the Sheeprock Mountains, and 1410 feet (430 feet) in the Simpson Mountains.

Cwh **Whirlwind Formation, Dome Limestone, Chisholm Formation, Howell Limestone, undivided** (Middle Cambrian) – ***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); ***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 330 to 830 feet (100-250 m) in the Stansbury Mountains, and 340 feet (103 m) in the Sheeprock Mountains, and 1410 feet (430 m) in the Simpson Mountains.

Cp **Pioche Formation** (Middle and 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; thickness is about 400 feet (120 m) or less.

Cpm **Prospect Mountain Quartzite** (Lower Cambrian) – 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; incomplete thicknesses in Stansbury Mountains about 4200 feet (1280 m) and Davis Mountain greater than 2800 feet (850 m); complete thicknesses of 4260 feet (1290 m) in Sheeprock Mountains, and 2800 feet (850 m) in northern Simpson Mountains.

Zm **Mutual Formation** (Neoproterozoic) – Maroon, pink, and purple quartzite that is feldspathic, medium to coarse grained, commonly gritty or pebbly with zones of red and white pebbles, locally contains abundant trough cross-beds; contact with overlying Prospect Mountain is transitional and can be difficult to place due to similar lithologies; 1660 feet (500 m) thick in Sheeprocks, and greater than 3900 feet (1180 m) exposed in 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; present in hanging wall of Government Canyon thrust fault in Sheeprock Mountains; in northern Simpson Mountains previously mapped as Inkom Formation? by Morris and Kopf (1986) and part of siltstone and quartzite unit, undivided (Moore and Sorensen, 1977); thickness is 600 feet (180 m) in Sheeprock Mountains, and greater than 790 feet (240 m) in northern Simpson Mountains.

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; similar to Prospect Mountain Quartzite but generally darker in color; queried in one large area of incomplete exposure in northern Simpson Mountains where neither top nor bottom contacts exposed (Morris and Kopf, 1986), greater than 3850 feet (1165 m) thick there.

PERMIAN TO CAMBRIAN STRATA OF SOUTHERN OQUIRRH MOUNTAINS, SOUTH MOUNTAIN, AND WESTERN TRAVERSE MOUNTAINS

The Permian-Pennsylvanian rocks of the southern Oquirrh Mountains are considered part of the Bingham Sequence, present south of the North Oquirrh thrust fault (Tooker and Roberts, 1970). Considering regional relations, and similar to Laes and others (1997) and Hintze and Kowallis (2009), we combine Lower Permian (Wolfcampian) and Pennsylvanian formations under the Oquirrh Group. This nomenclature differs from existing 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 strata of the southern Oquirrh Mountains total nearly 20,000 feet (6100 m) (Tooker and Roberts, 1970; Swenson, 1975), while equivalent strata in the Wasatch Range total up to approximately 29,000 feet (8850 m) (Constenius and others, 2011). Regarding the South Mountain-Stockton area, relations indicate that these rocks are in a different thrust plate than rocks of the southern Oquirrh Mountains, but we disagree with Tooker and Roberts' separate terminology of formational units (South Peak, Salvation, and Rush Lake) that they apply to Oquirrh Group rocks in their South Mountain nappe (Tooker and Roberts, 1988; Tooker and Roberts, 1992; Tooker and Roberts, 1998; Tooker, 1999); instead, we use nomenclature of the Bingham Sequence. We also revised the mapping and stratigraphic interpretations of Welsh and James (1998) on South Mountain. New fossil data are provided in table 6. Unit descriptions and ages for the Permian-Pennsylvanian-Mississippian strata are from Welsh and James (1961), Tooker and Roberts (1970), Swenson (1975), Jordan (1979a, 1979b), Tooker (1987), Biek (2004), Biek and others (2005), and this study.

Thrust fault

Pdk **Diamond Creek Sandstone and Kirkman Formation, undivided** (Lower Permian, Leonardian? to Wolfcampian) – Gray to tan, weathering to red brown, fine-grained sandstone and quartzite that is thin to medium bedded; slope-forming unit weathers to chips and blocks; the Kirkman 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; 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 age data; top not exposed, incomplete thickness is 2600 feet (790 m) in South Mountain.

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; thickness is 2900 feet (880 m) in South Mountain; 2400 feet (730 m) thick on Freeman Peak in Bingham district (Swenson, 1975).

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 thin bedded (poorly), 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; thickness is 1800 feet (550 m) in South Mountain; 2450 feet (750 m) thick in reference section on Curry Peak in Bingham district (Swenson, 1975).

Unconformity?

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

Tooker and Roberts (1970, 1998) separated the Bingham Mine Formation into the Markham Peak and Clipper Ridge Members based on lithology. Swenson (1975, p. 28) did not consider the type locality of the Markham Peak Member to represent a valid section and instead informally referred to these two divisions as the upper and lower members following Welsh and James (1961). Although subsequent Kennecott maps largely followed Swenson's mapping, they used the names Markham and Clipper Members for the upper and lower parts (Swenson and Kennecott, 1991; Laes and others, 1997). We use Swenson's informal two-member terminology only in the vicinity of Bingham mine.

IPobm **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; thickness is 5300 to 6500 feet (1600-2000 m) in Bingham district (Welsh and James, 1961; Swenson, 1975) and 6375 feet (1940 m) in South Mountain (Welsh and James, 1998).

IPobmu
Oquirrh Group, Bingham Mine Formation, upper member (Upper Pennsylvanian, Virgilian?) – Light-gray to brownish-tan, thin-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 in the Oquirrh Mountains (Swenson, 1975).

IPobml

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 were recovered from the Jordan Limestone east of Tooele (S.R. Ritter, Brigham Young University, written communication, October 27, 2009); thickness is about 3100 feet (945 m) near Middle Canyon (Swenson, 1975).

The Butterfield Peaks Formation was divided into upper and lower parts on Laes and others' (1997) map after Swenson (1975, p. 26). The upper part corresponds to the sandier upper portion of Swenson, whereas the lower part corresponds to Swenson's middle and lower parts, which contain more limestone. Swenson and Kennecott's (1991) map did not include this separation, and we do not find it useful regionally.

IPobp **Oquirrh Group, Butterfield Peaks Formation** (Middle to Lower Pennsylvanian, Desmoinesian-Morrowan) – Generally characterized by 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; overall limestone predominates over quartzite and sandstone, with clastic percentages increasing upsection; unit forms ledges and cliffs with regularly intervening slopes; thickness is 9000 feet (2765 m) on Butterfield Peaks in the Oquirrh Mountains (Tooker and Roberts, 1970).

IPowc **Oquirrh Group, West Canyon Limestone** (Lower Pennsylvanian, Morrowan) – Medium-gray limestone, sandy limestone, and fossiliferous limestone that is thin to medium bedded; locally laminated with silt and sand, some sparse chert; locally includes minor thin sandstone and quartzite in middle and near contacts; fossils include crinoid columnals, brachiopods, bryozoans, rugose corals, and fusulinids; forms ledgy exposures; forms basal carbonate package of Oquirrh Group; thickness from 1053 to 1456 feet (321-444 m) at reference and type sections in the Oquirrh Mountains (Nygreen, 1958; Tooker and Roberts, 1970).

IPMmc

Manning Canyon Shale (Lower Pennsylvanian to Upper Mississippian, Morrowan to 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; medium-gray to bluish-gray, thin to thick bedded, fossiliferous and argillaceous limestone; fossils include brachiopods, bryozoans, rare trilobites, and leaves; weak, slope-forming unit; in Soldier Canyon, conodont age data from Webster and others (1984), and palynomorphs (C. Morgan, UGS, verbal communication, April 13, 2009) suggest a middle to late Chesterian age (table 7); interval of regional decollement, commonly exhibiting substantial deformation; Soldier Canyon in the Oquirrh Mountains contains one of the few relatively intact sections, although some internal disturbance is noted; thickness at Soldier Canyon is 1140 feet (347 m) (Gilluly, 1932) to 1559 feet (475 m) (Moyle, 1959).

Faults

Mgbus

Great Blue Limestone, upper limestone and shale member (Upper Mississippian) – Interbedded, banded, silty and arenaceous, blue-gray, medium-bedded, sparsely fossiliferous limestone and thick section of fissile, greenish-black shale and interbedded thin chert and quartzite lenses; source of brick clay deposits and local variscite deposits north of Fivemile Pass; unit is a different facies of the upper limestone member with more shale at south end of the Oquirrh Mountains near Fivemile Pass, which Tooker (1999) called a separate structural block, whereas Laes and others (1997) mapped it as an upper shale unit within their upper limestone unit; Mgbus may be transitional with the Manning Canyon Shale; exposed thickness is roughly 2000 feet (610 m).

Fault

Mgbu **Great Blue Limestone, upper limestone member** (Upper Mississippian) – 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 changes to Mgbus southward across Wells-Clay Canyon fault near Fivemile Pass; Great Blue age data from Gordon and others (2000); thickness of upper limestone member is 3000 feet (915 m) (Gilluly, 1932), and north of Mercur Canyon is between 2500 and 2800 feet (760-850 m) (Kirby, in preparation).

Mgbs **Great Blue Limestone, Long Trail Shale Member** (Upper Mississippian) – Black to dark-green calcareous and carbonaceous shale in upper part, fossiliferous argillaceous limestone and silty limestone in lower part; thin-bedded, slope-forming interval between enclosing limestones; maximum thickness is 110 feet (33 m) (Gilluly, 1932).

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) (Gilluly, 1932).

Mh **Humbug Formation** (Upper Mississippian) – See unit description under northern East Tintic Mountains; thickness is 650 feet (200 m) (Gilluly, 1932).

Md **Deseret Limestone** (Upper to Lower Mississippian) – See unit description under northern East Tintic Mountains; thickness is 650 feet (200 m) (Gilluly, 1932).

Mg **Gardison Limestone** (Lower Mississippian) – See unit description under northern East Tintic Mountains; thickness is 460 feet (140 m) (Gilluly, 1932).

Unconformity

MDfp **Fitchville Formation and Pinyon Peak Limestone, undivided** (Lower Mississippian and Upper Devonian) – Also see unit description under northern East Tintic Mountains; gray, coarsely crystalline dolomite that weathers dark gray; within upper cliffy part of unit is one massive bed that contains conspicuous white calcite fossil casts up to a few inches in diameter, called the "eye bed" (Gilluly, 1932); some thin limestone and sandstone beds are present in slope below this bed; forms prominent cliff and slope in Dry and Ophir Canyons of the Oquirrh Mountains; Gilluly (1932) originally mapped as Jefferson(?) dolomite and Tooker (1987) subsequently used Fitchville-Pinyon Peak; thickness is 130 feet (40 m) (Kirby, in preparation).

Unconformity

Cambrian rock units are only exposed in the core of the Ophir anticline of the southwestern Oquirrh Mountains. Gilluly (1932) noted the lithologic similarities of Cambrian units 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). Descriptions and thickness data from Gilluly (1932) and Kirby (in preparation).

Cly **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 in the East Tintics (Gilluly, 1932; Morris and Lovering, 1961); thickness from 810 to 1050 feet (245-320 m).

Cb **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; sparse trilobite fauna; may correlate with upper part of Herkimer Limestone in East Tintics (Gilluly, 1932; Morris and Lovering, 1961); thickness is 310 to 345 feet (95-105 m).

Ch **Hartmann Limestone** (Middle? Cambrian) – Banded gray, mottled, thin-bedded, silty and shaley limestone; oolitic toward the top, and contains sparse trilobite fauna; may correlate to the lower part of Herkimer Limestone and Teutonic Limestone in East Tintics (Gilluly, 1932; Morris and Lovering, 1961); thickness is 590 to 630 feet (180-190 m).

Cop **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; brachiopod and trilobite (*Olenellus*) fauna; thickness in core of Ophir anticline is 280 to 310 feet (85-95 m).

Ct **Tintic Quartzite** (Middle? to Lower? Cambrian) – White quartzite that weathers to reddish brown; bedding is thick and locally irregular and cross-bedded; only upper part exposed in core of Ophir anticline, where it becomes increasingly shaley and grades into the overlying Ophir Formation; exposed thickness to 300 feet (90 m).

PENNSYLVANIAN TO NEOPROTEROZOIC STRATA OF THORPE HILLS AND NORTHERN EAST TINTIC MOUNTAINS

Unit descriptions, age and thickness data from Disbrow (1957, 1961) and Morris and Lovering (1961), in part modified from the work of Lindgren and Loughlin (1919).

IPobp **Oquirrh Group, Butterfield Peaks Formation** (Middle to Lower Pennsylvanian, Desmoinesian-Morrowan) – See unit description under Oquirrh Mountains; corresponds to Disbrow's (1957, 1961) Oquirrh formation units 2 through 5; Desmoinesian conodont age from Ten Mile Hill (McKean and others, 2011); incomplete thickness is about 3650 feet (1110 m).

IPowc **Oquirrh Group, West Canyon Limestone** (Lower Pennsylvanian, Morrowan) – See unit description under Oquirrh Mountains; corresponds to Disbrow's (1957, 1961) Oquirrh formation unit 1; about 750 feet (230 m) thick.

IPMmc
Manning Canyon Shale (Lower Pennsylvanian to Upper Mississippian, Morrowan to Chesterian) – See unit description under Oquirrh Mountains; medial

limestone interval about 30 to 80 feet (10-25 m) thick; unit thickness is up to 1050 feet (320 m).

Tenmile Pass fault

We re-evaluated the stratigraphic nomenclature of the Great Blue Limestone in the southern Oquirrh and northern East Tintic Mountains. Based on lithofacies relationships over a broader area and palynology data (table 7), we include strata previously mapped by Disbrow (1957, 1961) and Morris and Lovering (1961) as the Poker Knolls Limestone Member and Chiulos Shale Member with the Manning Canyon Shale, and the Paymaster Member and Topliff Limestone Member as the Great Blue Limestone, undivided.

Mgb **Great Blue Limestone, undivided** (Upper Mississippian) – Blue-gray limestone with chert; upper part (the Paymaster Member of others) is mostly limestone with some interbedded brown-weathering olive-green shale and quartzite; limestone is blue- and medium-gray to tan, fine to medium grained, commonly streaked with tan- and red-weathering siltstone and claystone; black chert is common as nodules, pods and thin layers; lower part (the Topliff Member of others) is blue-gray and medium-gray, fine- to medium-grained limestone that is distinctly bedded from thin to thick, locally with uncommon nodules of black and brown chert; fossils are locally abundant (crinoids, horn corals, bryozoans, brachiopods); thickness is 1080 feet (330 m).

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 some 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 for Oquirrh Group strata; about 600 feet (180 m) thick.

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 Shale Member (0 to 30 feet [10 m] thick) (also 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 we did not map these members separately; thickness is about 700 feet (215 m).

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; 450 feet (140 m) thick.

Unconformity

MDf **Fitchville Formation** (Lower Mississippian and 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 shaly limestone; fossils include corals and brachiopods; forms cliffs and ledges; thickness about 300 feet (90 m).

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 containing 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; separated by a probable unconformity from the underlying Victoria Formation; ***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; Dpv forms slopes and ledges; combined unit thickness is 250 to 300 feet (75-90 m).

Unconformity

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 in middle of formation (Colorado Chief marker bed of Morris and Lovering, 1961); ledge former; contains two unconformities (Budge and Sheehan, 1980); thickness is about 600 feet (180 m).

Of **Fish Haven 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 1/3 of formation; fossils include crinoids, corals, 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; Fish Haven is 270 feet (80 m) thick.

Unconformity

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 give a striped, mottled or mosaic appearance; flat-pebble conglomerate beds common throughout; pods of white chert typical in lower 1/3 of formation; basal beds are brown sandstone; slope forming unit with flaggy outcrops; thickness is about 800 feet (245 m).

We have not applied the changes to the Ordovician-Cambrian boundary reported in Hintze and Kowallis (2009), considering the ongoing debate on this issue.

Cao **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); ***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); combined unit thickness is 850 feet (260 m).

Cc **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) included; lower part (about 200 feet [60 m]) of 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).

Cbh **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); ***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); combined unit thickness is 600 feet (180 m).

Cdt **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; ***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); combined unit thickness is about 500 feet (150 m).

Cop **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).

Ct **Tintic Quartzite** (Middle? and Lower? Cambrian) – Pink, white, brown, and greenish-gray quartzite that is medium to very thick bedded, cross-bedded, and fractured, containing shaly 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; approximately 2500 feet (760 m) thick.

Unconformity

Zbc **Big Cottonwood Formation** (Neoproterozoic) – Olive-green to brownish-green phyllitic shale, argillite, quartzite, and quartzite conglomerate; well bedded and slightly metamorphosed; age from Dehler and others (2010); only about 200 feet (60 m) exposed along the core of the North Tintic anticline in the East Tintic Mountains; maximum exposed thickness in the Tintic district is 1675 feet (510 m).

ACKNOWLEDGMENTS

We thank Rachel Quist and Jason Raff (U.S. Army Dugway Proving Ground) and Jeff Fitzmayer (Parsons) for logistical and technical assistance with the DPG area mapping, and Nam Doan (U.S. Army Deseret Chemical Depot) for logistical support with mapping of the Tooele Army Depot South area. The New Mexico Geochronology Research Laboratory, under the supervision of Matthew Heisler, conducted some of the $^{40}Ar/^{39}Ar$ dating. Additional $^{40}Ar/^{39}Ar$ age analyses were conducted at the Nevada Isotope Geochronology Laboratory (University of Nevada, Las Vegas) operated by Terry Spell and Kathleen Zanetti. The late John Welsh contributed to the understanding of Permian-Pennsylvanian strata of this region and shared much of his unpublished data. A.J. Wells (independent paleontologist) identified fusulinids and reviewed Maurer's fusulinid data, Scott Ritter (Brigham Young University) identified conodonts for biostratigraphic control, and Gerald Waanders (independent) evaluated palynology data. Apatite to Zircon, Inc. conducted U-Pb zircon age dating. UGS staff Robert Biek, Grant Willis, Robert Ressetar, and Michael Hylland reviewed and improved this map and explanation, Jon King and Ken Krahulec provided technical assistance on geologic issues, Kent Brown prepared the GIS data and set up digital cartography, and Buck Ehler, Basia Matyjasik, Rich Emerson, Jay Hill, Lori Douglas, Paul Kuehne, and Jim Parker assisted in preparation of the map and explanatory materials.

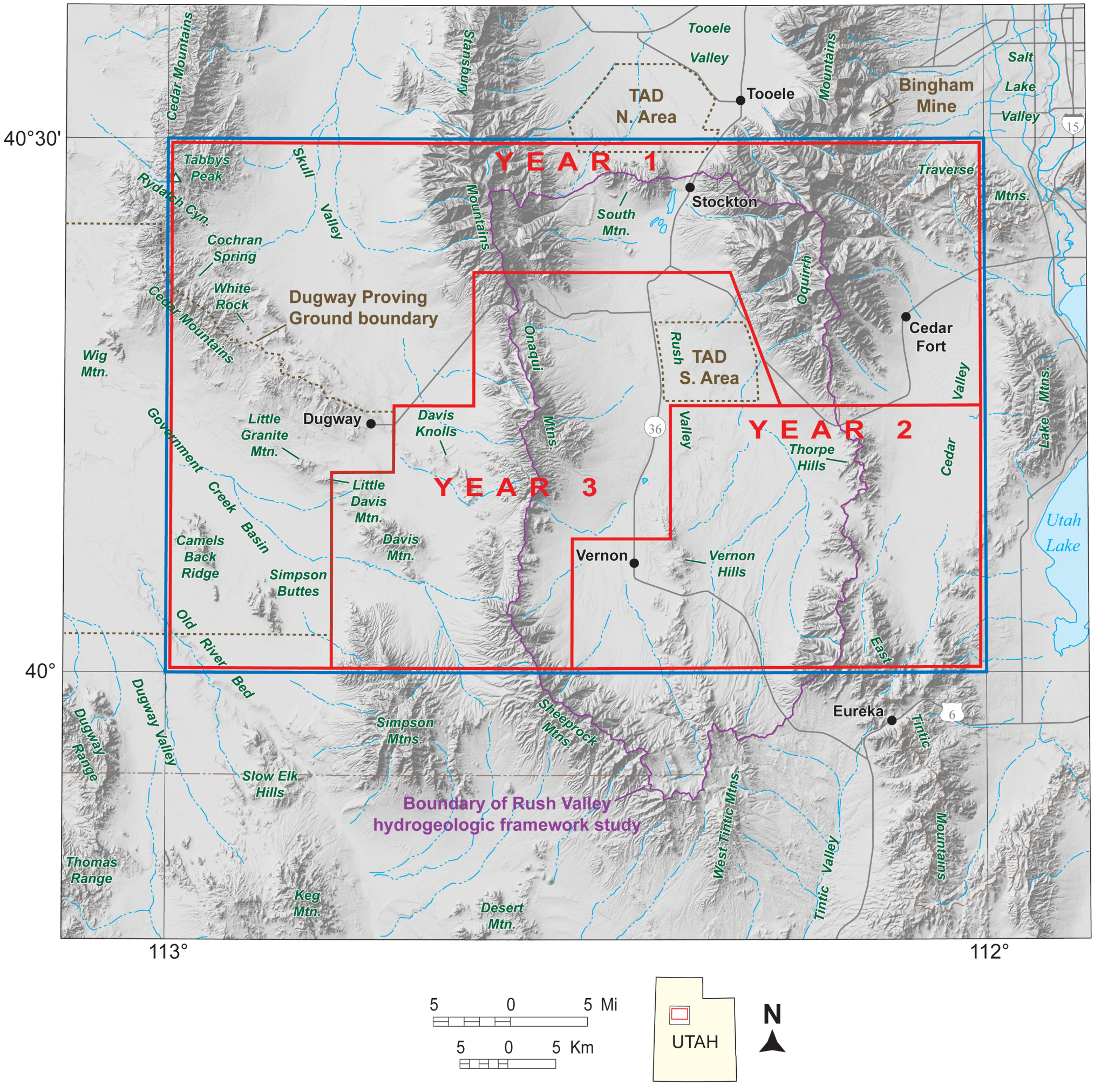


Figure 1. *Location map showing primary geographic features in the Rush Valley 30' x 60' quadrangle, years 1, 2 and 3 map areas, and hydrogeologic framework study area. TAD is Tooele Army Depot. The year 1 map area includes part of the Dugway Proving Ground and adjacent areas by Clark and others (2008). Gardner and Kirby (2011) and Kirby and Hurlow (in preparation) are conducting the Rush Valley hydrogeologic study.*

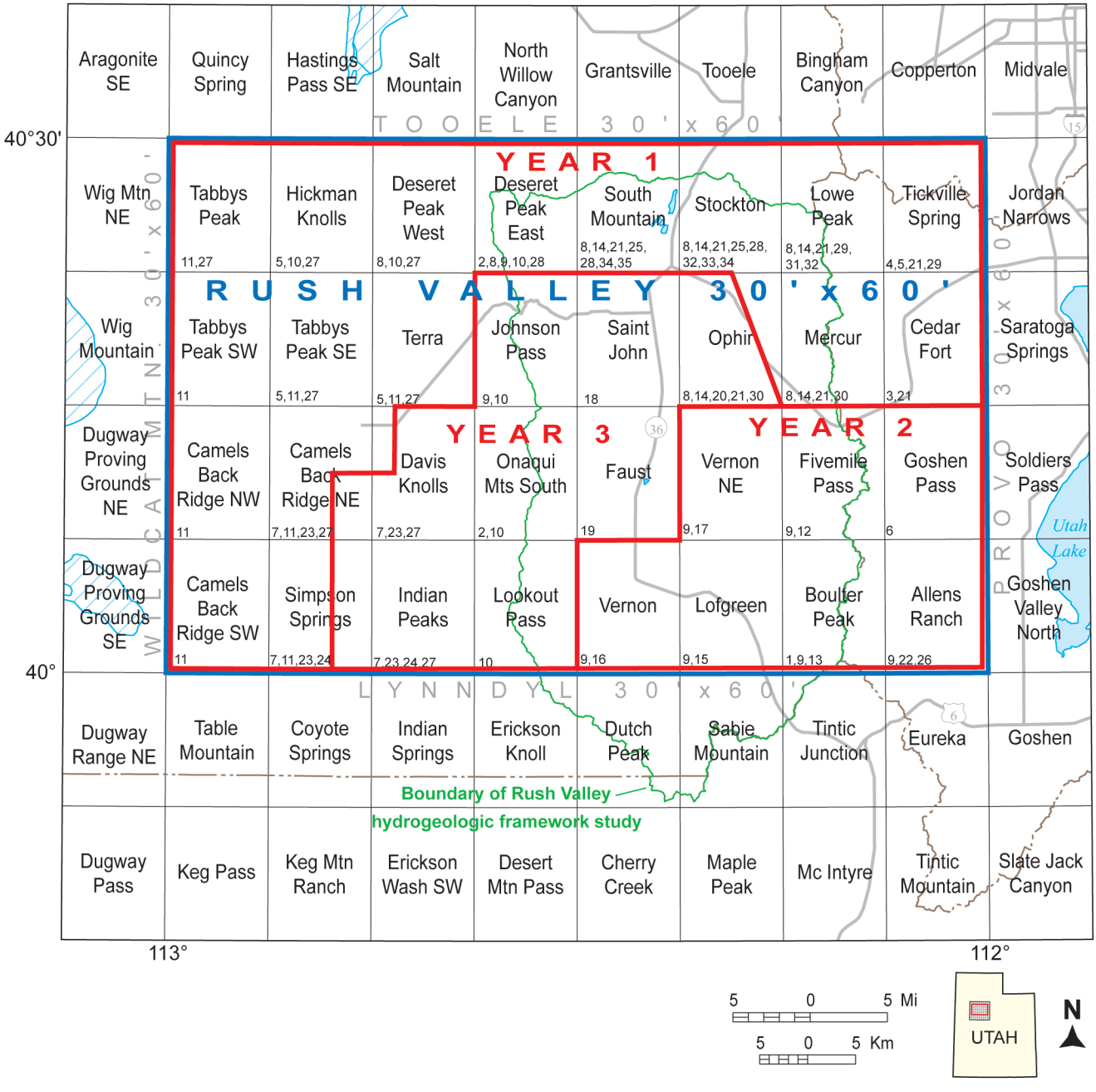


Figure 2. *Index map showing primary sources of geologic mapping in the Rush Valley 30' x 60' quadrangle, 7.5' quadrangles, and hydrogeologic framework study area.*

Maurer (1970)

Time-stratigraphic unit		Cochran Spring section Feet (Meters)	Overall Feet (Meters)	Oquirrh Formation unit
PERMIAN	Wolf-campian	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+)	

This Map

Map unit		Cochran Spring section Feet (Meters)	Overall Feet (Meters)	Sample Numbers	Time-stratigraphic unit		
PIPo	Pofc	2713 (827)	3500 (1070)	— D-60 — D-75 D-69	Wolfcampian	Lower	PERMIAN
PIPo	IPobm	1000 (305) fault	2800 (850)	— D-76 D-68 — D-52 D-57 — D-71	Misso.-Virgil.	Upper	PENNSYLVANIAN
PIPo	IPobp	fault / 2660 (811)	5400 (1650)	— D-70	Atokan-Desmoinesian	Middle	PENNSYLVANIAN
PIPo	IPowc	500 (150)	500-800 (150-245)	— D-50	Morro-wan	Lower	PENNSYLVANIAN
		6873 (2095)	12,350 (3770)				

Figure 3. *Comparison of Oquirrh strata of the southern Cedar Mountains. The stratigraphy used in this map for the Lower Permian (Wolfcampian) and Pennsylvanian formations is based on that of the Oquirrh Mountains/Bingham mining district.*

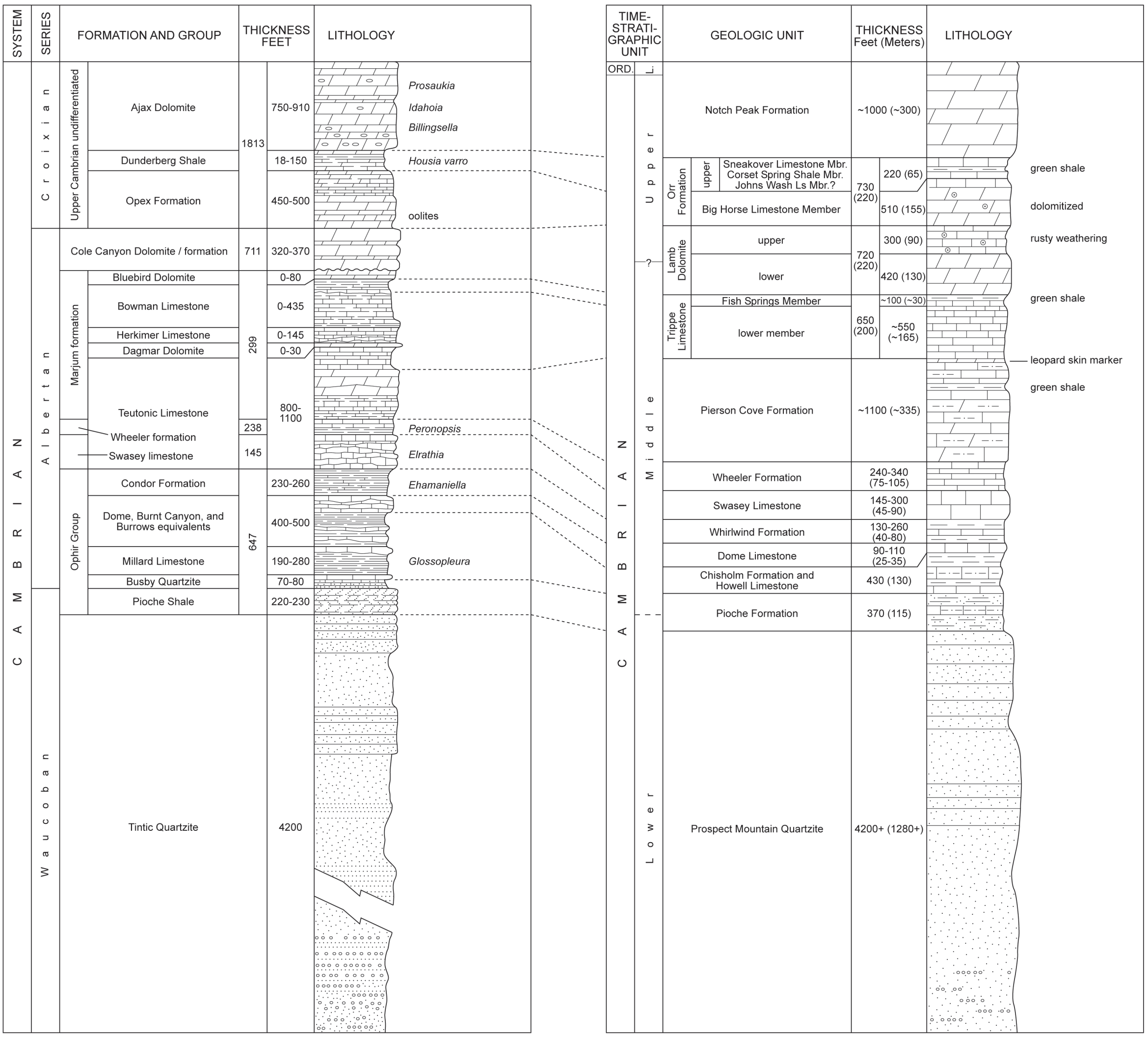


Figure 4. *Comparison of Cambrian stratigraphy of the Stansbury Mountains. The stratigraphy used in this map is the western Utah type rather than the East Tintic type.*

REFERENCES

Allen, T., in preparation, Cenozoic geology of the Boulter Peak quadrangle, Tooele and Utah Counties, Utah: unpublished map for EDMAP project, and M.S. thesis, Brigham Young University, scale 1:24,000.

Armin, R.A., 1979, Geology of the southeastern Stansbury Mountains and southern Onaqui Mountains, Tooele County, Utah with a paleoenvironmental study of part of the Oquirrh Group: San Jose, California, San Jose State University, M.S. thesis, 110 p., 1 plate, scale 1:48,000.

Armin, R.A., and Moore, W.J., 1981, Geology of the southeastern Stansbury Mountains and southern Onaqui Mountains, Tooele County, Utah: U.S. Geological Survey Open-File Report 81-247, scale 1:24,000. [superceded USGS MF-921 (1978) of Onaqui Mountains South quadrangle]

Ashland, F.X., 2003, Characteristics, causes, and implications of the 1998 Wasatch Front landslides, Utah: Utah Geological Survey Special Study 105, 49 p.

Biek, R.F., 2004, Geologic maps of the Saratoga Springs 7.5' and Cedar Fort 7.5' quadrangles, Utah County, Utah: Utah Geological Survey Maps 201 and 202, 3 plates, scale 1:24,000.

Biek, R.F., 2005, Geologic map of the Jordan Narrows quadrangle, Salt Lake and Utah Counties, Utah: Utah Geological Survey Map 208, 2 plates, scale 1:24,000.

Biek, R.F., 2006a, Geology of the Rose Canyon area, Salt Lake County, Utah – The exhumed flank of the Bingham volcanic center, *in* Harty, K.M., and Tabet, D.E., editors, Geology of northwest Utah: Utah Geological Association Publication 34, 21 p., CD.

Biek, R.F., 2006b, Whole-rock geochemical and electron microprobe data for the Tickville Spring quadrangle, Utah: Utah Geological Survey Open-File Report 475, 7 p., available online, <http://geology.utah.gov/online/ofr/ofr-475.pdf>.

Biek, R.F., Clark, D.L., Christiansen, E.H., 2009, Geologic map of the Soldiers Pass quadrangle, Utah County, Utah: Utah Geological Survey Map 235, 3 plates, scale 1:24,000, CD.

Biek, R.F., Solomon, B.J., Keith, J.D., and Smith, T.W., 2005, Geologic map of the Tickville Spring quadrangle, Salt Lake and Utah Counties, Utah: Utah Geological Survey Map 214, 2 plates, scale 1:24,000.

Budge, D.R., and Sheehan, P.M., 1980, Upper Ordovician through Middle Silurian of the eastern Great Basin, part 2, lithologic descriptions: Milwaukee Public Museum Contributions in Biology and Geology, no. 29, 80 p.

Burr, T.N., and Currey, D.R., 1988, The Stockton Bar, *in* Machette, M.N., editor, In the footsteps of G.K. Gilbert – Lake Bonneville and neotectonics of the eastern Basin and Range Province, Guidebook for Field Trip 12, Geological Society of America Annual Meeting, Denver, Colorado: Utah Geological and Mineral Survey Miscellaneous Publication 88-1, p. 66-73.

Burr, T.N., and Currey, D.R., 1992, Hydrographic modeling at the Stockton Bar, *in* Wilson, J.R., editor, Field guide to geologic excursions in Utah and adjacent areas of Nevada, Idaho, and Wyoming, for Geological Society of America Rocky Mountain Section Meeting, Ogden, Utah: Utah Geological and Mineral Survey Miscellaneous Publication 92-3, p. 207-219.

Cashman, P.H., 1992, Structural geology of the northeastern Stansbury Mountains, *in* Wilson, J.R., editor, Field guide to geologic excursions in Utah and adjacent areas of Nevada, Idaho, and Wyoming, for Geological Society of America, Rocky Mountain Section Meeting May 13-15, 1992: Utah Geological and Mineral Survey Miscellaneous Publication 92-3, p. 171-178.

Christiansen, E.H., Baxter, N., Ward, T., Zobell, E., Chandler, M.R., Dorais, M.J., Kowallis, B.J., Hart, G.L., and Clark, D.L., 2007, Cenozoic volcanism in the southern Lake Mountains, central Utah, *in* Willis, G.C., Hylland, M.D., Clark, D.L, and Chidsey, T.C., Jr., editors, Central Utah – Diverse geology of a dynamic landscape: Utah Geological Association Publication 36, p. 123-142.

Clark, D.L., 2008, Whole-rock geochemical data for the Granite Peak, Granite Peak SE, Dugway Proving Ground SW, Camels Back Ridge NE, Wig Mountain, Wig Mountain NE, Tabbys Peak, Tabbys Peak SE, Tabbys Peak SW, and Wildcat Mountain quadrangles, Utah: Utah Geological Survey Open-File Report 533, 4 p., also available online, <http://geology.utah.gov/online/ofr/ofr-533.pdf>.

Clark, D.L., and Kirby, S.M., 2009, Reevaluating Cambrian stratigraphy in the Stansbury and northern Sheeprock Mountains, northwest Utah – A progress report, *in* Tripp, B.T., Krahulec, K., and Jordan, L., editors, Geology and geologic resources and issues of western Utah: Utah Geological Association Publication 38, p. 17-26, CD.

Clark, D.L., Oviatt, C.G, and Page, D., 2008, Interim geologic map of Dugway Proving Ground and adjacent areas, parts of the Wildcat Mountain, Rush Valley, and Fish Springs 30' x 60' quadrangles, Tooele County, Utah: Utah Geological Survey Open-File Report 532, 3 plates, scale 1:75,000.

Cohenour, R.E., 1957, Geology of the Sheeprock Mountains, Tooele and Juab Counties, Utah: Salt Lake City, University of Utah, Ph.D. dissertation, 209 p., scale 1:31,680.

Cohenour, R.E., 1959, Sheeprock Mountains, Tooele and Juab Counties – Precambrian and Paleozoic stratigraphy, igneous rocks, structure, geomorphology, and economic geology: Utah Geological Survey Bulletin 63, 201 p., scale 1:33,400.

Constenius, K.N., Clark, D.L., King, J.K., and Ehler, J.B., 2011, Interim geologic map of the Provo 30' x 60' quadrangle, Utah, Wasatch, and Salt Lake Counties, Utah: Utah Geological Survey Open-File Report 586DM, DVD (42 p., 2 plates, [contains pdf and GIS data], scale 1:62,500.

Copfer, T.J., and Evans, J.P., 2005, Provisional geologic map of the Deseret Peak East 7.5' quadrangle, Tooele County, Utah: Utah Geological Survey Open-File Report 450, 32 p., 3 plates, scale 1:24,000, CD.

Crittenden, M.D., Jr., 1963, New data on the isostatic deformation of Lake Bonneville: U.S. Geological Survey Professional Paper 454-E, 31 p.

CRONUS-Earth Project, 2005, Draft sampling plan: Lake Bonneville Shorelines Sampling Trip, July 7-10, 2005 [CRONUS: Cosmic-Ray Produced Nuclide Systematics on Earth Project], http://tesla.physics.purdue.edu/cronus/bonneville_shoreline_sampling_plan.pdf.

Currey, D.R., 1982, Lake Bonneville – Selected features of relevance to neotectonic analysis: U.S. Geological Survey Open-File Report 82-1070, 30 p., 1 plate, scale 1:500,000.

Currey, D.R., 1996, Final report of a geomorphological survey of surficial lineaments north of Hickman Knolls, Tooele County, Utah: *in* Stone & Webster Engineering Corporation (SWEC), 1997, Appendix 2C.

Davis, B.L, 1959, Petrology and petrography of the igneous rocks of the Stansbury Mountains, Tooele County, Utah: Brigham Young University Research Studies, Geology Series, v. 6., no. 2.

Dean, L.E., 1978, Eolian sand dunes of the Great Salt Lake Basin: Utah Geology, v. 5, no. 2, p. 103-111.

Dehler, C.M., Fanning, C.M., Link, P.K., Kingsbury, E.M., and Rybczynski, D., 2010, Maximum depositional age and provenance of the Uinta Mountain Group and Big Cottonwood Formation, northern Utah – Paleogeography of rifting western Laurentia: Geological Society of America Bulletin, v. 122, no. 9/10, p. 1686-1699.

Deino, A., and Keith, J.D., 1997, Ages of volcanic and intrusive rocks in the Bingham mining district, Utah, *in* John, D.A., and Ballantyne, G.H., editors, Geology and ore deposits of the Oquirrh and Wasatch Mountains, Utah: Society of Economic Geologists Guidebook Series, v. 29, p. 91-100.

Disbrow, A.E., 1957, Preliminary geologic map of the Fivemile Pass quadrangle, Tooele and Utah Counties, Utah: U.S. Geological Survey Mineral Investigations Field Studies Map MF-131, 1 plate, scale 1:24,000.

Disbrow, A.E., 1961, Geology of the Boulter Peak quadrangle, Tooele and Utah Counties, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-141, 2 plates, scale 1:24,000.

Fairbanks, R.G., Mortlock, R.A., Chiu, T., Cao, L., Kaplan, A., Guilderson, T.P., Fairbanks, T.W., Bloom, A.L., Grootes, P.M., and Nadeau, M., 2005, Radiocarbon calibration curve spanning 0 to 50,000 years BP based on paired 230Th/ 234U/ 238U and 14C dates on pristine corals: Quaternary Science Reviews, v. 24, p. 1781-1796, http://www.radiocarbon.ldeo.columbia.edu/research/radcarbcal.htm.

Gardner, P.M., and Kirby, S.M., 2011, Hydrogeologic and geochemical characterization and groundwater resources of Rush Valley, Tooele County, Utah: U.S. Geological Survey, Scientific Investigations Report 2011-5068, 68 p.

Geomatrix Consultants, Inc., March 2001, Fault evaluation study and seismic hazard assessment at the Private Fuel Storage facility, Skull Valley, Utah (final report, volume I-III), prepared for Stone & Webster Engineering Corporation, Denver, Colorado.

Gilbert, G.K., 1890, Lake Bonneville: U.S. Geological Survey Monograph 1, 438 p.

Gillully, J., 1932, Geology and ore deposits of the Stockton and Fairfield quadrangles, Utah: U.S. Geological Survey Professional Paper 173, 171 p., 12 plates, scale 1:62,500.

Godsey, H.S., Currey, D.R., and Chan, M.A., 2005, New evidence for an extended occupation of the Provo shoreline and implications for regional climate change, Pleistocene Lake Bonneville, Utah, USA: Quaternary Research, v. 63, p. 212-223.

Gordon, M., Jr., Tooker, E.W., and Dutro, J.T., Jr., 2000, Type locality for the Great Blue Limestone in the Bingham Nappe, Oquirrh Mountains, Utah: U.S. Geological Survey Open-File Report 00-012, 61 p.

Hintze, L.F., 1959, Ordovician regional relationships in north-central Utah and adjacent areas, *in* Williams, N.C., editor, Guidebook to the geology of the Wasatch and

Uinta Mountains transition area: Intermountain Association of Petroleum Geologists Tenth Annual Field Conference Guidebook, p. 46-53.

Hintze, L.F., 1980, Preliminary geologic map of the Fish Springs NE and Fish Springs SE quadrangles, Juab and Tooele Counties, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1147, scale 1:24,000.

Hintze, L.F., and Davis, F. D., 2003, Geology of Millard County, Utah: Utah Geological Survey Bulletin 133, 305 p.

Hintze, L.F., and Kowallis, B.J., 2009, Geologic history of Utah: Brigham Young University Geology Studies, Special Publication 9, 225 p.

Hintze, L.F., and Robison, R.A., 1975, Middle Cambrian stratigraphy of the House, Wah Wah, and adjacent ranges in western Utah: Geological Society of America Bulletin, v. 86, p. 881-891.

Hughen, K.A., Baillie, M.G.L., Bard, E., Bayliss, A., Beck, J.W., Bertrand, C.J.H., Blackwell, P.G., Buck, C.E., Burr, G.S., Cutler, K.B., Damon, P.E., Edwards, R.L., Fairbanks, R.G., Friedrich, M., Guilderson, T.P., Kromer, B., McCormac, F.G., Manning, S.W., Bronk Ramsey, C., Reimer, P.J., Reimer, R.W., Remmele, S., Southon, J.R., Stuiver, M., Talamo, S., Taylor, F.W., van der Plicht, J., and Weyhenmeyer, C.E., 2004, Marine radiocarbon age calibration, 26 - 0 ka BP: Radiocarbon v. 46, p. 1059-1086.

Imbrie, J., Hays, J.D., Martinson, D.G., McIntyre, A., Mix, A.C., Morley, J.J., Pisias, N.G., Prell, W.L., and Shackleton, N.J., 1984, The orbital theory of Pleistocene climate – Support from a revised chronology of the marine ^{18}O record, *in* Berger, A., Imbrie, J., Hays, J., Kukla, G., and Saltzman, B., editors, Milankovitch and Climate Part I: Dordrecht, Holland, Reidel, p. 269-306.

Jordan, T.E., 1979a, Evolution of the Late Pennsylvanian-Early Permian western Oquirrh basin, Utah: Palo Alto, California, Stanford University, Ph.D thesis, 253 p.

Jordan, T.E., 1979b, Lithofacies of the upper Pennsylvanian and lower Permian western Oquirrh Group, northwest Utah: Utah Geology, v. 6, no. 2, p. 41-56.

Jordan, T.E., and Allmendinger, R.W., 1979, Upper Permian and Lower Triassic Stratigraphy of the Stansbury Mountains, Utah: Utah Geology, v. 6, no. 2., p. 69-74.

Kirby, S.M., 2010a, Interim geologic map of the Lofgreen quadrangle, Tooele County, Utah: Utah Geological Survey Open-File Report 563, 17 p., 2 plates, scale 1:24,000, CD.

Kirby, S.M., 2010b, Interim geologic map of the Vernon quadrangle, Tooele County, Utah: Utah Geological Survey Open-File Report 564, 18 p., 2 plates, scale 1:24,000, CD.

Kirby, S.M., 2010c, Interim geologic map of the Vernon NE quadrangle, Tooele County, Utah: Utah Geological Survey Open-File Report 562, 10 p., 2 plates, scale 1:24,000, CD.

Kirby, S.M., 2010d, Interim geologic map of the Saint John quadrangle, Tooele County, Utah: Utah Geological Survey Open-File Report 572, 11 p., 2 plates, scale 1:24,000, CD.

Kirby, S.M., 2010e, Interim geologic map of the Faust quadrangle, Tooele County, Utah: Utah Geological Survey Open-File Report 573, 12 p., 2 plates, scale 1:24,000, CD.

Kirby, S.M., in preparation, Geologic map of the Ophir quadrangle, Tooele County, Utah: Utah Geological Survey Map, scale 1:24,000, CD.

Kirby, S.M., and Hurlow, H.A., in preparation, Hydrogeologic framework of the Rush Valley drainage basin, Tooele County, Utah: Utah Geological Survey Special Study.

Krahulec, K.A., 2005, Rush Valley mining district, Tooele County, Utah, *in* Rasmussen, H., Crafford, E.J., O'Malley, P., and Callicrate, T., editors, Porphyry deposits of the Great Basin, Field Trip Guidebook 9: Geological Society of Nevada Symposium 2005 Window to the World, p. 75-80.

Kummel, B., 1954, Triassic stratigraphy of southeastern Idaho and adjacent areas (Wyoming-Montana), *in* Shorter contributions to general geology: U.S. Geological Survey Professional Paper 254-H, p. H165-H194.

Laabs, B.J.C., Marchetti, D.W., Munrow, J.S., Refsnider, K.A., Gosse, J.C., Lips, E.W., Becker, R.A., Mickelson, D.M., and Singer, B.S., in press, Chronology of latest Pleistocene mountain glaciation in the western Wasatch Mountains, Utah, U.S.A.: Quaternary Research, 13 p.

Laes, D.Y.M., Krahulec, K.A., and Ballantyne, G.H., compilers, 1997, Geologic map of the Oquirrh Mountains, Utah, *in* John, D.A., and Ballantyne, G.H., editors, Geology and ore deposits of the Oquirrh and Wasatch Mountains, Utah: Society of Economic Geologists Guidebook Series, v. 29, plate 1, scale 1:62,500.

Lanier, G., John, E.C., Swensen, A.J., Reid, J., Bard, C.E., Caddey, S.W., and Wilson, J.C., 1978, General geology of the Bingham mine, Bingham Canyon, Utah: Economic Geology, v. 73, no. 7, p. 1228-1241.

Le Bas, M.J., Le Maitre, R.W., Streckheisen, A., and Zenettin, B., 1986, A chemical classification of volcanic rocks based on the total alkali-silica diagram: Journal of Petrology, v. 27, p. 745-750.

Lindgren, W., and Loughlin, G.F., 1919, Geology and ore deposit of the Tintic mining district, Utah: U.S. Geological Survey Professional Paper 107, 282 p.

Ludwig, K.R., 2003, Isoplot 3.00: Berkeley Geochronology Center Special Publication No. 4, 70 p.

Lufkin, J.L., 1965, Geology of the Stockton stock and related intrusives, Tooele County, Utah: Brigham Young University Geology Studies, v. 12, p. 149-164.

Mako, D.A., 1999, A Post-mining view of the Mercur Gold District, Tooele County, Utah, 1999 Spring field trip guidebook – Bingham Canyon Mine, Barney's Canyon Mine, Mercur Mine: Geological Society of Nevada, Elko Chapter, Special Publication 30.

Maughan, D.T., 2001, Contributions to the mafic alkaline magmas to the Bingham porphyry Cu-Au-Mo deposit, Utah, U.S.A.: Provo, Brigham Young University, M.S. thesis, 238 p.

Maurer, R.E., 1970, Geology of the Cedar Mountains, Tooele County, Utah: Salt Lake City, University of Utah, Ph.D. dissertation, 184 p., 10 plates, scale 1:43,700.

McKean, A.P, 2011, Volcanic stratigraphy and a kinematic analysis of NE-trending faults of Allens Ranch 7.5' quadrangle, Utah County, Utah: Provo, Brigham Young University, M.S. thesis, 95 p., 2 plates, map scale 1:24,000.

McKean, A.P, Kowallis, B.J., and Christiansen, E.H., in preparation, Geologic map of the Allens Ranch quadrangle, Utah County, Utah: Utah Geological Survey Map, scale 1:24,000.

Middlemost, E.A.K., 1994, Naming materials in the magma/igneous rock system: Earth-Science Review, v. 37, p. 215-224.

Moore, W.J., 1973, A summary of radiometric ages of igneous rocks in the Oquirrh Mountains, north-central Utah: Economic Geology, v. 68, no. 1, p. 97-101.

Moore, W.J., Lanphere, M.A., and Obradovich, J.D., 1968, Chronology of intrusion, volcanism, and ore deposition at Bingham, Utah: Economic Geology, v. 63, no. 6, p. 612-621.

Moore, W.J., and McKee, E.H., 1983, Phanerozoic magmatism and mineralization in the Tooele 1° x 2° quadrangle, Utah, *in* Miller, D.M., Todd, V.R., and Howard, K.A., editors, Tectonic and stratigraphic studies in the eastern Great Basin: Geological

Society of America Memoir 157, p. 183-190.

Moore, W.J., and Sorensen, M.L., 1977, Reconnaissance geologic map of northern Simpson Mountains, Davis Mountain, and adjacent areas, Tooele County, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-905, 1 plate, scale 1:48,000.

Moore, W.J., and Sorensen, M.L., 1979, Geologic map of the Tooele 1° x 2° quadrangle, Utah: U.S. Geological Survey Miscellaneous Investigation Series Map I-1132, scale 1:250,000.

Morris, H.T., and Kopf, R.W., 1986, Preliminary geologic map of the Indian Springs quadrangle and adjacent part of the Coyote Springs quadrangle, Tooele and Juab Counties, Utah: unpublished map and explanation submitted to UGS, scale 1:24,000.

Morris, H.T., and Lovering, T.S., 1961, Stratigraphy of the East Tintic Mountains, Utah: U.S. Geological Survey Professional Paper 361, 145 p.

Morris, H.T., and Lovering, T.S., 1979, General geology and mines of the East Tintic mining district, Utah and Juab Counties, Utah: U.S. Geological Survey Professional Paper 1024, 203 p.

Moyle, R.W., 1959, Stratigraphy of the southern Oquirrh Mountains, Manning Canyon Shale: Utah Geological Society Guidebook 14, p. 59-92.

Mulvey, W.E., 1985, Reconstruction and interpretation of Late Pleistocene equilibrium-line altitudes in the Lake Bonneville region: Salt Lake City, M.S. thesis, University of Utah, 65 p.

New Mexico Geochronology Research Laboratory and Utah Geological Survey, 2006, $^{40}Ar/^{39}Ar$ geochronology results for the Cave Canyon, Fountain Green North, Hilgard Mountain, Pine Park, Skinner Peaks, Tickville Spring, and Veyo quadrangles, Utah: Utah Geological Survey Open-File Report 473, variously paginated, also available online, <http://geology.utah.gov/online/ofr/ofr-473.pdf>.

Nygreen, P.W., 1958, The Oquirrh formation – Stratigraphy of the lower portion in the type area and near Logan, Utah: Utah Geological and Mineral Survey Bulletin, no. 61, 67 p.

Osborn, G., and Bevis, K., 2001, Glaciation in the Great Basin of the western United States: Quaternary Science Reviews, v. 20, p. 1377-1410.

Oviatt, C.G., 1987, Lake Bonneville stratigraphy at the Old River Bed: American Journal of Science, v. 287, p. 383-398.

Oviatt, C.G., 1997, Lake Bonneville and global climate change: Geology, v. 25, p. 155-158.

Oviatt, C.G., Currey, D.R., and Miller, D.M., 1990, Age and paleoclimatic significance of the Stansbury shoreline of Lake Bonneville, northeastern Great Basin: Quaternary Research, v. 33, p. 291-305.

Oviatt, C.G., Currey, D.R., and Sack, D., 1992, Radiocarbon chronology of Lake Bonneville, eastern Great Basin, USA: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 99, p. 225-241.

Oviatt, C.G., Madsen, D.B., and Schmitt, D.N., 2003, Late Pleistocene and early Holocene rivers and wetlands in the Bonneville basin of western North American: Quaternary Research, v. 60 p. 200-210.

Oviatt, C.G., Miller, D.M., McGeehin, J.P., Zachary, C., and Mahan, S., 2005, The Younger Dryas phase of Great Salt Lake, Utah, USA: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 219, no. 3-4, p. 263-284.

Oviatt, C.G., Sack, D., and Felger, T.J., 1994, Quaternary geologic map of the Old River Bed, and vicinity, Millard, Juab, and Tooele Counties, Utah: Utah Geological Survey Map 161, 24 p., 1 plate, scale 1:62,500.

Oviatt, C.G., and Thompson, R.S., 2002, Recent developments in the study of Lake Bonneville since 1980, *in* Gwynn, J.W., editor, Great Salt Lake – An overview of change: Utah Department of Natural Resources Special Publication, p. 1-6.

Parry, W.T., Wilson, P.N., Moser, D., and Heizler, M.T., 2001, U-Pb dating of zircon and $^{40}Ar/^{39}Ar$ dating of biotite at Bingham, Utah: Economic Geology, v. 96, p. 1671-1683.

Perkins, M.E., Nash, W.P., Brown, F.H., and Fleck, R.J., 1995, Fallout tuffs of Trapper Creek, Idaho – A record of Miocene explosive volcanism in the Snake River Plain volcanic province: Geological Society of America Bulletin, v. 107, no. 12, p. 1484-1506.

Perkins, M.E., Brown, F.H., Nash, W.P., McIntosh, W., and Williams, S.K., 1998, Sequence, age, and source of silicic fallout tuffs in middle to late Miocene basins of the northern Basin and Range province: Geological Society of America Bulletin, v. 110, no. 3, p. 344-360.

Perkins, M.E., and Nash, B.P., 2002, Explosive silicic volcanism of the Yellowstone hotspot – The ash fall tuff record: Geological Society of America Bulletin, v. 114, no. 3, p. 367-381.

Proctor, P.D., and Clark, D.L., 1956, The Curley limestone – An unusual biostrome in central Utah: Journal of Sedimentary Petrology, v. 26, no. 4, p. 313-321.

Pulsifer, T., 2000, The correlation of Eocene extrusive block and ash flows to intrusions at the Bingham copper porphyry system, Utah: Provo, Utah, Brigham Young University, M.S. thesis, 104 p.

Rigby, J.K., 1958, Geology of the Stansbury Mountains, eastern Tooele County, Utah, *in* Rigby, J.K., editor, Geology of the Stansbury Mountains, Tooele County, Utah: Utah Geological Society, Guidebook to the Geology of Utah, no. 13, p. 1-134, map scale 1:63,360.

Rigby, J.K., 1959a, Upper Devonian unconformity in central Utah: Geological Society of America Bulletin, v. 70, p. 207-218.

Rigby, J.K, 1959b, Stratigraphy of the southern Oquirrh Mountains, lower Paleozoic succession, *in* Bissell, H.J., editor, Geology of the southern Oquirrh Mountains and Fivemile Pass – Northern Boulter Mountain area, Tooele and Utah Counties, Utah: Utah Geological Society Guidebook, no. 14, p. 9-36.

Sack, D., 1993, Quaternary geologic map of Skull Valley, Tooele County, Utah: Utah Geological Survey Map 150, 16 p., 1 plate, scale 1:100,000.

Sandberg, C.A., and Gutschick, R.C., 1984, Distribution, microfauna, and source-rock potential of Mississippian Delle Phosphatic Member of Woodman Formation and equivalents, Utah and adjacent states, *in* Woodward, J., Meissner, F.F., and Clayton, J.L., editors, Hydrocarbon source rocks of the greater Rocky Mountain region: Denver, Colorado, Rocky Mountain Association of Geologists, p. 135-178.

Sorensen, M.L., 1982, Geologic map of the Stansbury roadless areas, Tooele County, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1353-C, scale 1:62,500.

Staatz, M.H., 1972, Geologic map of the Dugway Proving Ground SW quadrangle, Tooele County, Utah: U.S. Geological Survey Map CQ-992, scale 1:24,000.

Staatz, M.H., and Carr, W.J., 1964, Geology and mineral deposits of the Thomas and Dugway Ranges, Juab and Tooele Counties, Utah: U.S. Geological Survey Professional Paper 415, 188 p., 9 plates.

Stuiver, M., and Reimer, P.J., 1993, Extended ^{14}C database and revised CALIB radiocarbon calibration program: Radiocarbon, v. 35, p. 215-230.

Stuiver, M., Reimer, P.J., and Reimer, R., 2005, CALIB radiocarbon calibration, version 5.0; http://radiocarbon.pa.qub.ac.uk/calib/.

SWEC (Stone & Webster Engineering Corporation), 1997, Safety Analysis Report, Private Fuel Storage Facility, Skull Valley, Utah, prepared for Private Fuel Storage LLC, 2 volumes.

Swenson, A.J., 1975, Sedimentary and igneous rocks of the Bingham mining district, *in* Bray, R.E., and Wilson, J.C., editors, Guidebook to the Bingham mining district: Bingham Canyon, Utah, Society of Economic Geologists and Kennecott Copper Corporation, p. 21-39.

Swenson, A.J., and Kennecott staff, compilers, 1991, Geologic map of the Bingham district, *in* Black, J.E., and Babcock, R.C., editors, Guidebook to the geology and ore deposits of the Bingham mining district and northern Oquirrh Mountains, Utah: RTZ Group Mining and Exploration Conference, Salt Lake City, Utah, map (Plate 1), scale 1:24,000.

Teichert, J.A., 1958, Geology of the southern Stansbury Range, Tooele County, Utah: Salt Lake City, University of Utah, M.S. thesis, 79 p., scale 1:20,000.

Teichert, J.A., 1959, Geology of the southern Stansbury Range, Tooele County, Utah: Utah Geological and Mineralogical Survey Bulletin 65, 75 p., 2 plates, scale 1:96,000.

Tooker, E.W., 1983, Variations in structural style and correlation of thrust plates in the Sevier foreland thrust belt, Great Salt Lake area, Utah, *in* Miller, D.M., editor, Tectonic and stratigraphic studies in the eastern Great Basin: Geological Society of America Memoir 157, p. 61-73.

Tooker, E.W., 1987, Preliminary geologic maps, cross sections, and explanation pamphlet for the Ophir and Mercur 7 ½-minute quadrangles, Utah: U.S. Geological Survey Open-File Report 87-152, 18 p., 3 plates, scale 1:24,000.

Tooker, E.W., 1992, Preliminary geologic map of the Lowe Peak 7 ½-minute quadrangle, Tooele, Utah, and Salt Lake Counties, Utah: U.S. Geological Survey Open-File Report 92-404, 1 plate, scale 1:24,000.

Tooker, E.W., 1999, Geology of the Oquirrh Mountains, Utah: U.S Geological Survey Open-File Report 99-571, map scale 1:50,000.

Tooker, E.W., and Roberts, R.J., 1970, Upper Paleozoic rocks in the Oquirrh Mountains and Bingham mining district, Utah, with a section on biostratigraphy and correlation by Gordon, M., Jr., and Duncan, H.M.: U.S. Geological Survey Professional Paper 629-A, 76 p.

Tooker, E.W., and Roberts, R.J., 1971, Structures related to thrust faults in the Stansbury Mountains, Utah: U.S. Geological Survey Professional Paper 750-B, p. B1-B12.

Tooker, E.W., and Roberts, R.J., 1988, Interim geologic maps and explanation pamphlet for parts of the Stockton and Lowe Peak 7 ½-minute quadrangles, Utah: U.S. Geological Survey Open-File Report 88-280, 20 p., 2 plates, scale 1:24,000.

Tooker, E.W., and Roberts, R.J., 1992, Preliminary geologic map of the Stockton 7 ½-minute quadrangle, Tooele County, Utah: U.S. Geological Survey Open-File Report 92-385, 22 p., 1 plate, scale 1:24,000.

Tooker, E.W., and Roberts, R.J., 1998, Geologic map of the Oquirrh Mountains and adjoining South and western Traverse Mountains, Tooele, Salt Lake, and Utah Counties, Utah: U.S. Geological Survey Open-File Report 98-581, 2 plates, scale 1:50,000.

Utah Geological Survey and Nevada Isotope Geochronology Lab (UGS & NIGL), 2012a, $^{40}Ar/^{39}$ Ar geochronology results for the Lofgreen, Vernon, and White Tower quadrangles: Utah Geological Survey Open-File Report 588, variously paginated, also available online, <http://geology.utah.gov/online/ofr/ofr-588.pdf>.

Utah Geological Survey and Nevada Isotope Geochronology Lab (UGS & NIGL), 2012b, $^{40}Ar/^{39}$ Ar geochronology results for the Gooseberry Creek, Haycock Mountain, Mercur, Stockton, and Tabbys Peak quadrangles: Utah Geological Survey Open-File Report 590, variously paginated, also available online, <http://geology.utah.gov/online/ofr/ofr-590.pdf>.

Utah Geological Survey and New Mexico Geochronology Research Laboratory (UGS & NMGRL), 2007, $^{40}Ar/^{39}Ar$ geochronology results for the Tintic Mountain and Champlin Peak quadrangles, Utah: Utah Geological Survey Open-File Report 505, variously paginated, also available online, <http://geology.utah.gov/online/ofr/ofr-505.pdf>.

Utah Geological Survey and New Mexico Geochronology Research Laboratory (UGS & NMGRL), 2009a, $^{40}Ar/^{39}Ar$ geochronology results for the Granite Peak, Granite Peak SE, and Camels Back Ridge NE quadrangles, Utah: Utah Geological Survey Open-File Report 542, variously paginated, also available online, <http://geology.utah.gov/online/ofr/ofr-542.pdf>.

Utah Geological Survey and New Mexico Geochronology Research Laboratory (UGS & NMGRL), 2009b, $^{40}Ar/^{39}Ar$ geochronology results for the Blind Lake, Deer Creek Lake, Flat Top, Henrie Knolls, Tabbys Peak, Tabbys Peak SW, Wig Mountain, and Wig Mountain NE quadrangles, Utah: Utah Geological Survey Open-File Report 547, variously paginated, also available online, <http://geology.utah.gov/online/ofr/ofr-547.pdf>.

Valora, P.J., 1968, Glaciation of The Jumpoff, Oquirrh Mountains, Utah: Provo, Brigham Young University, M.S. thesis.

Waite, K.A., 1996, Petrogenesis of the volcanic and intrusive rocks associated with the Bingham porphyry Cu-Mo deposit, Utah: Provo, Utah, Brigham Young, University, M.S. thesis, 143 p.

Waite, K.A., Keith, J.D., Christiansen, E.H., Whitney, J.A., Hattori, K., Tingey, D.G., and Hook, C.J., 1997, Petrogenesis of the volcanic and intrusive rocks associated with the Bingham Canyon porphyry Cu-Au-Mo deposit, Utah, *in* John, D.A., and Ballantyne, G.H., editors, Geology and ore deposits of the Oquirrh and Wasatch Mountains, Utah: Society of Economic Geologists Guidebook Series, v. 29, p. 69-90.

Webster, G.D., Gordon, M., Jr., Langenheim, R.L., and Henry, T.W., 1984, Road logs for the Mississippian-Pennsylvanian boundary in the eastern Great Basin – Salt Lake City, Utah, to Las Vegas, Nevada (Field Trip 1), *in* Lintz, J., Jr., editor, Western geological excursions: Geological Society of America Annual Meeting, Field Trip Guidebook, v. 1, p. 1-86.

Welsh, J.E., and James, A.H., 1961, Pennsylvanian and Permian stratigraphy of the central Oquirrh Mountains, Utah, *in* Cook, D.R., editor, Geology of the Bingham mining district and northern Oquirrh Mountains: Utah Geological Society Guidebook to the Geology of Utah, no. 16, p. 1-16.

Welsh, J.E., and James, A.H., 1998 (revised), Reconnaissance traverse and measured section of part of the South Mountain quadrangle, Tooele County, Utah: unpublished data submitted to the Utah Geological Survey.

Wright, R.W., 1961, Stratigraphic and tectonic interpretation of Oquirrh Formation, Stansbury Mountains, Utah: Brigham Young University Geology Studies, v. 8, p. 147-166.

Yambrick, R.A, 1990, Geology and geochemistry of Tertiary volcanic rocks, eastern Simpson Mountains, west-central Utah: Riverside, University of California, M.S. thesis, 181 p., 1 plate, scale 1:24,000.

Sources of Geologic Map Data

Primary sources of geologic map data; numbers correspond to index map (figure 2).

1. Allen, T., in preparation, Cenozoic geology of the Boulter Peak quadrangle, Tooele and Utah Counties, Utah: unpublished map for EDMAP project and M.S. thesis, Brigham Young University, scale 1:24,000.

2. Armin, R.A., and Moore, W.J., 1981, Geology of the southeastern Stansbury Mountains and southern Onaqui Mountains, Tooele County, Utah: U.S.Geological Survey Open-File Report 81-247, scale 1:24,000. [superceded U.S. Geological Survey Miscellaneous Field Studies Map MF-921 (1978) of Onaqui Mountains South quadrangle]

3. Biek, R.F., 2004, Geologic maps of the Saratoga Springs 7.5' and Cedar Fort 7.5' quadrangles, Utah County, Utah: Utah Geological Survey Maps 201 and 202, 3 plates, scale 1:24,000.

4. Biek, R.F., Solomon, B.J., Keith, J.D., and Smith, T.W., 2005, Geologic map of the Tickville Spring quadrangle, Salt Lake and Utah Counties, Utah: Utah Geological Survey Map 214, 2 plates, scale 1:24,000.

5. Clark, D.L. (Utah Geological Survey), 2008-2009, photogeologic and limited field mapping.

6. Clark, D.L. (Utah Geological Survey), 2009-2010, photogeologic and limited field mapping.

7. Clark, D.L. (Utah Geological Survey), 2010-2011, photogeologic and limited field mapping.

8. Clark, D.L., and Kirby, S.M. (Utah Geological Survey), 2008-2009, photogeologic and limited field mapping.

9. Clark, D.L., and Kirby, S.M. (Utah Geological Survey), 2009-2010, photogeologic and limited field mapping.

10. Clark, D.L., and Kirby, S.M. (Utah Geological Survey), 2010-2011, photogeologic and limited field mapping.

11. Clark, D.L., Oviatt, C.G, and Page, D., 2008, Interim geologic map of Dugway Proving Ground and adjacent areas, parts of the Wildcat Mountain, Rush Valley, and Fish Springs 30' x 60' quadrangles, Tooele County, Utah: Utah Geological Survey Open-File Report 532, 3 plates, scale 1:75,000.

12. Disbrow, A.E., 1957, Preliminary geologic map of the Fivemile Pass quadrangle, Tooele and Utah Counties, Utah: U.S. Geological Survey Mineral Investigations Field Studies Map MF-131, 1 plate, scale 1:24,000.

13. Disbrow, A.E., 1961, Geology of the Boulter Peak quadrangle, Tooele and Utah Counties, Utah: U.S. Geological Survey Geologic Quadrangle map GQ-141, 2 plates, scale 1:24,000.

14. Gillully, J., 1932, Geology and ore deposits of the Stockton and Fairfield quadrangles, Utah: U.S. Geological Survey Professional Paper 173, 171 p., 12 plates, scale 1:62,500.

15. Kirby, S.M., 2010a, Interim geologic map of the Lofgreen quadrangle, Tooele County, Utah: Utah Geological Survey Open-File Report 563, 17 p., 2 plates, scale 1:24,000, CD.

16. Kirby, S.M., 2010b, Interim geologic map of the Vernon quadrangle, Tooele County, Utah: Utah Geological Survey Open-File Report 564, 18 p., 2 plates, scale 1:24,000, CD.

17. Kirby, S.M., 2010c, Interim geologic map of the Vernon NE quadrangle, Tooele County, Utah: Utah Geological Survey Open-File Report 562, 10 p., 2 plates, scale 1:24,000, CD.

18. Kirby, S.M., 2010d, Interim geologic map of the Saint John quadrangle, Tooele County, Utah: Utah Geological Survey Open-File Report 572, 11 p., 2 plates, scale 1:24,000, CD.

19. Kirby, S.M., 2010e, Interim geologic map of the Faust quadrangle, Tooele County, Utah: Utah Geological Survey Open-File Report 573, 12 p., 2 plates, scale 1:24,000, CD.

20. Kirby, S.M., in preparation, Geologic map of the Ophir quadrangle, Tooele County, Utah: Utah Geological Survey Map, scale 1:24,000, CD.

21. Laes, D.Y.M., Krahulec, K.A., Ballantyne, G.H., compilers, 1997, Geologic map of the Oquirrh Mountains, Utah, *in* John, D.A., and Ballantyne, G.H., editors, Geology and ore deposits of the Oquirrh and Wasatch Mountains, Utah: Society of Economic Geologists Guidebook, v. 29, 256 p., scale 1:62,500.

22. McKean, A.P, Kowallis, B.J., and Christiansen, E.H., 2011, Geologic map of the Allens Ranch 7.5' quadrangle, Utah County, Utah: unpublished map for EDMAP project and M.S. thesis, Brigham Young University, scale 1:24,000.

23. Moore, W.J., and Sorensen, M.L., 1977, Reconnaissance geologic map of northern Simpson Mountains, Davis Mountain, and adjacent areas, Tooele

County, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-905, 1 plate, scale 1:48,000.

24. Morris, H.T., and Kopf, R.W., 1986, Preliminary geologic map of the Indian Springs quadrangle and adjacent part of the Coyote Springs quadrangle, Tooele and Juab Counties, Utah: unpublished map and explanation submitted to UGS, scale 1:24,000.

25. Nelson, D., and Jewell, P., in preparation, Surficial geologic map of the south parts of the South Mountain and Stockton quadrangles, Tooele County, Utah: unpublished map for EDMAP project and Ph.D dissertation, University of Utah, scale 1:24,000.

26. Proctor, P.D., 1985, Preliminary geologic map of the Allens Ranch quadrangle, North Tintic District, Utah County, Utah: Utah Geological and Mineral Survey Open-File Report 69, 18 p., 2 plates, scale 1:24,000.

27. Sack, D., 1993, Quaternary geologic map of Skull Valley, Tooele County, Utah: Utah Geological Survey Map 150, 16 p., 1 plate, scale 1:100,000.

28. Solomon, B.J., 1993, Quaternary geologic maps of Tooele Valley and the West Desert Hazardous Industry Area, Tooele County, Utah: Utah Geological Survey Open-File Report 296, 48 p., 20 plates, scale 1:24,000.

29. Swenson, A.J., and Kennecott staff, compilers, 1991, Geologic map of the Bingham district, *in* Black, J.E., and Babcock, R.C., editors, Guidebook to the geology and ore deposits of the Bingham mining district and northern Oquirrh Mountains, Utah: RTZ Group Mining and Exploration Conference, Salt Lake City, Utah, map (Plate 1), scale 1:24,000.

30. Tooker, E.W., 1987, Preliminary geologic maps, cross sections, and explanation pamphlet for the Ophir and Mercur 7 ½-minute quadrangles, Utah: U.S. Geological Survey Open-File Report 87-152, 18 p., 3 plates, scale 1:24,000.

31. Tooker, E.W., 1992, Preliminary geologic map of the Lowe Peak 7 ½-minute quadrangle, Tooele, Utah, and Salt Lake Counties, Utah: U.S. Geological Survey Open-File Report 92-404, 1 plate, scale 1:24,000.

32. Tooker, E.W., and Roberts, R.J., 1988, Interim geologic maps and explanation pamphlet for parts of the Stockton and Lowe Peak 7 ½-minute quadrangles, Utah: U.S. Geological Survey Open-File Report 88-280, 20 p., 2 plates, scale 1:24,000.

33. Tooker, E.W., and Roberts, R.J., 1992, Preliminary geologic map of the Stockton 7 ½-minute quadrangle, Tooele County, Utah: U.S. Geological Survey Open-File Report 92-385, 22 p., 1 plate, scale 1:24,000.

34. Tooker, E.W., and Roberts, R.J., 1998, Geologic map of the Oquirrh Mountains and adjoining South and western Traverse Mountains, Tooele, Salt Lake, and Utah Counties, Utah: U.S. Geological Survey Open-File Report 98-581, 2 plates, scale 1:50,000.

35. Welsh, J.E., and James, A.H., 1998 (revised), Reconnaissance traverse and measured section of part of the South Mountain quadrangle, Tooele County, Utah: unpublished data submitted to UGS.

Additional data sources used or considered for map preparation; not indicated in figure 2.

Armin, R.A., 1979, Geology of the southeastern Stansbury Mountains and southern Onaqui Mountains, Tooele County, Utah with a paleoenvironmental study of part of the Oquirrh Group: San Jose, San Jose State University, M.S. thesis, 110 p., 1 plate, scale 1:48,000.

Barnhard, T.P., and Dodge, R.L., 1988, Map of fault scarps formed on unconsolidated sediments, Tooele 1° x 2° quadrangle, northwestern Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1990, scale 1:250,000.

Black, B.D., Hecker, S., Hylland, M.D., Christenson, G.E., and McDonald, G.N., 2003, Quaternary fault and fold database and map of Utah: Utah Geological Survey Map 193DM, scale 1:500,000, CD.

Black, B.D., Solomon, B.J., and Harty, K.M., 1999, Geology and geologic hazards of Tooele Valley and the West Desert Hazardous Industry Area, Tooele County, Utah: Utah Geological Survey Special Study 96, 65 p., 6 plates, scale 1:100,000.

Bucknam, R.C., 1977, Map of suspected fault scarps in unconsolidated deposits, Tooele 2° sheet, Utah: U.S. Geological Survey, Open-File Report 77-495, scale 1:250,000.

Christie-Blick, N., 1983, Structural geology of the Sheeprock Mountains, *in* Miller, D.M., Todd, V.R., and Howard, K.A., editors, Tectonic and stratigraphic studies in the eastern Great Basin: Geological Society of America Memoir 157, p. 101-124.

Cohenour, R.E., 1957, Geology of the Sheeprock Mountains, Tooele and Juab Counties, Utah: Salt Lake City, University of Utah, Ph.D. dissertation, 209 p., scale 1:31,680

Cohenour, R.E., 1959, Sheeprock Mountains, Tooele and Juab Counties – Precambrian and Paleozoic stratigraphy, igneous rocks, structure, geomorphology, and economic geology: Utah Geological Survey Bulletin 63, 201 p., scale 1:33,400.

Cook, K.L., Bankey, V., Mabey, D.R., and DePangher, M., 1989, Complete Bouguer gravity anomaly map of Utah: Utah Geological and Mineral Survey Map 122, scale 1:500,000.

Copfer, T.J., and Evans, J.P., 2005, Provisional geologic map of the Deseret Peak East 7.5' quadrangle, Tooele County, Utah: Utah Geological Survey Open-File Report 450, 32 p., 3 plates, scale 1:24,000, CD.

Croft, M.G., 2004, Preliminary geologic map of the Johnson Pass quadrangle, Tooele County, Utah: unpublished map and explanation submitted to UGS, scale 1:24,000.

Currey, D.R., 1982, Lake Bonneville – Selected features of relevance to neotectonic analysis: U.S. Geological Survey Open-File Report 82-1070, 30 p., 1 plate, scale 1:500,000.

Everitt, B.L., and Kaliser, B.N., 1980, Geology for assessment of seismic risk in the Tooele and Rush Valleys, Tooele County, Utah: Utah Geological Survey Special Study 51, 33 p., 7 plates, scale 1:50,000.

Geomatrix Consultants, Inc., March 2001, Fault evaluation study and seismic hazard assessment, revision 1, Private Fuel Storage Facility, Skull Valley, Utah, prepared for Stone & Webster Engineering Corporation, 3 volumes.

Groff, S.L., 1957, Geology of the West Tintic Range and vicinity, Tooele and Juab Counties, Utah: Salt Lake City, University of Utah, Ph.D. dissertation, 183 p., 4 plates, scale 1:21,120.

Harrill, J.R., 1962, Geology of the Davis Knolls and northern Big Davis Mountains area, Tooele county, Utah: Salt Lake City, University of Utah, M.S. thesis, 68 p., 3 plates, scale 1:24,000.

Harty, K.M., 1992, Landslide map of the Rush Valley 30' x 60' quadrangle, Utah: Utah Geological Survey Open-File Report 254, 10 p., 1 plate, scale 1:100,000.

Hurlow, H.A., 2004, The geology of Cedar Valley, Utah County, Utah, and its relation to ground-water conditions: Utah Geological Survey Special Study 109, 74 p., 4 plates, map scale 1:100,000, CD.

Johnson, J.B., Jr., and Cook, K.L., 1957, Regional gravity survey of parts of Tooele, Juab, and Millard Counties, Utah: Geophysics, v. 22, no. 1, p. 48-61.

Maurer, R.E., 1970, Geology of the Cedar Mountains, Tooele County, Utah: Salt Lake City, University of Utah, Ph.D. dissertation, 184 p., 10 plates, scale 1:43,700.

Moore, W.J., and McKee, E.H., 1983, Phanerozoic magmatism and mineralization in the

Tooele 1° x 2° quadrangle, Utah, *in* Miller, D.M., Todd, V.R., and Howard, K.A., editors, Tectonic and stratigraphic studies in the eastern Great Basin: Geological Society of America Memoir 157, p. 183-190.

Moore, W.J., and Sorensen, M.L., 1979, Geologic map of the Tooele 1° x 2° quadrangle, Utah: U.S. Geological Survey Miscellaneous Investigation Series Map I-1132, scale 1:250,000.

Morris, H.R., 1987, Preliminary geologic structure map of the Delta 2° quadrangle and adjacent areas, west-central Utah: U.S. Geological Survey Open-File Report 87-189, scale 1:250,000.

Morris, H.T., and Lovering, T.S., 1961, Stratigraphy of the East Tintic Mountains, Utah, with a section on Quaternary deposits by H.D. Goode: U.S. Geological Survey Professional Paper 361, 145 p., 5 plates, map scale 1:96,000.

Mulvey, W.E., 1985, Reconstruction and interpretation of Late Pleistocene equilibrium-line altitudes in the Lake Bonneville region: Salt Lake City, M.S. thesis, University of Utah, 65 p. [unpublished mapping for M.S. thesis].

Olig, S.S., Gorton, A.E., and Chadwell, L., 1999, Mapping and Quaternary fault scarp analysis of the Mercur and West Eagle Hill faults, Wasatch Front, Utah: unpublished technical report submitted to the U.S. Geologic Survey, NEHRP Award No. 1434-HQ-97-GR-03154.

Rigby, J.K., 1958, Geology of the Stansbury Mountains, eastern Tooele County, Utah, *in* Rigby, J.K., editor, Geology of the Stansbury Mountains, Tooele County, Utah: Utah Geological Society, Guidebook to the Geology of Utah, no. 13, p. 1-134, map scale 1:63,360.

Sorensen, M.L., 1982, Geologic map of the Stansbury roadless areas, Tooele County, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1353-C, scale 1:62,500.

Teichert, J.A., 1958, Geology of the southern Stansbury Range, Tooele County, Utah: Salt Lake City, University of Utah, M.S. thesis, 79 p., scale 1:20,000.

Plate 1
Utah Geological Survey Open-File Report 593
Interim Geologic Map of the Rush Valley 30' x 60' quadrangle,
Tooele, Utah, and Salt Lake Counties, Utah

UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources

INTERIM 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]
2012

[1] Utah Geological Survey, P.O. Box 146100, Salt Lake City, UT 84114-6100
[2] Department of Geology, Kansas State University, Manhattan, KS 66506-3201

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

UTAH

QUADRANGLE LOCATION

APPROXIMATE MEAN DECLINATION, 2012

This open-file release makes information available to the public during the review and production period necessary for a formal UGS publication. The map may be incomplete and inconsistencies, errors, and omissions have not been resolved. While the document is in the review process, it may not conform to UGS standards; therefore it may be premature for an individual or group to take actions based on its contents. Although this product represents the work of professional scientists, the Utah Department of Natural Resources, Utah Geological Survey, makes no warranty, expressed or implied, regarding its suitability for a particular use. The Utah Department of Natural Resources, Utah Geological Survey, shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to claims by users of this product.

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, G09AC00152, and G10AC00386. 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.

Base from U. S. Geological Survey
Rush Valley 30' x 60' Quadrangle (1979)
Projection: UTM Zone 12
Datum: NAD 1927
Spheroid: Clarke 1886

Shaded relief created from 10 meter NED
(National Elevation Dataset)

Mapping by authors 2008-2011

GIS and Cartography: Kent D. Brown, Basia Matyjasik, James W. Parker, Richard L. Emerson, Donald L. Clark, Stefan M. Kirby

Project Manager: Robert F. Biek

Utah Geological Survey
1594 West North Temple, Suite 3110
Salt Lake City, UT 84116
(801) 537-3300
geology.utah.gov

UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources

Plate 2
Utah Geological Survey Open-File Report 593
Interim Geologic Map of the Rush Valley 30' x 60' Quadrangle

GEOLOGIC UNITS

SURFICIAL DEPOSITS

Alluvial Deposits

- Qal – Alluvial deposits
- Qai – Alluvial silt
- Qat – Alluvial-terrace deposits
- Qafy – Younger alluvial-fan deposits
- Qafb – Alluvial-fan deposits, graded to Lake Bonneville
- Qafo – Older alluvial-fan deposits, pre-Bonneville
- QTaf – High-level alluvial-fan deposits
- Taf – Tertiary alluvial-fan deposits

Spring Deposits

- Qsm – Spring and marsh deposits

Eolian Deposits

- Qe – Eolian deposits, undivided
- Qes – Eolian sheet sand deposits
- Qed – Eolian dune sand deposits
- Qei – Eolian silt

Lacustrine and Deltaic 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

Glacial Deposits

- Qg – Glacial deposits, undifferentiated

Colluvial deposits

- Qc – Colluvial deposits

Mass-Movement Deposits

- Qmtc – Talus and colluvium
- Qms – Landslide deposits

Mixed-Environment Deposits

- Qla – Lacustrine and alluvial deposits, undivided
- Qac – Alluvial and colluvial deposits

Human-Derived

- Qh – Human disturbance

Stacked-Unit Deposits

- Qei/Qal – Eolian silt over alluvial deposits
- Qei/Qlf – Eolian silt over lacustrine fine-grained deposits
- Qea/Qlf – Eolian and alluvial deposits over lacustrine fine-grained deposits
- Qe/Qlf – Eolian deposits over lacustrine-fine grained deposits
- Qes/Qlf – Eolian sheet sand deposits over lacustrine fine-grained deposits
- Qed/Qlf – Eolian dune sand deposits over lacustrine fine-grained deposits
- Qes/Qla – Eolian sheet sand deposits over lacustrine and alluvial deposits
- Qes/Qafy – Eolian sheet sand deposits over younger alluvial-fan deposits
- Qes/Qafo – Eolian sheet sand deposits over older alluvial-fan deposits
- Qed/Qla – Eolian dune sand deposits over lacustrine and alluvial deposits
- Qlf/Qls – Lacustrine fine-grained deposits over lacustrine sand deposits
- Qed/Tac – Eolian dune sand deposits over andesitic and dacitic rocks of southern Cedar Mountains
- Qlg/R – Lacustrine gravel over undifferentiated bedrock

BASIN FILL AND BEDROCK UNITS

- Tsl – Salt Lake Formation
- Ts – Tertiary strata

Southern Cedar Mountains, Davis Knolls, Northern Simpson Mtns., Northern Sheeprock Mtns., Southern Stansbury Mtns.

- Trr – Rhyolite of Rydalch Canyon area
- Trdc – Rhyodacite of Cherry Springs
- Trj – Rhyolite of Judd Creek
- Tlg – Latite of Government Creek
- Tdi – Dacitic intrusions of Little Granite Mountain and White Rock
- Tac – Andesitic and dacitic rocks of southern Cedar Mountains
- Taci – Andesitic intrusions of southern Cedar Mountains
- Tvs – Intermediate volcanic rocks of Stansbury Mountains

Southern Oquirrh Mountains, South Mountain, Western Traverse Mountains

Younger Volcanic and Intrusive Suite

- Tvbs – Younger volcanic breccia
- Tvfs – Younger lava flows
- Tvfb – Intermediate lava flows of Black Ridge
- Tvlb – Lahars and debris flows of Black Ridge
- Trf – Rhyolitic lava flows of Tickville Gulch
- Tvfa – Basaltic andesite lava flow
- Tdio – Dacitic dike
- Tri – Rhyolitic intrusions
- Tai – Andesitic intrusion
- Tpqmi – Porphyritic quartz monzonite intrusions

Older Volcanic and Intrusive Suite

- Tvfo – Nepheline minette and shoshonite lava flows
- Tsu – Lacustrine strata
- Tvfou – Older intermediate lava flows
- Tvlo – Older lahars and debris flows
- Tdmo – Mafic dikes
- Tqmi – Quartz monzonite porphyry intrusion
- Tmi – Monzonite intrusions
- Tli – Latite to dacite porphyry sills and dikes
- Tqli – Quartz latite porphyry dikes
- Tbi – Basalt sill

Vernon Hills

- Tbav – Basaltic andesite
- Tdv – Dacite
- Trv – Rhyolite

Northern East Tintic Mountains

- Tb – Mosida Basalt
- Tfb – Mafic lava of Broad Canyon
- Tdm – Mafic dikes
- Tvm – Minette intrusion
- Tpc – Pinyon Creek Conglomerate
- Tlsl – Laguna Springs Volcanic Group, lava flow unit
- Tlsa – Laguna Springs Volcanic Group, tuff unit
- Tlst – Laguna Springs Volcanic Group, tuff of Twelvemile Pass unit
- Tsw – Soldiers Pass Formation, White Knoll Member
- Tsb – Soldiers Pass Formation, breccia member
- Tsc – Soldiers Pass Formation, Chimney Rock Pass Tuff Member
- Ttlr – Tintic Mountain Volcanic Group, Latite Ridge Latite
- Tp – Packard Quartz Latite, undivided
- TKj – Jasperoid

Camels Back Ridge, Southern Cedar Mtns., Skull Valley, Davis Mtns., Northern Simpson Mtns., Southern Stansbury Mtns., Onaqui Mtns., Northern Sheeprock Mtns., Vernon Hills

- Ʈtw – Thaynes Limestone and Woodside Formation, undivided
- Ppfm – Park City Formation, Franson Member, and Phosphoria Formation, Meade Peak Phosphatic Shale Tongue, undivided
- Ppg – Park City Formation, Grandeur Member
- Pdk – Diamond Creek Sandstone and Kirkman Formation, undivided
- Pdc – Diamond Creek Sandstone
- Pk – Kirkman Formation
- ℙPo – Oquirrh Group strata, undivided
- ℙPofm – Oquirrh Group, Freeman Peak, Curry Peak, and Bingham Mine Formations, undivided
- Pofc – Oquirrh Group, Freeman Peak and Curry Peak Formations, undivided
- Pofp – Oquirrh Group, Freeman Peak Formation
- Pocp – Oquirrh Group, Curry Peak Formation
- ℙo – Oquirrh Group, Bingham Mine and Butterfield Peaks Formations, undivided
- ℙobm – Oquirrh Group, Bingham Mine Formation
- ℙobmu – Oquirrh Group, Bingham Mine Formation, upper member
- ℙobml – Oquirrh Group, Bingham Mine Formation, lower member
- ℙobw – Oquirrh Group, Butterfield Peaks Formation and West Canyon Limestone, undivided
- ℙobp – Oquirrh Group, Butterfield Peaks Formation
- ℙMwm – Oquirrh Group, West Canyon Limestone and Manning Canyon Shale, undivided
- ℙowc – Oquirrh Group, West Canyon Limestone
- ℙMmc – Manning Canyon Shale
- 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, Long Trail Shale Member
- Mgbl – Great Blue Limestone, lower limestone member
- 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 and Ely Springs Dolomites, undivided
- Sl – Laketown Dolomite, undivided
- Ou – Ordovician strata, undivided
- Oes – Ely Springs Dolomite
- OꞒu – Lower Ordovician and Upper-Middle Cambrian strata, undivided
- Oe – Eureka Quartzite
- Ok – Pogonip Group, Kanosh Shale
- Op – Pogonip Group, undivided
- Ꞓu – Upper Cambrian strata, undivided
- Ꞓum – Upper and Middle Cambrian strata, undivided
- Ꞓn – Notch Peak Formation
- Ꞓo – Orr Formation
- Ꞓou – Orr Formation, upper part
- Ꞓob – Orr Formation, Big Horse Limestone Member
- Ꞓm – Middle Cambrian strata, undivided
- Ꞓl – Lamb Dolomite
- Ꞓtl – Trippe Limestone
- Ꞓpc – Pierson Cove Formation
- Ꞓws – Wheeler Formation and Swasey Limestone, undivided
- Ꞓwh – Whirlwind Formation, Dome Limestone, Chisholm Formation, Howell Limestone, undivided
- Ꞓp – Pioche Formation
- Ꞓpm – Prospect Mountain Quartzite
- Zm – Mutual Formation
- Zi – Inkom Formation
- Zcc – Caddy Canyon Quartzite

Southern Oquirrh Mountains

- Ꞓly – Lynch Dolomite
- Ꞓb – Bowman Limestone
- Ꞓh – Hartmann Limestone
- Ꞓop – Ophir Formation
- Ꞓt – Tintic Quartzite

Northern East Tintic Mountains

- MDf – Fitchville Formation
- Dpv – Pinyon Peak Limestone and Victoria Formation, undivided
- DOb – Bluebell Dolomite
- Of – Fish Haven Dolomite
- Oo – Opohonga Limestone
- Ꞓao – Ajax Dolomite and Opex Formation
- Ꞓc – Cole Canyon Dolomite
- Ꞓbh – Bluebird Dolomite and Herkimer Limestone, undivided
- Ꞓdt – Dagmar Dolomite and Teutonic Limestone, undivided
- Ꞓop – Ophir Formation
- Ꞓt – Tintic Quartzite
- Zbc – Big Cottonwood Formation

GEOLOGIC SYMBOLS

- Contact – Angled where scratch
- Normal fault – Dashed where approximately located, dotted where concealed; bar and ball on down-thrown side
- Normal fault, concealed – Inferred principally from gravity data; bar and ball on down-thrown side
- Strike-slip or oblique-slip fault – Dashed where approximately located, dotted where concealed; arrows and bar and ball indicate relative displacement
- Fault of unknown geometry – Dashed where approximately located, dotted where concealed
- Thrust fault – Dashed where inferred, dotted where concealed; teeth on hanging wall
- Reverse fault – Dotted where concealed; teeth on hanging wall
- Attenuation fault – Dotted where concealed; boxes on hanging wall
- Low-angle normal fault – Dotted where concealed; boxes on hanging wall
- Lineament – From air photo interpretation
- Igneous dike (map unit Tqli)
- Igneous dike (map unit Tdio)
- Igneous dike (map unit Tdmo)
- Igneous dike (map unit Tpqmi)
- Igneous dike (map unit Tri)
- Axial trace of anticline – Dashed where approximately located, dotted where concealed; arrow shows plunge
- Axial trace of overturned anticline – Dashed where approximately located, dotted where concealed; 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
- Major shorelines of the Bonneville lake cycle (see table 1) –
  - Bonneville shoreline (B)
  - Provo shoreline (P)
  - Shambip shoreline (Sh)
  - Smelter Knolls shoreline (SK)
  - Stansbury shoreline (S)
  - other transgressive and regressive shorelines
- Lake Bonneville crest of barrier ridge or delta ridge
- Delta distributary channel crest (on map unit Qlf/Qls in Skull Valley)
- Holocene shoreline of Rush Lake (H)
- Strike and dip of bedding (refer to index map for prior mapping sources) –
  - 20 Inclined from current mapping
  - 20 Inclined from prior mapping
  - 30 Inclined approximate, approximate dip included where known
  - Vertical
  - 50 Overturned from current mapping
  - 50 Overturned from prior mapping
- Sand and gravel pit
- Mine or quarry
- Adit
- Shaft
- Drill hole
- Rock sample location and number for geochemical analyses and Ar/Ar age (see tables 3, 4)
- Rock sample location and number for prior Ar/Ar age analyses (see table 4)
- Rock sample location and number for geochemical analyses (see table 3)
- Tephra sample location and number for geochemical analyses and age (see table 2)
- Fossil sample location and number for age evaluation (see table 6)
- Rock sample location and number for U-Pb zircon age analyses (see table 5)
- Rock sample location and number for palynology age analyses (see table 7)
- Qed/Qlf – Indicates thin cover of the first unit overlying the second unit

LITHOLOGIC COLUMN
Southern Cedar Mountains, Skull Valley

TIME-STRATIGRAPHIC UNIT		GEOLOGIC UNIT	MAP SYMBOL	THICKNESS Feet (Meters)	NOTES
TERTIARY	Eocene	Rhyolite of Rydalch Canyon area	Trr	650 (200)	Tuff; 39.18 Ma Ar/Ar
TERTIARY	Eocene	Andesitic and dacitic rocks of southern Cedar Mountains	Tac	1200 (370)	Lava flows, lahars, tuffs; 38.17 Ma Ar/Ar; 40.66 Ma Ar/Ar; 41.73 Ma Ar/Ar
TERTIARY		Tertiary strata	Ts	0-200 (60)	Unconformity
PERMIAN	Lower	Oquirrh Group: Freeman Peak and Curry Peak Formations	Pofc [ℙPo, ℙPofm]	3500 (1070)	*Schwagerina*; "Worm trail" markings; Unconformity?
PENNSYLVANIAN	Upper	Oquirrh Group: Bingham Mine Formation	ℙobm [ℙPo, ℙPofm]	2800 (850)	*Triticites*
PENNSYLVANIAN	Middle	Oquirrh Group: Butterfield Peaks Formation	ℙobp [ℙPo, ℙobw]	5400 (1650)	Cliffy near top; *Fusulina*; *Beedeina*; Cyclic lithologic character; *Millerella*; *Chaetetes*
PENNSYLVANIAN	Lower	Oquirrh Group: West Canyon Limestone	ℙowc [ℙPo, ℙobw, ℙMwm]	500-800 (150-245)	
MISSISSIPPIAN	Upper	Manning Canyon Shale	ℙMmc [ℙMwm]	1500-2000 (450-600)	Interval of regional decollement
faults					
MISSISSIPPIAN	Upper	Great Blue Limestone	Mgb	2440+ (745+)	
MISSISSIPPIAN	Upper	Humbug Formation	Mh	1014+ (310+)	
fault					
M	L	Gardison Ls?	Mg?	>600 (180)	
faults					
ORD.	L-U	Ord. strata undiff.	Ou	~200+ (~60+)	Hickman Knolls breccia

LITHOLOGIC COLUMN
Camels Back Ridge and Simpson Buttes

TIME-STRATIGRAPHIC UNIT		GEOLOGIC UNIT	MAP SYMBOL	THICKNESS Feet (Meters)	NOTES
DEVONIAN	M. & U.	Guilmette Formation?	Dg?	500+ (150+)	
fault					
DEVONIAN	Middle	Simonson Dolomite	Dsi	500+ (150+)	
DEVONIAN	Lower	Sevy Dolomite	Dsy	250 (75)	Light-gray, laminated dolomite
fault					
SILURIAN		Laketown Dolomite undivided	Sl	500+ (150+)	Cherty
ORDOVICIAN	Upper	Ely Springs Dolomite	Oes	250 (75)	Light-gray dolomite - Floride unit; Unconformity - Tooele Arch
ORDOVICIAN	M. & L.	Pogonip Group	Op [OꞒu]	150+ (45+)	
fault					
O / CAMBRIAN	L. / Upper	Notch Peak Formation	Ꞓn [OꞒu]	500+ (150+)	Cliffs
CAMBRIAN	Upper	Orr Formation, upper part	Ꞓou [OꞒu]	200 (60)	
CAMBRIAN	Upper	Orr Formation, Big Horse Limestone Member	Ꞓob [OꞒu]	425 (130)	
CAMBRIAN	?	Lamb Dolomite	Ꞓl [OꞒu]	900 (275)	Upper - less resistant, rusty and pink weathering
CAMBRIAN	Middle	Tripple Limestone	Ꞓtl	700 (215)	Less resistant and ledgy
CAMBRIAN	Middle	Pierson Cove Formation	Ꞓpc	800+ (245+)	Locally dolomitized

(OꞒu interval, Notch Peak Formation through Lamb Dolomite: 2300 (700))

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

TIME-STRATIGRAPHIC UNIT			GEOLOGIC UNIT	MAP SYMBOL	THICKNESS FEET (METERS)	NOTES
TERTIARY	Miocene?-Eocene?		Igneous and sedimentary rocks	see correlation chart	various	
Tertiary - Cret.			Jasperoid	TKj	variable	
TRIASSIC	L.		Thaynes Limestone, Woodside Fm.	Ʈtw	800 (245)	
PERMIAN	M.		Park City-Phosph. Fms.: Franson Mbr., Meade Pk. Sh.	Ppfm	510 (155)	
PERMIAN	Lower		Park City-Phosph. Fms.: Grandeur Mbr.	Ppg	500 (150)	
PERMIAN	Lower		Diamond Creek Ss.	Pdc	350 (105)	
PERMIAN	Lower		Kirkman Formation	Pk	400 (120)	
fault						
PERMIAN	Lower	Wolfcampian	Oquirrh Group: Freeman Peak and Curry Peak Formations	Pofc	3500+ (1100+)	Unconformity?
PENNSYLVANIAN	Upper	Missourian - Virgilian	Oquirrh Group: Bingham Mine Formation	ℙobm	8000 (2450)	Fault in Vernon Hills
PENNSYLVANIAN	Middle	Atokan - Desm.	Oquirrh Group: Butterfield Peaks Formation	ℙobp	6000+ (1800+)	
faults						Faults in Stansbury Mtns. and Vernon Hills
PENNSYLVANIAN	Lower	Morrowan	West Canyon Limestone	ℙowc	1150-1650 (350-500)	
MISSISSIPPIAN	Upper		Manning Canyon Shale	ℙMmc	0-1300 (400)	
MISSISSIPPIAN	Upper		Great Blue Limestone (Mgb): upper limestone mbr.	Mgbu	800 (240)	Fault in Vernon Hills
MISSISSIPPIAN	Upper		Great Blue Limestone (Mgb): Long Trail Shale Mbr.	Mgbs	30-80 (10-25)	
MISSISSIPPIAN	Upper		Great Blue Limestone (Mgb): lower limestone mbr.	Mgbl	700-820+ (210-250+)	
MISSISSIPPIAN	Upper		Humbug Formation	Mh	700-1250 (210-380)	Fault in Vernon Hills
MISSISSIPPIAN	Upper		Deseret Limestone	Md	525 (160)	
MISSISSIPPIAN	Lower		Gardison Limestone	Mg [MDgs]	700-840 (210-260)	Unconformity
MISSISSIPPIAN / DEVONIAN	Lower / U.		Fitchville Formation, Pinyon Peak Limestone	MDfp [MDfs, MDgs]	60-200 (20-60)	Unconformity - Stansbury uplift
DEVONIAN	U.		Stansbury Fm.	Dst [MDfs, MDgs]	0-200 (60)	
DEVONIAN	U.		Guilmette Fm.	Dg [DOu]	180 (50)	
DEVONIAN	M.		Simonson Dolomite	Dsi [DOu]	570-890 (170-270)	
DEVONIAN	L.		Sevy Dolomite	Dsy [DOu]	710-830 (220-250)	
S. / ORDOVICIAN	Upper		Laketown Dolomite, Ely Springs Dolomite	SOu [DOu]	1060-1280(320-390)	Unconformity
ORDOVICIAN	Upper		Eureka Quartzite	Oe	0-80 (25)	Unconformity where Eureka absent
ORDOVICIAN	Lower-Middle		Kanosh Shale	Ok	0-250 (75)	
ORDOVICIAN	Lower-Middle		Pogonip Group	Op	0-1350 (410)	
CAMBRIAN	Upper		Notch Peak Fm. (Upper Cambrian strata)	Ꞓn [Ꞓu, Ꞓum]	700-1000 (210-330)	
CAMBRIAN	Upper		Orr Fm. (Upper Cambrian strata)	Ꞓo [Ꞓu, Ꞓum]	>1200 (365)	
CAMBRIAN	Middle		Lamb Dol. (Upper and Middle Cambrian strata)	Ꞓl [Ꞓum]	1290 (390)	Fault in Sheeprock Mtns
CAMBRIAN	Middle		Tripple Ls. (Upper and Middle Cambrian strata)	Ꞓtl [Ꞓum]	1000-1600 (305-490)	
CAMBRIAN	Middle		Pierson Cove Fm. (Middle Cambrian strata)	Ꞓpc [Ꞓum, Ꞓm]	620-1970 (190-600)	
CAMBRIAN	Middle		Wheeler Formation, Swasey Ls. (Middle Cambrian strata)	Ꞓws [Ꞓum, Ꞓm]	340-1410 (100-430)	
CAMBRIAN	Middle		Whirlwind, Dome, Chisolm, Howell	Ꞓwh	340-1410 (100-430)	
CAMBRIAN	Lower		Pioche Formation	Ꞓp	400 (120)	
CAMBRIAN	Lower		Prospect Mountain Quartzite	Ꞓpm	2800–4200+ (850–1280+)	
NEOPROTEROZOIC			Mutual Formation	Zm	1660-3900+ (500-1180+)	
NEOPROTEROZOIC			Inkom Formation	Zi	600-790+ (180-240+)	Fault in Sheeprock Mtns
NEOPROTEROZOIC			Caddy Canyon Quartzite	Zcc	3850+ (1165+)	

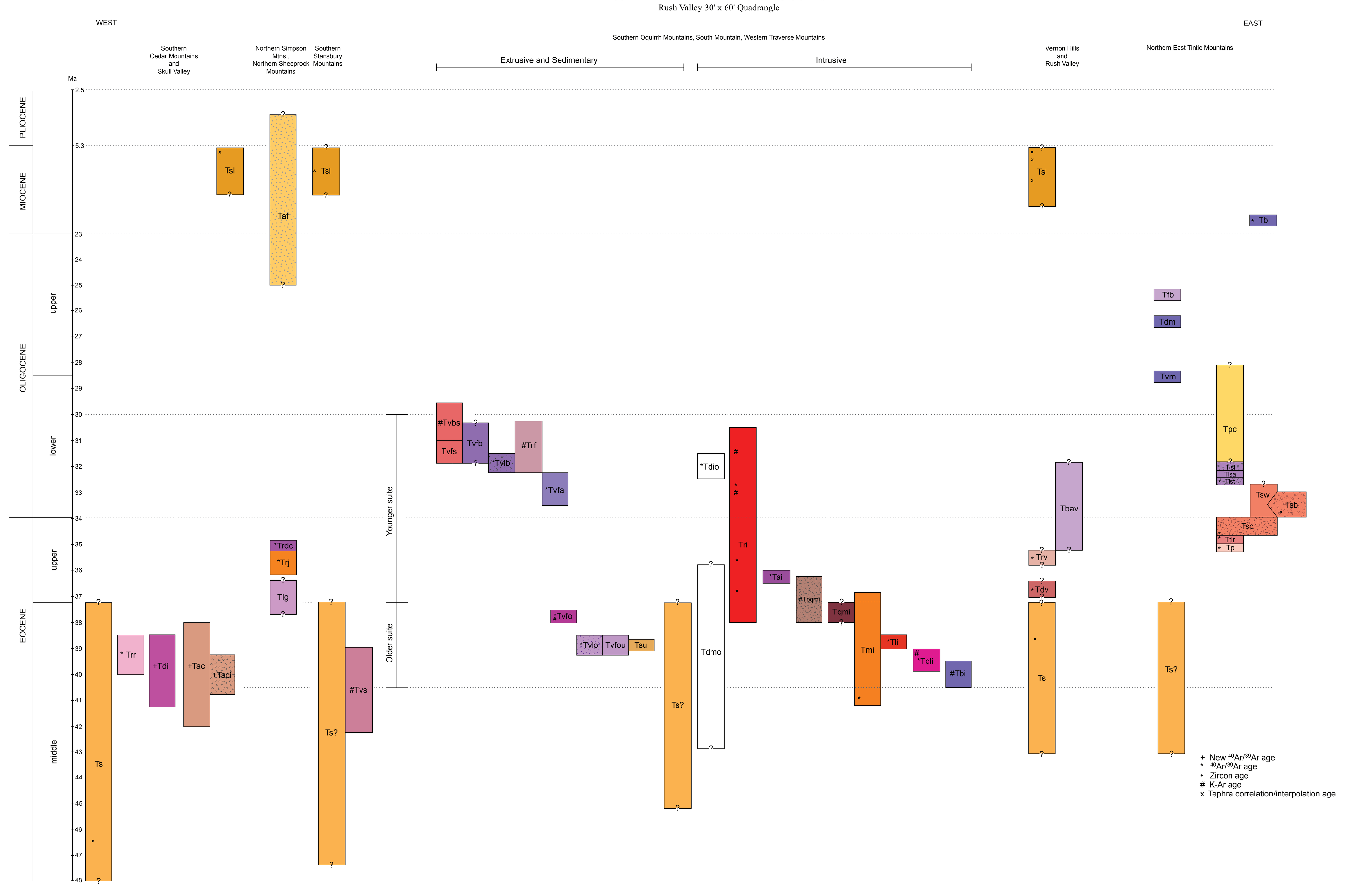
LITHOLOGIC COLUMN
Southern Oquirrh Mountains, South Mountain, Western Traverse Mountains

TIME-STRATIGRAPHIC UNIT			GEOLOGIC UNIT	MAP SYMBOL	THICKNESS Feet (Meters)	NOTES
Tertiary	Lower / Middle	Oligocene / Eocene	Igneous and Sedimentary rocks	see correlation chart	various	Younger Volcanic and Intrusive Suite ~30-37 Ma; Older Volcanic and Intrusive Suite ~37-40 Ma
Tert.-Cret.			Jasperoid	TKj	variable	
PERMIAN	Lower	Leonardian?	Diamond Creek Sandstone and Kirkman Formation	Pdk	2600 (790)	Thin, atypical Kirkman?
PERMIAN	Lower	Wolfcampian	Oquirrh Group: Freeman Peak Formation	Pofp	2900 (880)	
PERMIAN	Lower	Wolfcampian	Oquirrh Group: Curry Peak Formation	Pocp	1800 (550)	worm trails; Unconformity
PENNSYLVANIAN	Upper	Missourian - Virgilian	Oquirrh Group: Bingham Mine Formation, upper member	ℙobmu [ℙo, ℙobm]	2200 (670)	
PENNSYLVANIAN	Upper	Missourian - Virgilian	Oquirrh Group: Bingham Mine Formation, lower member	ℙobml [ℙo, ℙobm]	3100 (945)	Commercial and Jordan Limestones
			(Bingham Mine Formation total)	ℙobm	5300–6500 (1600–2000)	
PENNSYLVANIAN	Middle	Atokan - Desmoinesian	Oquirrh Group: Butterfield Peaks Formation	ℙobp [ℙo]	9000 (2765)	Cyclic lithologic character
PENNSYLVANIAN	Lower	Morrowan	Oquirrh Group: West Canyon Limestone	ℙowc	1053-1456 (321-444)	
MISSISSIPPIAN	Upper		Manning Canyon Shale	ℙMmc	1140-1559 (347-475)	
MISSISSIPPIAN	Upper		Great Blue Limestone: upper limestone member / upper ls. and shale mbr.	Mgbu / Mgbus	1545-2800 (475-850)	~2000 (~610)
MISSISSIPPIAN	Upper		Great Blue Limestone: Long Trail Shale Mbr.	Mgbs	110 (33)	
MISSISSIPPIAN	Upper		Great Blue Limestone: lower limestone member	Mgbl	460-850 (140-260)	
MISSISSIPPIAN	Upper		Humbug Formation	Mh	650 (200)	
MISSISSIPPIAN	Upper		Deseret Limestone	Md	650 (200)	Delle phosphatic shale
MISSISSIPPIAN	Lower		Gardison Limestone	Mg	460 (140)	Unconformity
D.	Up.		Fitchville Fm., Pinyon Peak Ls.	MDfp	130 (40)	Major unconformity
CAMBRIAN	Up.		Lynch Dolomite	Ꞓly	810-1050 (245-320)	
CAMBRIAN	Middle		Bowman Ls.	Ꞓb	310-345 (95-105)	
CAMBRIAN	Middle		Hartmann Limestone	Ꞓh	590-630 (180-190)	
CAMBRIAN	Middle		Ophir Formation	Ꞓop	280-310 (85-95)	
CAMBRIAN	L.		Tintic Quartzite	Ꞓt	300+ (90+)	

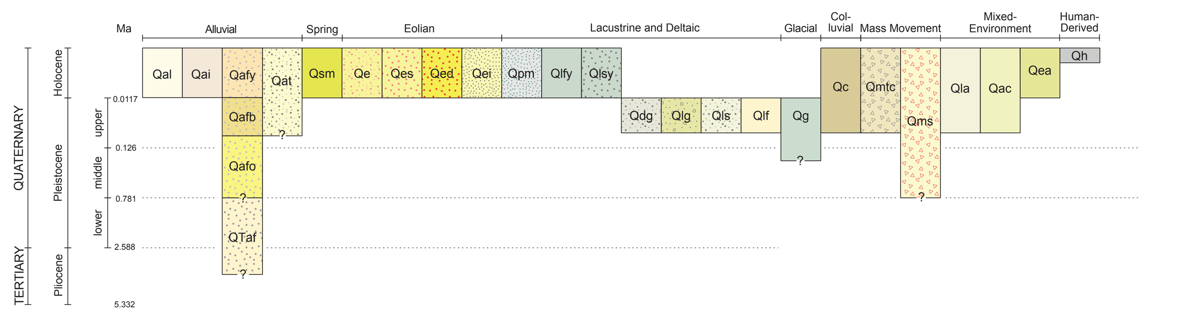
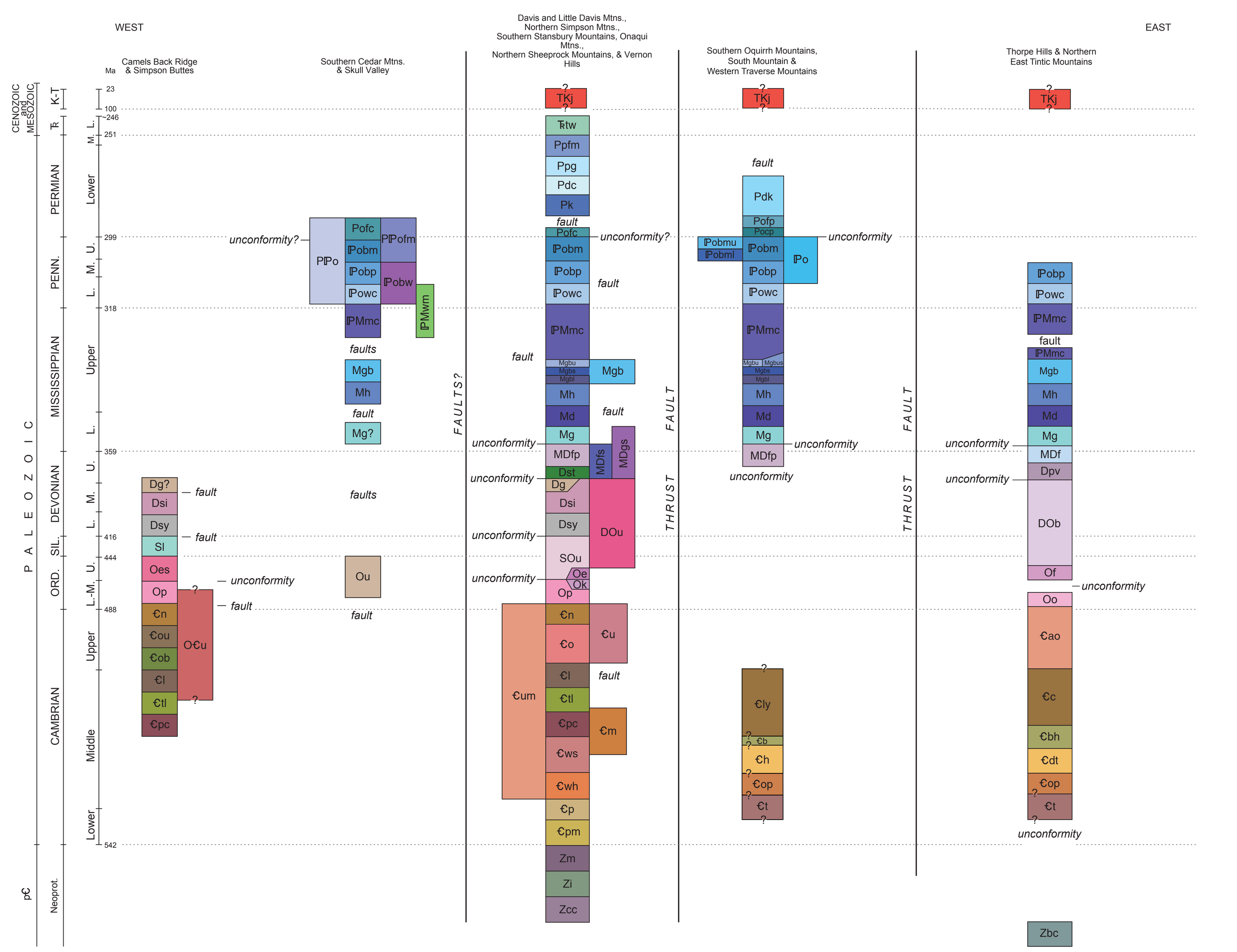
LITHOLOGIC COLUMN
Thorpe Hills and Northern East Tintic Mountains

TIME-STRATIGRAPHIC UNIT			GEOLOGIC UNIT	MAP SYMBOL	THICKNESS FEET (METERS)	NOTES
Tert.	Miocene-upper Eocene		Volcanic and sedimentary rocks	see correlation chart	various	Basalt 19.5 Ma; ~30-35 Ma
Tert. - Cret.			Jasperoid	TKj	variable	
PENNSYLVANIAN	Middle	Atokan - Desmoinesian	Oquirrh Group: Butterfield Peaks Formation	ℙobp	3650 (1110)	
PENNSYLVANIAN	Lower	Morr.	Oquirrh Group: West Canyon Limestone	ℙowc	750 (230)	
			Manning Canyon Shale	ℙMmc	1050 (320)	
fault						
				ℙMmc		
MISSISSIPPIAN	Upper		Great Blue Limestone	Mgb	1080 (330)	
MISSISSIPPIAN	Upper		Humbug Formation	Mh	600 (180)	
MISSISSIPPIAN	Upper		Deseret Limestone	Md	700 (215)	
MISSISSIPPIAN	Lower		Gardison Limestone	Mg	450 (140)	Unconformity
D.	Up.		Fitchville Formation	MDf	300 (90)	
D.	M. Up.		Pinyon Peak Ls., Victoria Fm.	Dpv	250-300 (75-90)	Unconformity
S.			Bluebell Dolomite	DOb	600 (180)	
ORD.	Up.		Fish Haven Dol.	Of	270 (80)	Unconformity
ORD.	Lower		Opohonga Limestone	Oo	800 (245)	
CAMBRIAN	Up.		Ajax Dolomite, Opex Formation	Ꞓao	850 (260)	
CAMBRIAN	Middle		Cole Canyon Dolomite	Ꞓc	825 (250)	
CAMBRIAN	Middle		Bluebird Dol., Herkimer Ls.	Ꞓbh	600 (180)	
CAMBRIAN	Middle		Dagmar Dol., Teutonic Ls.	Ꞓdt	500 (150)	
CAMBRIAN	Middle		Ophir Formation	Ꞓop	430 (130)	
CAMBRIAN	? Lower		Tintic Quartzite	Ꞓt	2500 (760)	Unconformity
Neoproterozoic			Big Cottonwood Fm.	Zbc	200+ (60+)	

CORRELATION OF TERTIARY GEOLOGIC UNITS
Rush Valley 30' x 60' Quadrangle



CORRELATION OF QUATERNARY GEOLOGIC UNITS
Rush Valley 30' x 60' Quadrangle



CORRELATION OF MESOZOIC, PALEOZOIC, AND PRECAMBRIAN GEOLOGIC UNITS
Rush Valley 30' x 60' Quadrangle