UTAH GEOLOGICAL SURVEY
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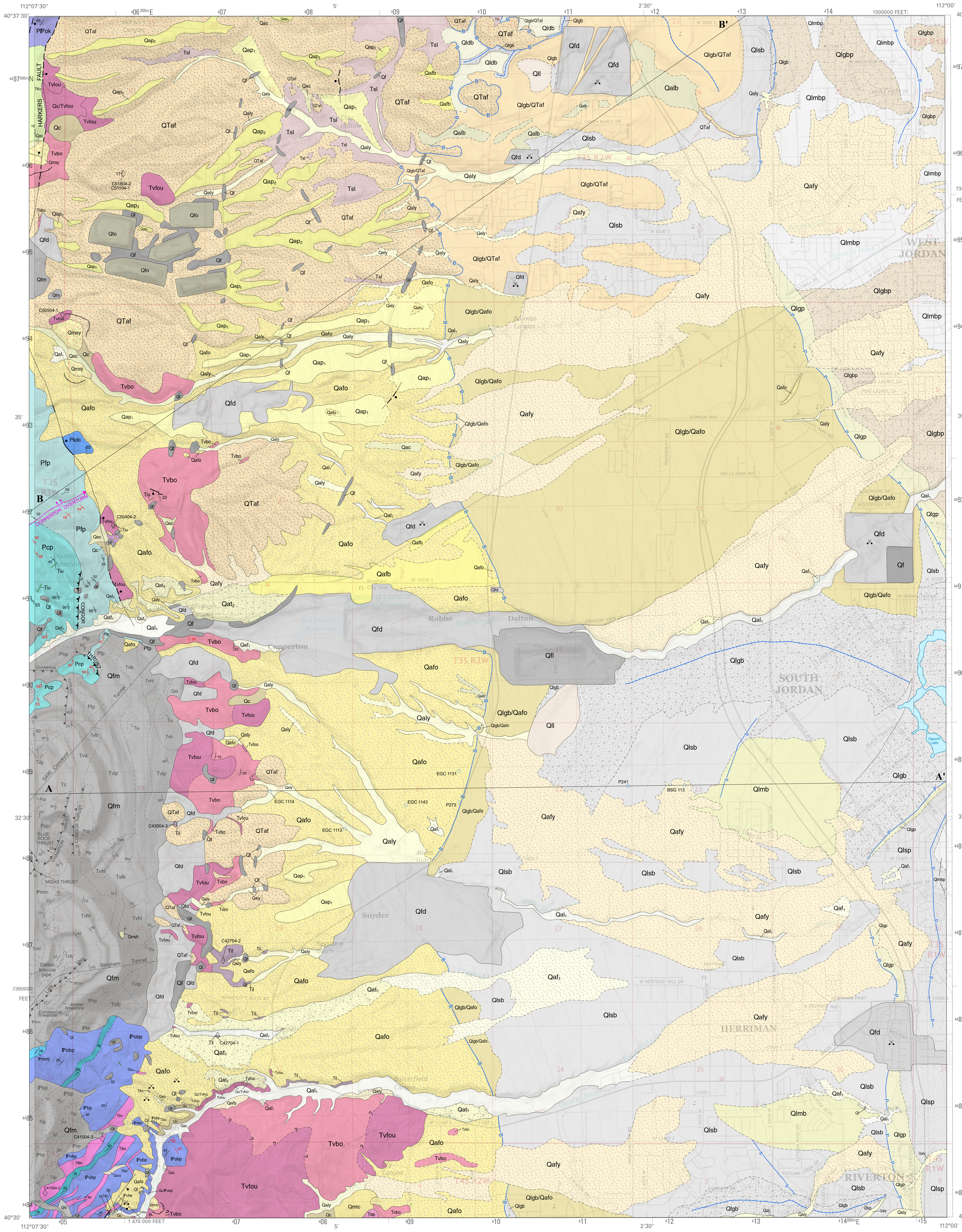

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11°42'
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 2018

SCALE 1:24,000
1 0.5 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 0.5 0 1 KILOMETER
CONTOUR INTERVAL 20 FEET

GEOLOGIC MAP OF THE COPPERTON QUADRANGLE, SALT LAKE COUNTY, UTAH (GIS REPRODUCTION OF 2007 MAP)

by
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2018

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UTAH
QUADRANGLE LOCATION

Base from USGS Copperton 7.5' Quadrangle (2017). Projection and datum for base map and GIS data are UTM NAD83. To conform to adjoining geologic maps, the geology is mapped to the 7.5' boundary of older UTM NAD 27 base maps; this explains the visible shift between geology and base map. The geology is accurately shown relative to cultural and topographic features on the US Topo base map.
Projection: UTM Zone 12
Datum: NAD 1983

Project Manager: Grant C. Willis
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1	2	3
4		5
6	7	8

1. Farnsworth Peak
2. Magna
3. Salt Lake City South
4. Bingham Canyon
5. Midvale
6. Lowe Peak
7. Tickville Spring
8. Jordan Narrows

ADJOINING 7.5' QUADRANGLE NAMES

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MAP UNIT DESCRIPTIONS

QUATERNARY

Alluvial deposits

Qal$_1$ — **Modern stream deposits** (Holocene) – Moderately to well-sorted sand, silt, clay, and pebble to boulder gravel in active stream channels and flood plains; locally includes small alluvial-fan and colluvial deposits, and minor terraces up to 10 feet (3 m) above current base level; equivalent to the younger part of Qaly, but differentiated where deposits can be mapped separately; mapped principally along the larger streams, including Barneys, Bingham, Butterfield, and Midas Creeks, Copper Gulch, and Barneys Wash; generally 0 to 20 feet (0-6 m) thick.

Qat$_1$, Qat$_2$ — **Stream-terrace deposits** (Holocene to middle Pleistocene) – Moderately to well-sorted sand, silt, clay, and pebble to boulder gravel that forms level to gently sloping terraces incised by modern streams; subscript denotes relative height above modern stream channels; level-1 deposits are 10 to 30 feet (3-10 m) above modern drainages and are found along Butterfield Creek, Copper Gulch, and Bingham Creek; level-2 deposits are greater than 30 feet (10 m) above modern drainages and are mapped at the mouths of Butterfield and Bingham Canyons; deposited in stream channels and flood plains; older terraces may include a loess veneer; generally 0 to 20 feet (0-6 m) thick.

Qaly — **Young alluvial deposits** (Holocene to upper Pleistocene) – Moderately sorted sand, silt, clay, and pebble to boulder gravel deposited in stream channels and flood plains; includes abandoned alluvial flood plains that postdate the Bonneville shoreline of latest Pleistocene Lake Bonneville, which occupied the valley from about 32,500 to 11,600 calendar years B.P. (calendar-calibrated ages from D.R. Currey, University of Utah, written communication to Utah Geological Survey, 1996); the alluvial deposits are incised by active stream channels, and locally include small alluvial-fan and colluvial deposits; equivalent to modern stream deposits (Qal$_1$) and older, post-Lake Bonneville stream deposits that are undifferentiated because units are complexly overlapping; mapped along streams draining the Oquirrh and Traverse Mountains; probably less than 20 feet (6 m) thick.

Qalb — **Alluvial deposits related to the Bonneville (transgressive) phase of the Bonneville lake cycle** (upper Pleistocene) – Moderately sorted sand, silt, and pebble to boulder gravel deposited by streams graded to shorelines of the transgressive phase of Lake Bonneville; incised by active streams; mapped east of Clay Hollow and in small, unnamed drainages south of Bingham Creek; about 20 feet (6 m) thick.

Qaf$_1$ — **Modern alluvial-fan deposits** (Holocene) – Poorly to moderately sorted, weakly to non-stratified, clay- to boulder-size sediment deposited principally by debris flows at the mouths of small, active drainages; upper parts characterized by abundant boulders and debris-flow levies that radiate away from the fan apex; equivalent to the younger part of Qafy but differentiated where deposits can be mapped separately; generally less than 30 feet (9 m) thick.

Qafy — **Younger alluvial-fan deposits** (Holocene to upper Pleistocene) – Poorly to moderately sorted, weakly to non-stratified, clay- to boulder-size sediment deposited principally by debris flows, debris floods, and streams; commonly obscures Lake Bonneville shorelines, and is equivalent to modern and level-2 alluvial-fan deposits (Qaf$_1$ and Qaf$_2$) that are undifferentiated because units are complexly overlapping or too small to show separately (level-2 alluvial-fan deposits are not recognized in the quadrangle, but are mapped in the adjacent Tickville Spring quadrangle [Biek and others, 2005]); upper parts of fans are locally deeply incised; mapped near the margins of the Oquirrh and Traverse Mountains, and extending as much as 3 miles (5 km) from the Oquirrh Mountains where major drainages incise Lake Bonneville deposits beyond the range front; probably less than 40 feet (12 m) thick.

Qafb — **Alluvial-fan deposits related to the Bonneville (transgressive) phase of the Bonneville lake cycle** (upper Pleistocene) – Poorly to moderately sorted, clay- to cobble-size sediment deposited principally by debris flows on fan surfaces graded to the Bonneville shoreline; incised by active streams; mapped near Bingham Creek and Clay Hollow where the unit may locally include topset beds of deltaic deposits related to the transgressive phase of Lake Bonneville (Qldb); probably less than about 40 feet (12 m) thick.

Qafo — **Older alluvial-fan deposits** (upper to middle Pleistocene) – Poorly to moderately sorted, weakly to non-stratified, clay- to boulder-size sediment deposited principally by debris flows; mapped as part of the Harkers fanglomerate by Slentz (1955); forms deeply dissected alluvial apron on piedmont slopes of the Oquirrh Mountains north of the Traverse Mountains; older alluvial-fan deposits are truncated by, and thus predate, the Bonneville shoreline; underlies piedmont slopes below the Bonneville shoreline beneath a thin veneer of lacustrine deposits; locally contains thin, white to light gray volcanic ash; may be undifferentiated from underlying Quaternary to Tertiary alluvial-fan deposits where mapped in deeply incised stream channels; late to middle Pleistocene age is suggested by development of stage II to III calcic paleosols on fan surfaces, characterized by calcium-carbonate coatings on clasts in a loose matrix with dispersed calcium carbonate; exposed thickness as much as 150 feet (45 m).

Qap$_1$, Qap$_2$ — **Pediment-mantle alluvium** (upper to middle Pleistocene) – Poorly to moderately well-sorted sand, silt, clay, and pebble to boulder gravel that forms a thin veneer on gently sloping erosional surfaces; subscript denotes relative height above modern stream channels; level-1 deposits are less than 100 feet (30 m) above modern drainages and are mapped near Barneys Canyon, overlying Qafo, and near Clay Hollow in the northwest corner of the quadrangle, overlying the Tertiary Salt Lake Formation (Tsl) and QTaf; level-2 deposits are as much as 300 feet (90 m) above modern drainages and are mapped overlying QTaf at the foot of the Oquirrh Mountains from Barneys Canyon northward to Harkers Canyon in the adjacent Magna quadrangle (Solomon and others, in press); level-1 deposits are younger than level-2 deposits, grade to the Bonneville shoreline, and are equivalent to pediment number 3 of Slentz (1955); level-2 deposits are equivalent to both pediment numbers 1 and 2 of Slentz (1955), which are approximately the same age and are assigned to the same unit on our map; as much as about 15 feet (5 m) thick.

Artificial deposits

Qf — **Artificial fill** (historical) – Engineered fill used in the construction of road and railroad embankments crossing drainages in the Oquirrh Mountains foothills, and for the Barneys Canyon heap-leach operation; a large area of fill is also mapped south of the Old Bingham Highway at the east edge of the quadrangle; unmapped fill may be present in any developed area; typically less than about 40 feet (12 m) thick.

Qfd — **Disturbed land** (historical) – Land disturbed by sand, gravel, aggregate, and mining and mining reclamation operations; only the larger operations are mapped and their outlines are based on aerial photographs taken in July and October 1997; land within these areas contains a complex, rapidly changing mix of cuts and fills; most operations along the Oquirrh Mountains range front between Barneys and Harkers Canyon are extracting material from Quaternary and Tertiary alluvial-fan deposits (QTaf) beneath a thin cover of Lake Bonneville sediments and some contain excellent exposures of the underlying Jordan Narrows unit of the Tertiary Salt Lake Formation (Tsl); the operation northeast of Copperton near the New Bingham Highway (State Route 48) has exposed a thick sequence of topset and foreset beds related to the Bonneville (transgressive) phase of the Bonneville lake cycle; the large area in section 28, T. 3 S., R. 2 W., just east of the old Lark townsite, is an old mine tailings area.

Qfl — **Landfill** (historical) – The Trans-Jordan Sanitary Landfill is an active disposal site for municipal waste and other debris, placed in an abandoned sand and gravel pit south of Bingham Creek near the center of the quadrangle; variable thickness up to several tens of feet.

Qfm — **Mine Dumps** (historical) – Extensive deposits of waste rock from the Kennecott Copper mine are present along the Oquirrh Mountains front from Butterfield Canyon to Bingham Canyon; variable thickness up to several hundred feet (100+ m).

Qfo — **Ore leach piles** (historical) – Ore from the Barneys Canyon and Melco mines that is part of a leach-pad operation at the mouth of Barneys Canyon; overlies engineered, lined pads; ore piles generally 100 to 150 feet (30-45 m) thick.

Colluvial deposits

Qc — **Colluvial deposits** (Holocene to upper Pleistocene) – Poorly to moderately sorted, angular, clay- to boulder-size, locally derived sediment deposited by rock fall, slopewash, and soil creep on moderate slopes and in shallow depressions; most bedrock is covered by at least a thin veneer of colluvium, and only the larger, thicker deposits are mapped; maximum thickness about 20 feet (6 m).

Lacustrine deposits

Regressive-phase deposits of the Bonneville lake cycle.

Qlgp — **Lacustrine gravel and sand related to the Provo (regressive) phase of the Bonneville lake cycle** (upper Pleistocene) – Moderately well-sorted, moderately to well-rounded, clast-supported, pebble to cobble gravel and pebbly sand deposited at and below the Provo shoreline; thin to thick bedded; typically interbedded with, or laterally gradational to, lacustrine sand and silt; gastropods locally common in sandy lenses; locally partly cemented with calcium carbonate. Lake Bonneville occupied the Provo shoreline from about 16,800 to 13,500 calendar years B.P. (calendar-calibrated age for the start of the Provo shoreline from D.R. Currey, University of Utah, written communication to Utah Geological Survey [1996]; calendar-calibrated age for the end of the Provo shoreline obtained from data in Godsey and others [2005]) (table 1). The most extensive deposits form beaches along the Provo shoreline; forms cuspate barrier beach formed by converging currents of Lake Bonneville, called V-bars by Gilbert (1890), along the Provo shoreline; Eardley and others (1957) named the largest the "Evaporating Ponds spit" because it was once used by Kennecott Utah Copper as containment for an evaporating pond; this barrier beach lies mostly in the adjacent Midvale quadrangle (Davis, 2000), where Currey (1982) measured the altitude of the Provo shoreline at about 4813 feet (1467 m), but the gravelly northern limb extends into the eastern edge of the Copperton quadrangle in South Jordan; as much as 25 feet (8 m) thick.

Qlsp — **Lacustrine sand and silt related to the Provo (regressive) phase of the Bonneville lake cycle** (upper Pleistocene) – Fine- to coarse-grained lacustrine sand and silt with minor gravel deposited at and below the Provo shoreline; grades downslope to finer grained Lake Bonneville deposits; typically thick bedded and well sorted; gastropods locally common; forms the south limb of the large cuspate barrier beach in South Jordan and additional deposits downslope; as much as 50 feet (15 m) thick.

Transgressive-phase deposits of the Bonneville lake cycle.

Qlgb — **Lacustrine gravel and sand related to the Bonneville (transgressive) phase of the Bonneville lake cycle** (upper Pleistocene) – Moderately to well-sorted, moderately to well-rounded, clast-supported, pebble to cobble and rare boulder gravel and pebbly sand deposited between the Bonneville and Provo shorelines; thin to thick bedded; typically interbedded with, or laterally gradational to, lacustrine sand and silt; gastropods locally common in sandy lenses; locally partly cemented with calcium carbonate; forms a beach intermittently along the Bonneville shoreline at elevations between about 5175 to 5200 feet (1580-1585 m) near the base of the Oquirrh Mountains; also forms large spits south of Bingham Creek and north of Rose Creek, and small barrier beaches on deltaic deposits between Clay Hollow and Harkers Canyon. Lake Bonneville rose to its highest level, the Bonneville shoreline, about 18,000 calendar years B.P. (D.R. Currey, University of Utah, written communication to Utah Geological Survey, 1996), and overflowed its threshold intermittently until about 16,800 calendar years B.P. when the threshold failed and the lake fell to the Provo level (table 1). Thickness uncertain, but likely less than about 40 feet (12 m).

Qlsb — **Lacustrine sand and silt related to the Bonneville (transgressive) phase of the Bonneville lake cycle** (upper Pleistocene) – Fine- to coarse-grained lacustrine sand and silt with minor gravel deposited between the Bonneville and Provo shorelines; grades downslope to finer grained Lake Bonneville deposits; typically thick bedded and well sorted; gastropods locally common; forms extensive deposits in the east part of the quadrangle; as much as 50 feet (15 m) thick where sand and silt fill paleotopographic lows east of Clay Hollow, but thinner elsewhere.

Qlmb — **Lacustrine silt and clay related to the Bonneville (transgressive) phase of the Bonneville lake cycle** (upper Pleistocene) – Calcareous silt, clay, and minor fine-grained sand deposited between the Bonneville and Provo shorelines; typically laminated or thin bedded; grades upslope into lacustrine sand and silt; mapped between Bingham Creek and Riverton in the southeast part of the quadrangle; the thickness of this unit cannot be determined from map relationships, but the expected maximum thickness is about 50 feet (15 m).

Qldb — **Deltaic deposits related to the Bonneville (transgressive) phase of the Bonneville lake cycle** (upper Pleistocene) – Moderately to well-sorted, moderately to well-rounded, clast-supported, pebble and cobble gravel in a sand matrix; thin to thick bedded; locally partly cemented with calcium carbonate; mapped at the mouths of some abandoned drainages between Clay Hollow and Harkers Canyon; commonly associated with small gravel barrier beaches (Qlgb) at and slightly below the Bonneville shoreline; may include topset alluvium undifferentiated at the map scale; maximum thickness about 40 feet (12 m).

Undivided deposits of the Bonneville lake cycle.

Qlgbp — **Lacustrine gravel and sand of the Bonneville lake cycle, undivided** (upper Pleistocene) – Moderately to well-sorted, moderately to well-rounded, clast-supported, pebble to cobble gravel and pebbly sand; deposited at and below the Provo shoreline, where transgressive- and regressive-phase deposits cannot be differentiated and deposits cannot be directly correlated with regressive-phase shorelines; thin to thick bedded; typically interbedded with, or laterally gradational to, lacustrine sand and silt; locally partly cemented with calcium carbonate; mapped north of Bingham Creek in the northeast part of the quadrangle; may be as much as 75 feet (25 m) thick.

Qlmbp — **Lacustrine silt and clay of the Bonneville lake cycle, undivided** (upper Pleistocene) – Calcareous silt, clay, and minor fine-grained sand deposited below the Provo shoreline; typically laminated or thin bedded; ostracodes locally common; grades upslope into lacustrine sand and silt; mapped in the east part of the quadrangle; may be as much as 75 feet (25 m) thick.

Qll — **Lagoon-fill deposits** (upper Pleistocene) – Silt and clay, with minor fine-grained sand and pebbles; underlies level, grass-covered fields in closed depressions behind Lake Bonneville barrier beaches formed during the transgressive phase of Lake Bonneville; mapped south of Bingham Creek near the center of the quadrangle; maximum thickness about 20 feet (6 m).

Mass-movement deposits

Qmsh — **Historical landslide deposits** (historical) – A small landslide in mine-dump deposits above Keystone Gulch; maximum thickness about 20 feet (6 m).

Qmsy — **Younger landslide deposits** (historical to upper Pleistocene) **–** Very poorly sorted, clay- to boulder-size gravel in a matrix of silt, sand, clay, and pebbles; grain size and texture varies with the nature of the deposits in the source area; mapped in the Barneys Canyon area and in Butterfield Canyon; surfaces of rupture are in older block and ash flow tuff (Tvbo) and lava flows (Tvfou) and older alluvial-fan deposits (Qafo); younger landslide deposits are characterized by moderately subdued landslide features suggestive of Holocene or late Pleistocene age; older landslide deposits are not recognized in this quadrangle, but are mapped in the Traverse Mountains to the south (Biek and others, 2005; Biek, 2005a, 2005b); thicknesses of the deposits are highly variable.

Qmfh — **Debris-flow deposit** (historical) – Very poorly sorted, subangular, cobble- to boulder-size gravel in a matrix of silt, sand, clay, and pebbles; derived from mine-dump deposits and mapped in the upper reaches of Castro Gulch; probably less than 10 feet (3 m) thick.

Mixed-environment deposits

Qac — **Alluvial and colluvial deposits** (Holocene to upper Pleistocene) – Poorly to moderately sorted, generally poorly stratified, clay- to boulder-size, locally derived sediment deposited in swales, small drainages, and the upper reaches of larger ephemeral streams by fluvial, rock-fall, slopewash, and creep processes; mapped in a few drainages north of Bingham Canyon; generally less than 30 feet (9 m) thick.

Qaco — **Older alluvial and colluvial deposits** (upper to middle Pleistocene) – Poorly to moderately sorted, generally poorly stratified, clay- to boulder-size, locally derived sediment deposited in swales, small drainages, and the upper reaches of larger ephemeral streams by fluvial, rock-fall, slopewash, and creep processes; forms isolated remnants deeply incised by adjacent streams in the southwest part of the quadrangle; generally less than 30 feet (9 m) thick.

Qmtc — **Talus and colluvial deposits** (Holocene to middle Pleistocene) – Very poorly sorted, angular to subangular cobbles and boulders and finer grained interstitial sediment deposited principally by rock fall and slopewash on and at the base of steep slopes; typically grades downslope from talus to colluvial deposits; mapped on the north side of Shaggy Peak; generally less than 30 feet (9 m) thick.

Stacked-unit deposits

Qc/Tvfou — **Colluvial deposits over older lava flows, undivided** (Holocene/late Eocene) – Mapped along Butterfield Creek where colluvium derived from level-2 terrace deposits (Qat$_2$) conceals underlying older lava flows; colluvial cover typically less than about 15 feet (5 m) thick.

Qc/IPobp — **Colluvial deposits over the Butterfield Peaks Formation** (Holocene/Middle Pennsylvanian) – Mapped along Butterfield Creek where colluvium derived from older alluvial-fan deposits (Qafo) conceals underlying quartzitic sandstone of the Butterfield Peaks Formation; colluvial cover typically less than about 15 feet (5 m) thick.

Qlgb/Qafo — **Lacustrine gravel and sand related to the Bonneville (transgressive) phase of the Bonneville lake cycle over older alluvial-fan deposits** (upper Pleistocene) – Older alluvial-fan deposits partly concealed by a discontinuous veneer of sediment reworked by Lake Bonneville wave action; closely spaced, well-preserved shorelines are common on the steeper, upper parts of fans, but are less well developed lower on the fans where lacustrine deposits are finer grained and thicker; mapped on piedmont slopes between Rose Canyon and Barneys Creek; surficial deposits are generally less than 10 feet (3 m) thick.

Qlgb/QTaf — **Lacustrine gravel and sand related to the Bonneville (transgressive) phase of the Bonneville lake cycle over oldest alluvial-fan deposits** (upper Pleistocene) – Oldest alluvial-fan deposits partly concealed by a discontinuous veneer of sediment reworked by Lake Bonneville wave action; closely spaced, well-preserved shorelines are common; mapped on piedmont slopes between drainages from Barneys and Harkers Canyons, where irregular landscape below the Bonneville shoreline reflects buried topography of fan deposits; surficial deposits are generally less than 10 feet (3 m) thick.

unconformity

QUATERNARY-TERTIARY

QTaf — **Oldest alluvial-fan deposits** (middle Pleistocene to upper Miocene[?]) – Poorly to moderately well-sorted, weakly to non-stratified sand, silt, and pebble to boulder gravel deposited principally by debris flows; thin to thick beds of white to light gray tuff and tuffaceous sediments near the base of the unit indicate a gradational contact with the underlying Jordan Narrows unit of the Tertiary Salt Lake Formation (Tsl), which is consistently overlain by the oldest alluvial-fan deposits; mapped as part of the informally named Harkers fanglomerate by Slentz (1955); erosionally resistant fan remnants form steep, deeply dissected foothills in the Oquirrh Mountains north of Bingham Canyon; the unit is separated from the Lower Permian to Upper Pennsylvanian Kessler Canyon Formation (PIPok) by the Harkers fault, a range-front normal fault with at least several hundred feet of down-to-the-east movement of at least Miocene age and possibly as young as middle Pleistocene; may be undifferentiated from overlying alluvial-fan deposits where the latter are mapped in deeply incised stream channels downslope from outcrops of QTaf; glass-shard analyses of samples C51104-1 and C51804-2 suggest a chemical correlation to the 6.4 ± 0.1 Ma Walcott Tuff; a late to middle Pleistocene age for the youngest part of the unit is suggested by development of a stage IV calcic paleosol on fan surfaces, characterized by an indurated matrix cemented with laminated calcium carbonate; exposed thickness as much as 350 feet (100 m).

TERTIARY

Salt Lake Formation (Pliocene to Miocene)

Tsl — **Jordan Narrows unit** – White to light-gray tuffaceous marlstone and micrite, lesser claystone, sandstone, and rhyolitic tuff, and minor limestone that is locally cherty or oolitic; part of the Jordan Narrows unit of Slentz (1955); poorly and incompletely exposed, but locally well exposed along road cuts and in sand and gravel pits; upper contact with Late Tertiary/Quaternary alluvial-fan deposits is gradational, and we have restricted Salt Lake strata to non-conglomeratic beds; probably deposited principally in a lacustrine environment (see, for example, Slentz, 1955); Bryant and others (1989) reported a fission-track age of 4.4 ± 1.0 Ma for a rhyolitic tuff in the reclaimed Pioneer pit in the SW1/4 section 11, T. 2 S., R. 2 W.; the total thickness is unknown along the west side of Salt Lake Valley; exposed thickness probably 300 to 500 feet (90-150 m).

unconformity

Volcanic and intrusive rocks of the Bingham district

Waite (1996) and Waite and others (1997) divided igneous rocks of the Bingham district into four informal yet distinct compositional suites: (1) younger volcanic suite, (2) older volcanic suite, (3) nepheline minette-shoshonite suite within the upper part of the older volcanic suite, and (4) Bingham intrusive suite. Parts of the older volcanic suite, Bingham intrusive suite, and younger volcanic suite are mapped in the Copperton quadrangle. Waite (1996), Pulsipher (2000), and Maughan (2001) described field and chemical characteristics of the older and younger volcanic suites based principally on observations in the Rose Canyon area in the adjacent Tickville Spring quadrangle. Moore (1973), Swensen (1975a), and Biek and others (2005) also provided descriptions of many of the units below. See Clark and Biek (2017) for major and trace element whole-rock analyses of samples collected during this project (available at the Utah Geological Survey Web site http:/ugspub.nr.utah.gov/publications/open_file_reports/ofr-665/ofr-665.pdf).

Younger volcanic suite

Volcanic and intrusive rocks of the west Traverse Mountains, generally south and east of Rose Canyon in the adjacent Tickville Spring quadrangle, are part of the younger volcanic suite of Waite (1996) and Waite and others (1997), which is mostly several million years younger than the Bingham intrusions and older volcanic suite.

Tisp — **Rhyolite plug of Shaggy Peak** (upper Eocene) – Light- to medium-gray porphyritic rhyolite in two main phases (Swensen, 1975a): (1) a border phase with abundant 0.04- to 0.08-inch- (1-2 mm) size subhedral to euhedral plagioclase, smoky quartz, and biotite phenocrysts and with well-developed, locally chaotic, but typically near-vertical flow foliations, and (2) an interior phase with slightly larger phenocrysts and little or no evidence of flow foliation. Forms a volcanic neck or plug that intrudes volcanic block and ash flow tuffs and flows of the older volcanic suite; yielded two K-Ar ages on biotite of 32.0 ± 1.0 and 34.1 ± 0.9 Ma (Moore and others, 1968) and a new $^{40}Ar/^{39}Ar$ plateau age of 35.49 ± 0.13 Ma on sanidine (Biek and others, 2005).

Older volcanic suite

Petrographic, geochemical, and age data indicate that rocks of the older volcanic suite are largely comagmatic with the Bingham intrusive complex (Waite, 1996) and contain significantly higher chromium concentrations than the younger volcanic suite (Pulsipher, 2000).

Tvbo — **Older block and ash flow tuff** (upper Eocene) – Gray to white, locally well bedded in medium to thick lenticular beds, but commonly massive, block and ash flow tuff; polylithic with subangular to subrounded pebbles to large boulders of mostly dacite, andesite, latite, and trachydacite composition in a matrix of lithic and crystal fragments; locally contains mostly mafic clasts; contains thin discontinuous lava flows of similar composition; typically forms poorly exposed slopes covered by lag of resistant volcanic clasts, but excellent exposures are present in the adjacent Tickville Spring quadrangle; erupted from the Bingham intrusive complex (Waite, 1996; Waite and others 1997); Deino and Keith (1997) reported an $^{40}Ar/^{39}Ar$ plateau age of 39.18 ± 0.11 Ma on biotite from a latite clast (their sample Tick-23) in a debris avalanche flow near the base of the unit; Maughan (2001) reported an $^{40}Ar/^{39}Ar$ plateau age of 38.68 ± 0.13 Ma on sanidine from a waterlain tuff (his sample Tick-113) near the top of the section at the head of Water Fork; thickness may exceed 4000 feet (1200 m) between Butterfield and Rose Canyons.

Tvfou — **Older lava flows, undivided** (upper Eocene) – Dark-gray lava flows classified as borderline dacite, trachydacite, latite, and andesite on the TAS diagram of LeBas and others (1986); may locally include small areas of volcanic block and ash flow tuffs, especially between Butterfield and Dry Canyons where exposures and access are limited; derived from the Bingham intrusive complex; exposed thickness likely exceeds 1000 feet (300 m).

Bingham intrusive suite

Tiu — **Older intrusive rocks, undivided** (upper Eocene) – Denotes two distinct rock types in exposures northwest of Copperton: (1) partly altered, medium-gray to greenish-gray, fine-grained trachydacite exposed in northeast-trending dikes, and (2) a deeply weathered, light-gray, plug-like mass of probable dacitic composition, with common phenocrysts of bronze-colored biotite and hornblende altered to chlorite in a fine-grained, chalky weathering matrix.

Til — **Dacite plug of Lark** (upper Eocene) – Light- to medium-gray dacite porphyry with abundant plagioclase and euhedral biotite phencrysts and fewer smaller hornblende phenocrysts in a fine-grained groundmass; typically weathers to grussy soils; Midas Gulch exposure is highly altered and weathers to greenish-gray clayey soils; exposed at the former Lark townsite, and in isolated exposures north in Midas Gulch and south to Butterfield Canyon; a sample from the Bingham tunnel portal yielded K-Ar ages of 36.9 ± 1.0 Ma on biotite and 36.9 ± 0.9 Ma on hornblende (Moore and others, 1968).

Tibc — **Sills of Butterfield Canyon** (upper Eocene) – Greenish-gray to dark-gray dacite to latite porphyry with abundant plagioclase and hornblende phenocrysts and fewer, smaller biotite phenocrysts; locally deeply weathered and yellowish brown; two samples collected for this study are dacite on the TAS diagram of LeBas and others (1986), but plot near the common intersection of the andesite, dacite, trachydacite, and latite fields; Deino and Keith (1997) and Pulsipher (2000) called them latite porphyry dikes, but in the Copperton and Tickville Spring quadrangles, most appear to be subparallel to bedding in the Butterfield Peaks Formation and therefore most are properly termed sills (see also Moore, 1973); Pulsipher (2000) reported rare, microscopic sapphire crystals from these rocks; Stavast (2002) reported on magmatic sulfides preserved in the quenched margins of the sills and dikes, and reasoned that they were emplaced at relatively shallow depth, probably less than 1000 feet (300 m); typically best exposed near ridge crests and commonly partly covered by colluvium on adjacent slopes; sills vary from 0 to about 400 feet (0-120 m) thick; yielded $^{40}Ar/^{39}Ar$ plateau age of 38.84 ± 0.19 Ma on plagioclase (Deino and Keith, 1997, sample Bing-6).

Tv — **Volcanic rocks of the Bingham district and west Traverse Mountains, undivided** (Oligocene and Eocene) – Used on cross section only. May include Paleogene basin-fill deposits.

unconformity

TERTIARY and CRETACEOUS, undivided

TKc — **Conglomerate** (Paleocene to Upper Cretaceous) – Silica-cemented, ledge-forming, pebble to small boulder conglomerate; clasts are subangular to subrounded quartzitic sandstone and calcareous sandstone; lacks volcanic clasts (and is locally overlain by Eocene volcanics in the adjacent Tickville Spring and Magna quadrangles) and so predates Eocene-Oligocene volcanism; mapped in the lower reaches of Castro Gulch where it is about 50 feet (15 m) thick; age uncertain, but likely Late Cretaceous to early Tertiary.

unconformity

PERMIAN and PENNSYLVANIAN

Rogers Canyon Sequence

Defined by Tooker and Roberts (1970) to include folded, upper-plate strata of the North Oquirrh thrust.

Oquirrh Group

PIPok — **Kessler Canyon Formation** (Lower Permian to Upper Pennsylvanian) – Thin- to medium-bedded, yellowish-brown quartzitic sandstone and calcareous and dolomitic sandstone, and minor light-gray dolomitic limestone sedimentary breccia and yellowish-brown sandy limestone; incompletely exposed in the extreme northwest corner of the quadrangle; poorly constrained age from Gordon and Duncan (1970); upper and lower contacts not exposed in this quadrangle, but Tooker and Roberts (1970) reported that the total thickness of the formation is probably in excess of 4300 feet (1300 m) in the adjacent Farnsworth Peak (formerly Garfield) quadrangle.

Bingham Sequence

Originally defined by Tooker and Roberts (1970) to include only folded upper-plate strata of the Midas thrust; redefined by Swensen (1975a) to include upper- and lower-plate rocks of the Midas thrust and lower-plate rocks of the North Oquirrh thrust.

PERMIAN

Pkdc — **Kirkman Limestone and Diamond Creek Sandstone, undivided** (Lower Permian) – Small exposure mapped near the head of Barneys Wash in the Copperton quadrangle consists of highly altered fine-grained sandstone of yellowish-brown, reddish-brown, and white hues that probably belongs to the Diamond Creek Sandstone and sedimentary limestone breccia that may represent poorly developed Kirkman Limestone; Swensen (1975a) reported that the complexity of discontinuous beds and intraformational breccia precludes separation and accurate thickness measurements of the two formations in the Bingham district, but collectively they are about 2000 feet (600 m) thick in the north Oquirrh Mountains.

Pfp — **Freeman Peak Formation** (Lower Permian [Wolfcampanian]) – Yellowish-brown to grayish-brown, very fine to fine-grained quartzitic sandstone, calcareous sandstone, and minor siltstone; typically medium to thick bedded in laterally continuous, planar beds with faint, planar laminae and low-angle ripple cross stratification; typically forms poor, colluvium-covered slopes west of Copperton on the northeast-plunging nose of the "Copperton overturn" (overturned anticline), but excellent exposures are present along new pipeline west of Copperton in the SW1/4SW1/4 section 7 and NW1/4NW1/4 section 18, T. 3 S., R. 2 W.; upper contact not exposed in the Copperton quadrangle; age from Welsh and James (1961); Swensen (1975a) reported the formation is 2400 feet (730 m) thick at Freeman Peak in the Bingham Canyon quadrangle.

Pcp — **Curry Peak Formation** (Lower Permian [Wolfcampanian]) – Similar to the Freeman Peak Formation, but Swensen (1975a) reported that it is typically thinner bedded, has abundant worm tracks on bedding surfaces, and contains three silty limestone and calcareous sandstone marker beds; upper contact placed at the base of a thin, yellowish-brown, chert-pebble conglomerate as much as a few feet thick; age from Welsh and James (1961); lower part not exposed in the Copperton quadrangle, but Swensen (1975a) reported the formation is 2450 feet (750 m) thick at Curry Peak in the Bingham Canyon quadrangle.

PENNSYLVANIAN

Oquirrh Group (Upper Pennsylvanian) – Divided into, in ascending order, the West Canyon Limestone, Butterfield Peaks Formation, and Bingham Mine Formation, which are part of the Bingham sequence of Tooker and Roberts (1970); only parts of the Butterfield Peaks and Bingham Mine Formations are exposed in this quadrangle; best exposed along or just below ridge crests, but elsewhere, slopes are commonly covered by a veneer of colluvium and talus not practical to map at a scale of 1:24,000; ages from Gordon and Duncan (1970), Douglas and others (1974), and Davis and others (1994); the group is in excess of 17,800 feet (5400 m) thick in the Oquirrh Mountains (Tooker and Roberts, 1970) and about 25,000 feet (7600 m) thick near Mt. Timpanogos (Baker, 1964).

Bingham Mine Formation (Upper Pennsylvanian [Missourian and Virgilian]) – Concealed by mine dumps except for part of the Jordan limestone, which marks the base of the formation; upper contact is exposed west of the mapped area where it corresponds to the base of a thin, discontinuous, chert-pebble conglomerate bed that marks the base of the Curry Peak Formation (Swenson, 1975a); the formation is about 7300 feet (2200 m) thick in the Oquirrh Mountains (Tooker and Roberts, 1970).

IPobmj — **Jordan Limestone** – Thin- to medium-bedded, medium- to dark-gray, sandy, silty, and argillaceous limestone with irregular black chert nodules; typically thin to medium bedded and locally fossiliferous with bryozoans, brachiopods, and corals; mapped at the head of Yosemite Gulch, in the southwest corner of the quadrangle; upper part is not exposed; Tooker and Roberts (1970) reported the unit is 361 feet (110 m) thick in the Bingham Canyon quadrangle to the west.

IPobp — **Butterfield Peaks Formation** (Middle Pennsylvanian [Desmoinesian – Atokan]) – Interbedded, brown-weathering, fine-grained quartzitic sandstone and calcareous sandstone, medium-gray, fine-grained sandy limestone, and several limestone intervals; typically cyclically interbedded with several tens of feet of calcareous sandstone capped by gray limestone several feet thick; contains minor siltstone and mudstone interbeds that are very poorly exposed; forms ledgy to cliffy slopes. Calcareous sandstone is typically medium to thick and planar bedded, light brownish gray to medium gray but grayish orange to brown weathering, very fine to fine grained, locally with low-angle and ripple cross-stratification and bioturbation; commonly non-calcareous on weathered surfaces and so appears similar to quartzitic sandstone, but fresh surfaces are invariably calcareous. Quartzitic sandstone is grayish orange pink to light brown, very thick bedded, very fine to fine grained, with faint low-angle cross-stratification and a prominent conchoidal fracture. Limestone intervals, some mapped separately as 'ls' marker beds (**ls**), are typically medium gray, medium to thick bedded, and commonly sandy with very fine to fine-grained sand; fossils include syringoporid and rugose corals, bryozoans, brachiopods, and fossil hash; locally contain irregularly shaped black chert nodules and ribbon chert; commonly grade upward to finer grained, platy weathering limestone and argillaceous limestone. Upper, conformable contact exposed above Yosemite Gulch in the southwest part of the quadrangle where it corresponds to the base of the Jordan Limestone; Tooker and Roberts (1970) reported the formation is about 9000 feet (2750 m) thick in the Oquirrh Mountains.

Geology under the Bingham mine dumps

Geology under the Bingham mine dumps was taken from the Geologic Map of the Bingham District and conforms to pre-mine dump topography (Swensen, 1975b). Paleozoic strata belong to the Bingham Sequence (see descriptions above). Volcanic and intrusive rocks belong to the older volcanic suite and include both lava flows and block and ash flow tuff as described above. The Champion thrust is shown under the dumps, but not on the north side of Bingham Canyon where we could not verify its existence. The sequence of volcanic and intrusive rocks listed below is uncertain.

Qal	Undifferentiated alluvial deposits
Tiu	Undifferentiated sills and dikes
Tvb	Latite breccia with interbedded tuff, sand, and gravel
Tvlb	Latite breccia
Tvlp	Latite
Tvhl	Hornblende latite porphyry
Tilp	Latite porphyry (sill or dike)
Tva	Andesite
Tc	Conglomerate
Pfp	Freeman Peak Formation
Pcp	Curry Peak Formation
IPbmc	Bingham Mine Formation, Clipper member
	Commercial limestone
	Jordan limestone
IPbp	Butterfield Peaks Formation
	lst – limestone marker bed

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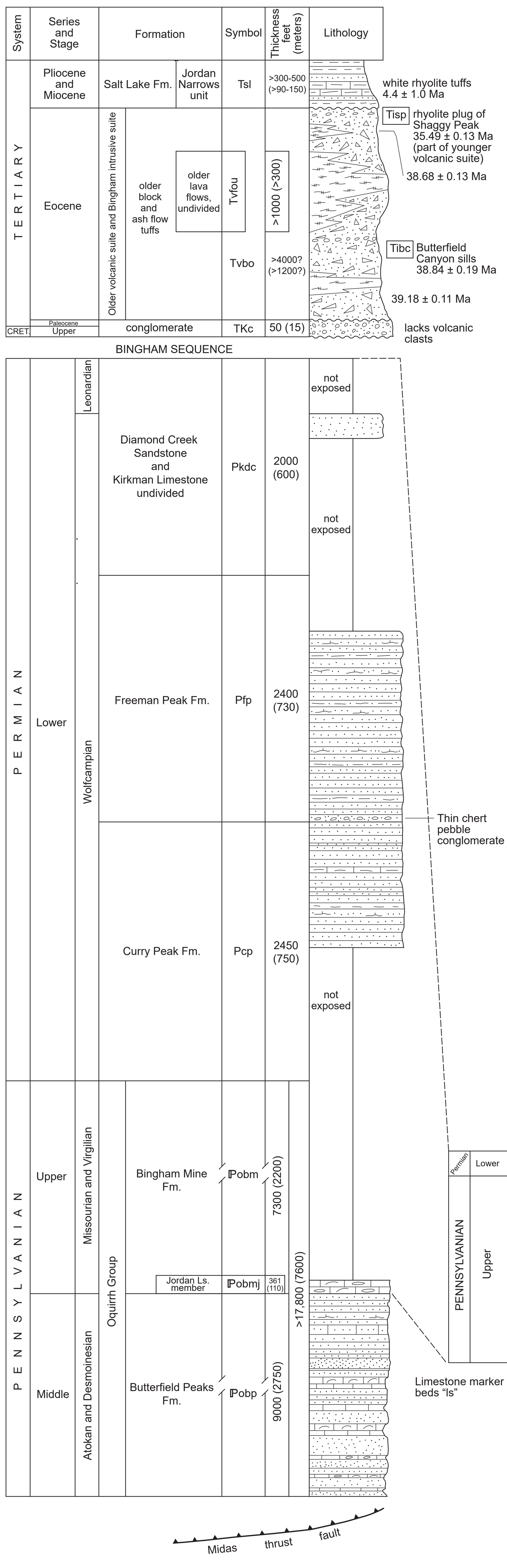
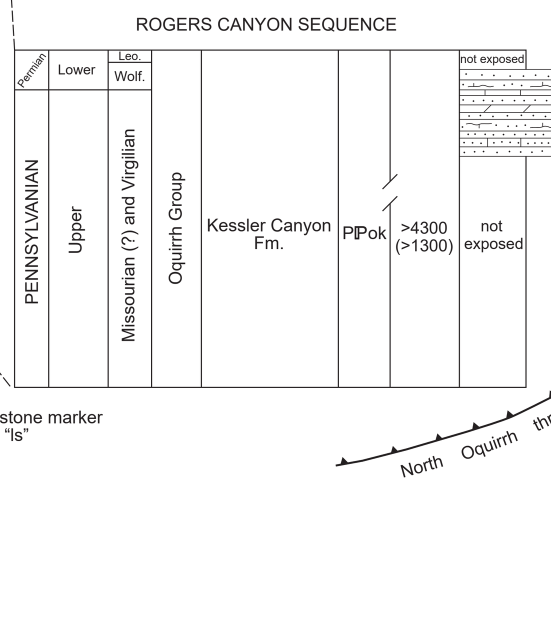
MAP SYMBOLS

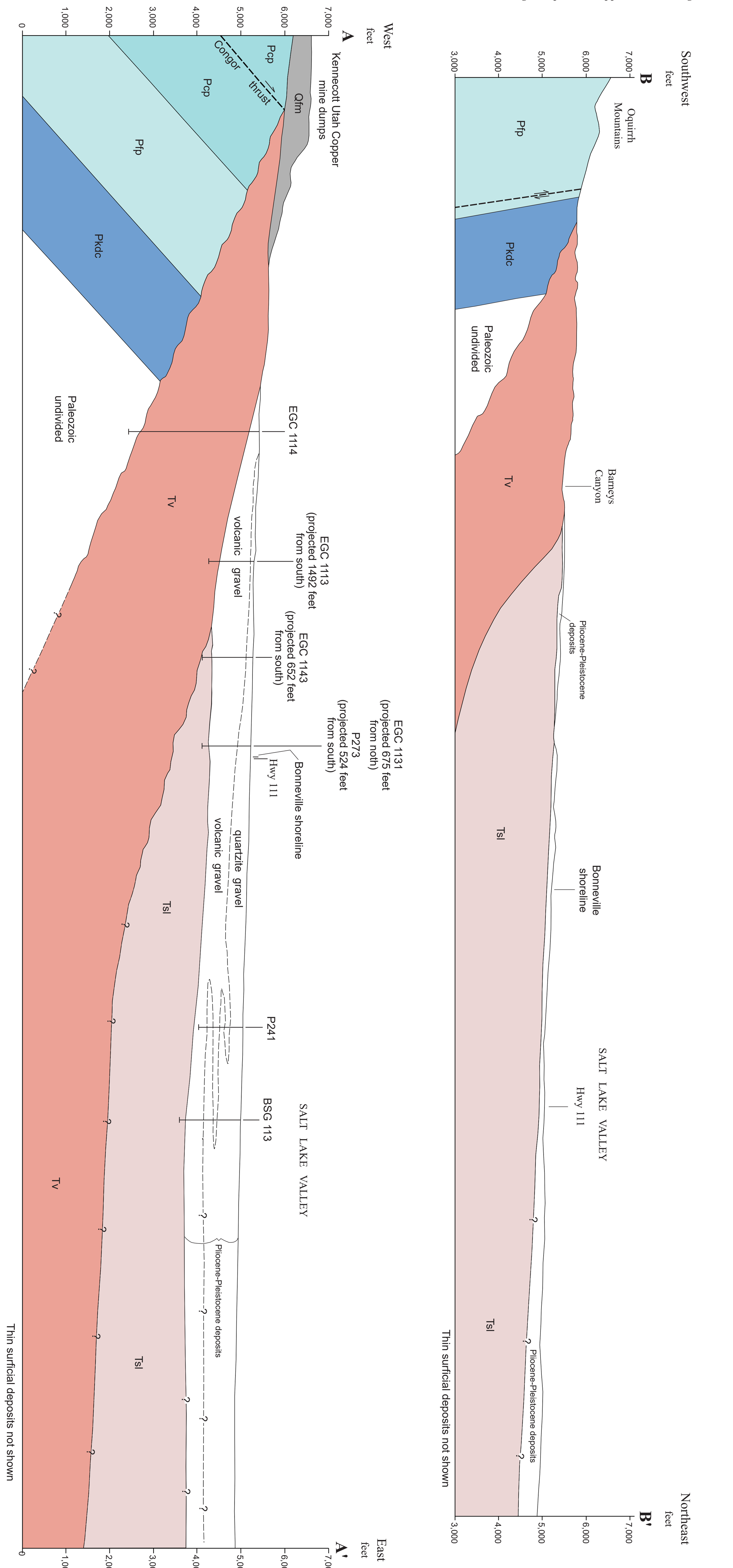
- Contact, dashed where approximately located, dotted where concealed
- Normal fault, dashed where approximately located, dotted where concealed and approximately located; query indicates uncertain presence; bar and ball on down-dropped side
- Thrust fault, dashed where approximately located, dotted where concealed and approximately located; teeth on upper plate
- Axial trace of overturned anticline, dashed where approximately located; arrow indicates direction of plunge
- Major shorelines of the Bonneville lake cycle. Mapped at the top of the wave-cut platform, dashed where approximately located; may coincide with geologic contacts
  - B — Highest shoreline of the Bonneville (transgressive) phase
  - b — Other shorelines of the Bonneville phase – mostly transgressive
  - P — Highest shoreline of the Provo (regressive) phase
  - p — Other shorelines of the Provo phase – mostly regressive shorelines of the Provo phase, but may include some shorelines of the Bonneville (transgressive) phase
- Crest of Lake Bonneville barrier beach or spit
- Landslide scarp, hachures on down-dropped side
- 38 — Strike and dip of inclined bedding
- 70 — Strike and dip of overturned bedding; red symbols are from Swensen (1975b)
- 20 — Approximate strike and dip of inclined bedding
- 60 — Strike and dip of flow foliation in igneous rocks
- Strike of vertical flow foliation in igneous rocks
- Sand and gravel pit
- Adit
- C51804-2 — Sample location and number
- ECG 1114 — Ground water monitoring well

LITHOLOGIC COLUMN



ROGERS CANYON SEQUENCE





CORRELATION OF MAP UNITS

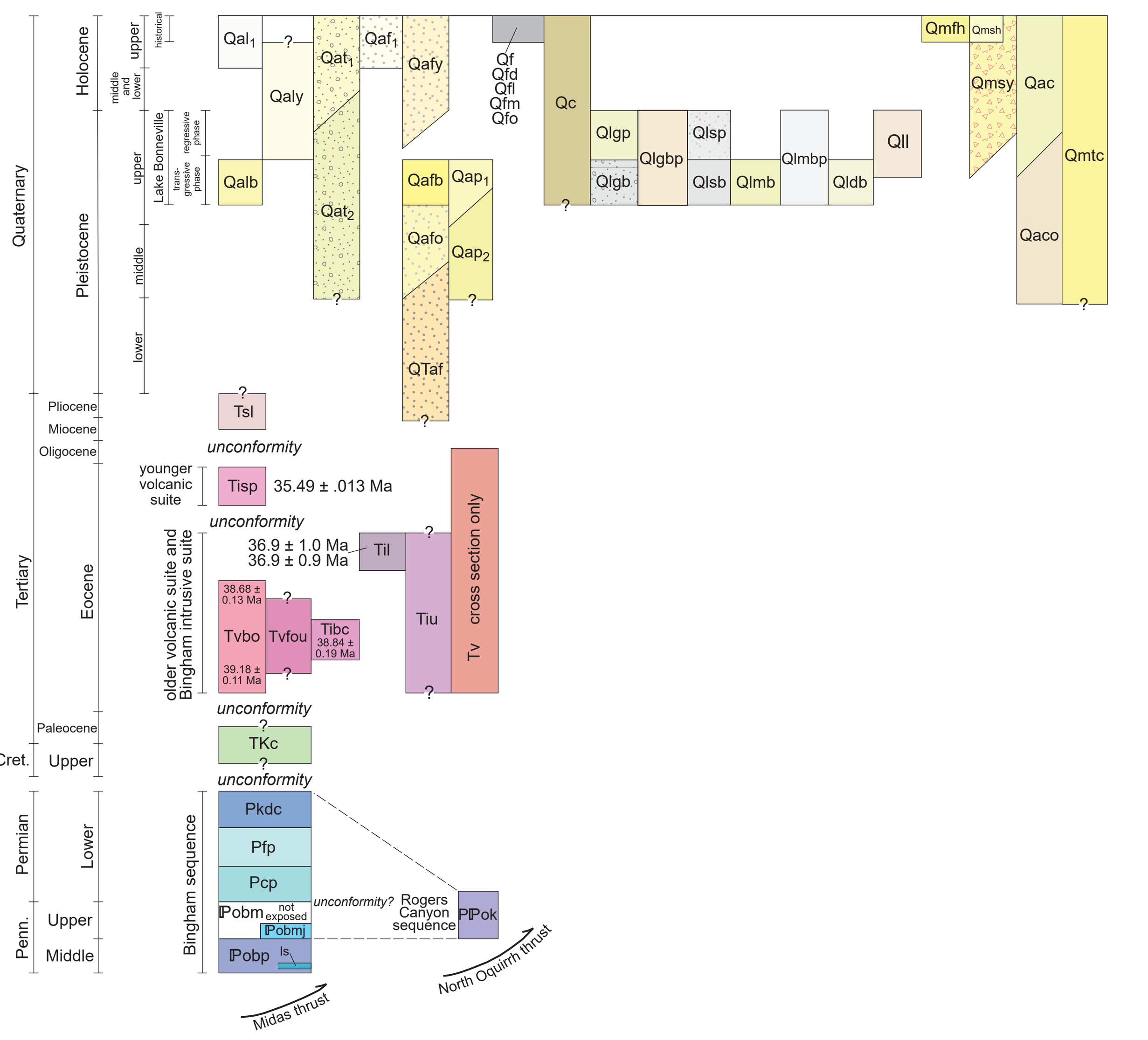
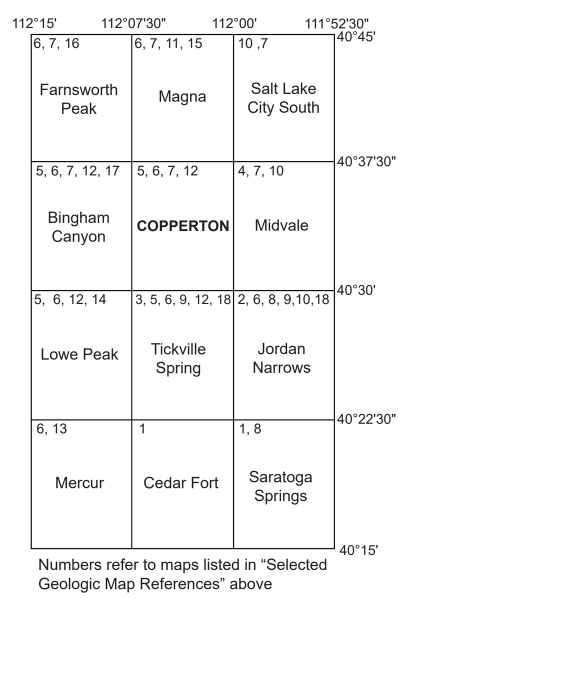


Table 1. Ages of major shorelines of Lake Bonneville and Great Salt Lake and shoreline elevations in the Copperton quadrangle.

Lake Cycle and Phase	Shoreline (map symbol)	Age: radiocarbon years B.P.	Age: calendar years B.P.[1]	Elevation feet (meters)
Lake Bonneville				
Transgressive Phase	Stansbury	22,000-20,000[2]	24,400-23,200	Not exposed
	Bonneville (B) — flood	15,500-14,500[3]	18,000-16,800	5,175-5,200 (1,575-1,585)
Regressive Phase	Provo (P)	14,500-12,000[4]	16,800-13,500[5]	4,790-4,820 (1,460-1,470)
	Gilbert	11,000-10,000[6]	12,800-11,600	Not exposed
Great Salt Lake				
	Holocene highstand	3000-2000[7]	-----	Not exposed

[1]Calendar-calibrated ages of most shorelines have not been published. Calendar-calibrated ages shown here, except for the age of the end of the Provo shoreline, are from D.R. Currey, University of Utah (written communication to Utah Geological Survey, 1996; cal yr B.P. = 1.16 ^{14}C yr B.P.).
[2]Oviatt and others (1990); Currey (written communication to Utah Geological Survey, 1996, assumed a maximum age for the Stansbury shoreline of 21,000 ^{14}C yr B.P., which is used in the conversion to calendar years).
[3]Oviatt and others (1992), Oviatt (1997).
[4]Godsey and others (2005) revised the timing of the occupation of the Provo shoreline and subsequent regression; Oviatt and others (1992) and Oviatt (1997) proposed a range from 14,500 to 14,000 ^{14}C yr B.P. Oviatt and Thompson (2002) summarized many recent changes in the interpretation of the Lake Bonneville radiocarbon chronology.
[5]Calendar-calibrated age of the end of the Provo shoreline estimated by interpolation from data in Godsey and others (2005), table 1, who used Stuiver and Reimer (1993) for calibration.
[6]Murchison (1989), figure 20.
[7]Currey (1990).

INDEX MAP



Numbers refer to maps listed in "Selected Geologic Map References" above