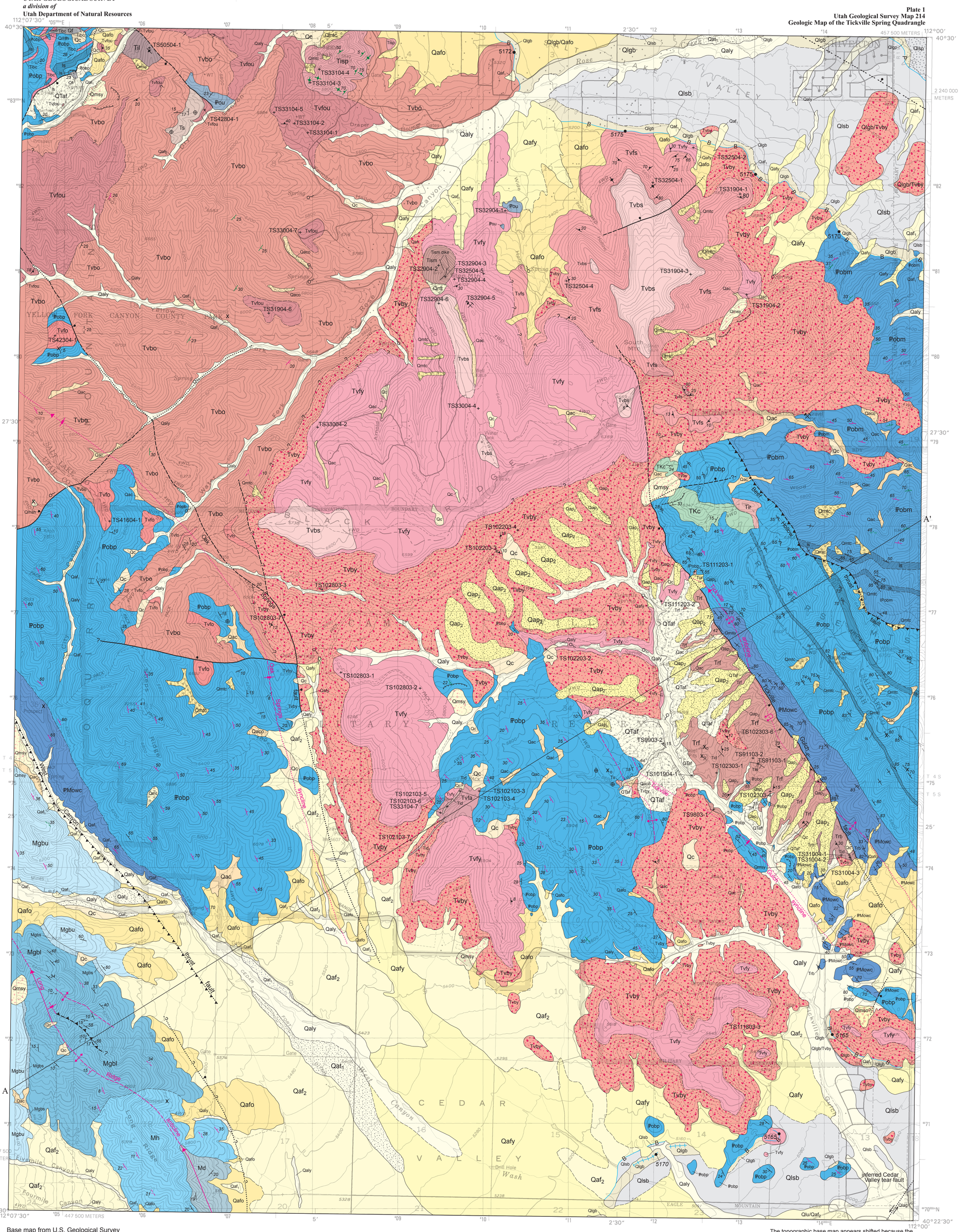
UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources

Plate 1
Utah Geological Survey Map 214
Geologic Map of the Tickville Spring Quadrangle


A
A'
Tickville
Cedar
Valley
inferred Cedar Valley tear fault
syncline
Black
Mountain
Military
Ridge
Long
Ridge
Fivemile
Canyon
Fourmile
Canyon
Yellow
Fork
Canyon
Salt
Lake
Valley
Draper
Rose
Canyon
Wide
Hollow
Bear
Hollow
Wood
Hollow
Gulch
Gulch
Wash
Drill Hole
Wash
Eagle
Mountain
Cedar
Fort
Ranch
Road
Gate
Spring
Springs
Prospect
Mines
Tailings
Pit
Quarry
Gravel
Water tank
Well
Cabin
Ruins
Tailings
Prospect
Mine
Drill Hole
Water tank
Gate
Spring
Springs

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 along the larger stream of Butterfield Creek; 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 flood plains that post-date the Bonneville shoreline of latest Pleistocene Lake Bonneville, which occupied the valley from about 32,000 to 10,000 years ago (Currey and Oviatt, 1985); 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 the smaller streams in the quadrangle; probably less than 20 feet (6 m) thick.*

Qat$_{1,2}$ 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-2 deposits are greater than 30 feet (10 m) above modern drainages and are found between West Canyon and its Left Fork in the southwest part of the quadrangle; level-1 deposits are 10 to 30 feet (3-10 m) above modern drainages and are found along the lower parts of West Canyon Wash and Rose Creek; deposited in stream channels and flood plains; older terraces may include a loess veneer; generally 0 to 20 feet (0-6 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 part of fans 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.*

Qaf$_2$ Level 2 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; forms moderately dissected surfaces incised by modern streams; mapped at the north end of Cedar Valley; level-2 deposits lie mostly above the Bonneville shoreline, incised into and overlying older alluvial-fan deposits (Qafo), but, in the southeast corner of the Tickville Spring quadrangle, level-2 deposits are etched by a poorly developed Bonneville shoreline; in the Cedar Fort quadrangle (Biek, 2004) to the south, equivalent deposits both obscure, and are cut by, the Bonneville shoreline; mostly equivalent to the lower part of Qafy, but may locally be equivalent to alluvial-fan deposits related to the Bonneville (transgressive) phase of the Bonneville lake cycle; probably less than 30 feet (9 m) thick.*

Qafy Young 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; upper parts of fans are locally deeply incised; mapped near the margins of the Oquirrh and Traverse Mountains; probably less than 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; forms deeply dissected alluvial apron near the base of the Oquirrh and Traverse Mountains and probably underlies southwest Salt Lake and northern Cedar Valleys; older alluvial-fan deposits are truncated by, and thus predate, the Bonneville shoreline; Upper to Middle Pleistocene age is suggested by development of stage II or 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$_2$ 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; lower and younger level-1 (Qap$_1$) deposits are mapped in the adjacent Copperton quadrangle (Biek and others, in press); level 2 deposits are typically several tens of feet to as much as 200 feet (60 m) above modern drainages in the Tickville Gulch area; as much as about 15 feet (5 m) thick.*

Artificial deposits

Qf Artificial fill (Historical) – *Engineered fill used in road construction and reclamation north of Butterfield Canyon; unmapped fill of variable composition may be present in any developed area; variable thickness up to about 40 feet (12 m).*

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 (Currey and Oviatt, 1985).

Qlgp Lacustrine gravel and sand related to the Provo (regressive) phase of the Bonneville lake cycle (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 in the northeast corner of the quadrangle; 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; likely less than 20 feet (6 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 in the extreme northeast corner of the quadrangle; typically thick bedded and well sorted; gastropods locally common; grades downslope to finer grained Lake Bonneville deposits off the quadrangle; probably less than 20 feet (6 m) thick in this quadrangle.*

Transgressive-phase deposits of the Bonneville lake cycle (Currey and Oviatt, 1985).

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 the base of the Traverse Mountains; typically less than 20 to 30 feet (6-9 m) thick in this quadrangle.*

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; poorly exposed but probably less than a few tens of feet thick.*

Mass-movement deposits

Qmsh Historical landslide deposit (Historical) – *Very poorly sorted, clay- to boulder-size material deposited by rotational movement in City Canyon at the west edge of the quadrangle; characterized by fresh scarps, hummocky topography, and tilted vegetation; derived from weathered older Tertiary block and ash flow tuff; maximum thickness about 30 feet (10 m).*

Qmsy Younger landslide deposits (Historical to Upper Pleistocene) – *Very poorly sorted, clay- to boulder-size, locally derived material deposited by rotational and translational movement; characterized by moderately subdued landslide features suggesting an early Holocene or Late Pleistocene age, but a densely vegetated rotational landslide in Butterfield Canyon has hummocky topography and a steep main scarp suggesting middle to late Holocene movement; landslides may have historical movement; several other small landslides are scattered throughout the west Traverse Mountains, with surfaces of rupture in Tertiary volcanic rocks, Pennsylvanian Butterfield Peaks Formation, Mississippian Great Blue Formation, and in the Mississippian Manning Canyon Shale exposed immediately west of the Tickville Spring quadrangle in West Canyon; variable thicknesses as much as several tens of feet.*

Qmso? Older landslide deposit (Upper to Middle Pleistocene) – *Very poorly sorted, clay- to boulder-size material deposited by rotational movement; characterized by deeply eroded and subdued topography suggestive of an older landslide, but query indicates uncertain designation; derived from younger block and ash flow tuff near the mouth of Tickville Gulch in the southeast corner of the quadrangle; about 30 feet (10 m) thick.*

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.*

Qmt Talus deposits (Holocene to Upper Pleistocene) – *Very poorly sorted, angular cobbles and boulders and finer-grained interstitial sediment deposited principally by rock fall on and at the base of steep slopes; only a few small, widely scattered deposits are mapped because most talus in the map area is gradational with colluvial deposits and is thus mapped as talus and colluvium undivided (Qmtc); generally less than 20 feet (6 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, slopewash, and creep processes; 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, slopewash, and creep processes; forms isolated remnants deeply incised by adjacent streams in the Rose Canyon and Wood Hollow drainages; 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 throughout the west Traverse Mountains, where it may include minor alluvial sediment at the bottom of the washes; generally less than 30 feet (9 m) thick.*

Qlag Lacustrine and alluvial coarse-grained deposits (Pleistocene) – *Poorly to moderately sorted, clay- to boulder-size sediment deposited principally by debris flows and streams, which is locally overlain by moderately to well-sorted, moderately to well-rounded, clast-supported, pebble to cobble gravel and lesser pebbly sand of the Bonneville lake cycle; typically exhibits well-developed shorelines; mapped at the west end of Beverly Hills in the extreme southeast corner of the Tickville Spring quadrangle where it is impractical to differentiate alluvial-fan, alluvial, and nearshore lacustrine deposits; only about 20 feet (6 m) thick in the Tickville Spring quadrangle, but up to about 60 feet (18 m) thick in the nearby Beverly Hills (Biek, 2004).*

Stacked-unit deposits

Qlu/Qaf$_2$ Undifferentiated deposits of the Bonneville lake cycle over level-2 alluvial-fan deposits (Upper Pleistocene) – *Level 2 alluvial-fan deposits partly concealed by a discontinuous veneer of sediment reworked by Lake Bonneville wave action; mapped in northern Cedar Valley in the southeast corner of the quadrangle; the Bonneville shoreline is weakly etched into distal fan deposits, suggesting that the upper part of the alluvial fan at this location may grade to the shoreline; surficial deposits are generally less than 10 feet (3 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/Upper-Middle 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 north of Rose Canyon at the north margin of the quadrangle; lacustrine deposits are generally less than 10 feet (3 m) thick.*

Qlgb/Tvby Lacustrine gravel and sand related to the Bonneville (transgressive) phase of the Bonneville lake cycle over Tertiary block and ash flow tuff (Upper Pleistocene/Oligocene) – *Block and ash flow tuff near Riverton and east of Tickville Gulch, partly concealed by a discontinuous veneer of sediment eroded and reworked by Lake Bonneville wave action; where lacustrine deposits are thin or absent, the ground surface is commonly covered by a lag of angular to subangular volcanic boulders; surficial deposits are generally less than 10 feet (3 m) thick.*

unconformity

QUATERNARY-TERTIARY

QTaf Oldest alluvial-fan deposits (Middle Pleistocene to late 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 Miocene-Pliocene Salt Lake Formation in Tickville Gulch and in the Copperton quadrangle (Biek and others, in press); mapped in Butterfield Canyon and Tickville Gulch; glass shard analyses of samples TS9903-2 and TS101904-1 (table 1 available at http://geology.utah.gov/) suggest a chemical correlation to the 6.4 ± 0.1 Ma Walcott Tuff; an Upper 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 250 feet (75 m).*

TERTIARY

Volcanic and intrusive rocks of the west Traverse Mountains

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. Volcanic and intrusive rocks of the west Traverse Mountains, generally south and east of Rose Canyon, are part of their younger volcanic suite, which is several million years younger than the Bingham intrusions and older volcanic suite. 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. However, the boundary between these two volcanic suites appears to be within a sequence of similar laharic breccias and no clear mapping contact exists between the units; we place the contact where it locally corresponds to a subtle break in slope. Moore (1973b) and Swensen (1975a) also provided descriptions of many of the units below. See table 2 for major and trace element whole-rock analyses, and table 3 for $^{40}Ar/^{39}Ar$ data, of samples collected during this project. Tables available at http://geology.utah.gov/

Tvbs Volcanic breccia of South Mountain (early Oligocene) – *Well-lithified, distinctive block and ash-fall tuff; plots near the intersection of the dacite, andesite, latite, and trachydacite fields on the TAS diagram of LeBas and others (1986); clasts are dark gray to black, angular to subangular, pebble to large boulder size set in a reddish-brown matrix of devitrified glass and lithic and crystal fragments; clasts typically make up more than 50% of the rock and contain phenocrysts of plagioclase, hornblende, and biotite 0.08 to 0.16 inch (2 to 4 mm) in size set in a dark-gray to black glassy matrix; forms broad, north-sloping surface of South Mountain and isolated exposures atop Black Ridge; likely formed as a collapsed pyroclastic column that erupted from poorly defined vent area at the north end of South Mountain; Moore (1973a) reported a K-Ar age on biotite of 30.7 ± 0.9 Ma from one of the clasts; attains its maximum thickness of nearly 300 feet (90 m) at South Mountain.*

Tvfs Lava flows of South Mountain (early Oligocene) – *Chemically and mineralogically identical to the volcanic breccia of South Mountain but strongly flow foliated with reddish-brown and dark-gray to black layering; underlies South Mountain volcanic breccia with typically subvertical flow foliation suggesting that the South Mountain area, especially its north end, may be the eruptive center of the volcanic breccia of South Mountain (Tvbs); flow foliation is locally poorly developed and reddish-brown color locally lacking; chaotic and steeply dipping flow foliations complicate thickness determinations, but maximum exposed thickness likely exceeds 1000 feet (300 m).*

Tvfy Younger lava flows (early Oligocene) – *Dark-gray to pinkish-gray porphyritic dacite, trachydacite, andesite, and latite lava flows commonly with conspicuous 0.04 to 0.2 inch (1-5 mm) plagioclase phenocrysts and rare to common euhedral biotite and hornblende; locally flow banded; weathers to boulder-covered slopes; probably derived from volcanic centers in the west Traverse Mountains, including Step Mountain, South Mountain, and nearby smaller vents; maximum exposed thickness may exceed 600 feet (180 m).*

Tvby Younger block and ash-flow tuffs (early Oligocene) – *White to light-gray, typically massive, coarse-grained dacitic to andesitic crystal lithic tuff with a diverse assemblage of subangular to subrounded, pebble- to boulder-size volcanic clasts; matrix typically contains abundant feldspar and euhedral biotite, and variable amounts of sand- to pebble-size volcanic fragments; contains uncommon quartzite pebbles in stratigraphically lowest deposits; typically matrix supported and locally shows bedding indicative of laharic or mudflow deposition; volcanic clasts are mostly dark-gray or reddish-gray porphyritic biotite dacite and andesite with abundant feldspar phenocrysts; biotite from a dacite tuff – sample JN22703-1, SW1/4 section 7, T. 5 S., R. 1 W., from near the base of the section in the adjacent Jordan Narrows quadrangle (Biek, 2005) – yielded an $^{40}Ar/^{39}Ar$ plateau age of 31.68 ± 0.24 Ma; Deino and Keith (1997) reported an $^{40}Ar/^{39}Ar$ plateau age on plagioclase (their sample Tick 28) of 32.12 ± 0.14 Ma from a dacite block and ash flow tuff near the base of the section near the head of Oak Hollow; locally includes thin, poorly exposed lava flows of similar composition; forms poorly exposed slopes covered by lag of resistant volcanic clasts; probably derived from volcanic centers in the west Traverse Mountains, including Step Mountain, South Mountain, and nearby smaller vents; maximum thickness is uncertain, but likely exceeds 1000 feet (300 m).*

Trf Rhyolite lava flows of Tickville Gulch (early Oligocene) – *Rhyolite vitrophyre flows that are commonly finely flow-banded in shades of green, pink, white, and less commonly black, and less common but similarly colored rhyolite vitrophyre flow breccia; contains phenocrysts of biotite and plagioclase in a glassy groundmass; plagioclase commonly altered to clay and locally entire flows are altered and chalky with pastel colors of white, pink, rusty orange, and light purple; locally flow foliation is chaotic, but overall flow foliation dips east toward the Tickville Gulch fault; best section is exposed in wash east of Tickville Gulch in the SW1/4SE1/4 section 35, T. 4 S., R. 2 W., where it contains a lens of interbedded block and ash-flow tuff (Tvby) and is cut by a deeply weathered dacite dike (Tid); north end of outcrop belt is of borderline dacitic composition and the relationship between typical rhyolitic lavas and dacitic lava flows (Tvfy) is unclear; probably erupted from concealed vent near Tickville Wash; Moore and others (1968) reported a K-Ar age of 31.2 ± 0.9 Ma for a rhyolite vitrophyre in the NE1/4 section 2, T. 5 S, R. 2 W.; thickness may exceed 1500 feet (460 m).*

Trb Rhyolite flow breccia of Tickville Gulch (early Oligocene) – *Similar to rhyolite lava flows of Tickville Gulch (Trf), but forms a blocky flow breccia; exposed thickness likely about 500 feet (150 m).*

Tvfa Basaltic andesite lava flow (early Oligocene) – *Dark-gray, very fine grained basaltic andesite flow with local volcanic bombs and abundant reddish-brown cinders present in the NE1/4 section 4, T. 5 S., R. 2 W.; pin-point size olivine phenocrysts, altered to iddingsite, are the only phenocrysts visible in hand samples; presumed to be deeply eroded vent area, which is cut by a large dacite dike (Tid) and overlain by younger block and ash-flow tuff (Tvby); sample TS33104-7 yielded a somewhat disturbed $^{40}Ar/^{39}Ar$ whole rock age spectrum of 32.86 ± 0.48 Ma; maximum exposed thickness about 120 feet (35 m).*

Tir Rhyolite plugs (early Oligocene to late Eocene) – *Small, highly altered and chalky-weathering, white to very light yellowish brown rhyolitic intrusions that contain abundant quartz phenocrysts 0.04 to 0.08 inch (1-2 mm) in length, and common but less abundant quartzite xenoliths; feldspar phenocrysts and matrix completely altered to clay, and no mafic minerals are recognizable; intrudes Butterfield Peaks Formation near the head of Wood Hollow and in the southeast corner of section 34, T. 4. S., R. 2 W. west of Tickville Gulch; age uncertain, but likely about 30 to 35 million years old.*

Tid Dacite dikes (early Oligocene to late Eocene) – *Light-gray dacite porphyry with 0.04 to 0.08 inch (1-2 mm) phenocrysts of plagioclase, hornblende, and biotite in a fine-grained matrix; large dike in section 4, T. 5 S., R. 2 W. trends northeast and exhibits subvertical to steeply west-dipping flow foliation and chilled, but not glassy contact that weathers to a slight recess; smaller, northwest-trending dacite dikes are present east of Tickville Gulch; sample TS102103-5, from the larger dike, yielded an $^{40}Ar/^{39}Ar$ age on biotite of 32.05 ± 0.13 Ma; dikes near Tickville Gulch intrude Oligocene Tickville rhyolite lava flows; large dike maintains a fairly uniform width of about 75 to 90 feet (23-27 m), whereas smaller dikes are typically a few feet to about 15 feet (5 m) wide.*

Tia Andesite plug (early Oligocene to late Eocene) – *Dark-gray, fine-grained andesite; forms small plug-like mass that intrudes Butterfield Peaks Formation in upper Tickville Gulch; capped by opalized rock that is about 10 to 15 feet (3-5 m) thick; age uncertain, but probably about 30 to 35 million years old; exposed thickness of andesite is about 200 feet (60 m).*

Tisp Rhyolite plug of Shaggy Peak (late 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) 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 tuff and lava flows of the Bingham Canyon suite; yielded two K-Ar ages on biotite of 32.0 ± 1.0 and 34.1 ± 0.9 Ma (Moore and others, 1968), and sample TS33104-4 yielded an $^{40}Ar/^{39}Ar$ age on sanidine of 35.49 ± 0.13 Ma.*

Tism Andesite plug of Step Mountain (late Eocene) – *Medium-gray andesite porphyry with abundant plagioclase phenocrysts as large as 0.5 inch (1.5 cm) but typically 0.15 to 0.3 inch (4-8 mm) and common but smaller hornblende and minor biotite phenocrysts 0.04 to 0.1 inch (1-3 mm) in size in a medium-grained matrix; forms prominent volcanic neck at mouth of Rose Canyon with two spectacular dikes that exhibit well developed subhorizontal columnar jointing, first interpreted as part of a ring dike by Gilluly (1932); adjacent Step Mountain andesite is only locally jointed; classified as an andesite on the TAS diagram of LeBas and others (1986); sample TS32904-3 yielded an $^{40}Ar/^{39}Ar$ age on biotite of 36.26 ± 0.18 Ma.*

Til Dacite plug of Lark (late Eocene) – *Light- to medium-gray dacite porphyry with abundant plagioclase and euhedral biotite phenocrysts and fewer, smaller hornblende phenocrysts in a fine-grained groundmass; typically weathers to grussy soils; exposed at and near the former Lark townsite in the adjacent Copperton quadrangle, and in an isolated exposure in 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).*

Volcanic and intrusive rocks of the Bingham Canyon suite

Includes volcanic and intrusive rocks that together belong to the older volcanic suite, nepheline minette-shoshonite suite, and intrusive suite of Waite (1996) and Waite and others (1997); petrographic, geochemical, and age data indicate that the older volcanic rocks are largely comagmatic with Bingham intrusive complex (Waite, 1996), and contain significantly higher chromium concentrations than the younger volcanic suite (Pulsipher, 2000). See table 2 for major and trace element whole-rock analyses, of samples collected during this project. Tables available at http://geology.utah.gov/

Tvfo Nepheline minette and shoshonite lava flows (late Eocene) – *Pulsipher (2000) and Maughan (2001) provided detailed descriptions of these rocks in the Rose Canyon area, which are summarized below; both minette and shoshonite flows are typically dark gray and fine grained and difficult to differentiate in poor exposures. Minettes are of two types: (1) minette that contains abundant olivine phenocrysts and less than 1% phlogopite and pyroxene phenocrysts and is classified as basanite on the TAS diagram of LeBas and others (1986) and as a melanephelinite using the LeBas (1989) classification scheme for nephelinitic rocks, and (2) minette that nearly lacks olivine, but has more abundant phlogopite and pyroxene phenocrysts and rare microscopic sapphires and is classified as latite on the TAS diagram of LeBas and others (1986). Shoshonite (potassium-rich basaltic trachyandesite) and olivine latite lava flows contain abundant, small phenocrysts of olivine, pyroxene, and biotite; most exposures reveal oxidized, red, aa-type lava flows. Typically overlies Butterfield Peaks Formation, but locally intercalated with older block and ash-flow tuff; Maughan (2001) reported that the minette forms dikes, plugs, and flows, but limited exposures suggest that most outcrops may be part of a single flow or eruptive event; Deino and Keith (1997) reported a whole-rock $^{40}Ar/^{39}Ar$ plateau age of 37.82 ± 0.14 Ma for a minette lava flow (their sample Tick 43) at the head of Water Fork of Rose Canyon; Moore and McKee (1983) reported an anomalously old K-Ar age of 40.1 ± 0.5 Ma for the minette flow in the NE1/4 section 31, T. 4 S., R. 2 W.; maximum exposed thickness about 150 feet (45 m).*

Ts Lacustrine strata of Dry Canyon (late Eocene) – *Yellowish-brown, brownish-gray, and light-gray, typically thin-bedded and tuffaceous mudstone, siltstone, oncolitic limestone, and volcaniclastic sandstone; locally silicified; deposited in a small lake basin on the lower flanks of the Bingham volcano; exposed thickness about 150 feet (45 m).*

Tvfou Older lava flows, undivided (late 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 tuff, 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).*

Tvbo Older block and ash-flow tuffs (late Eocene) – *Gray to white, locally well bedded in medium to thick lenticular beds, but commonly massive, block and ash flow tuffs; subangular to subrounded pebbles to large boulders of mostly dacite, andesite, latite, and trachydacite composition in a matrix of lithic and crystal fragments, although locally contains mostly mafic clasts; contains thin discontinuous lava flows of similar composition; locally, as on divide between Oak Springs Hollow and Water Fork, contains lenses rich in quartzitic sandstone and calcareous sandstone clasts derived from adjacent Oquirrh Group highlands; typically forms poorly exposed slopes covered by lag of resistant volcanic clasts, but excellent exposures are present in Water Fork and Yellow Fork; 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.*

Tibc Sills of Butterfield Canyon (late 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 – C41504-2 and C41504-3 in the adjacent Copperton quadrangle (Biek and others, in press) – 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 Tickville Spring and Copperton quadrangles, most appear to be subparallel to bedding in the Butterfield Peaks Formation and therefore are properly termed sills (see also Moore, 1973b); 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).*

unconformity

TERTIARY and CRETACEOUS, undivided

TKc Conglomerate (Paleocene to Upper Cretaceous) – *Silica-cemented and very resistant, medium- to very thick bedded, white to rusty-brown pebbly conglomerate, pebbly sandstone, and gritstone; clasts are angular to subangular, light-brown to light-gray quartzitic sandstone and black chert likely derived from the Oquirrh Group; contains rare cobble-size clasts and is locally partly opalized; locally contains planar laminae defined by grit layers; lacks volcanic clasts and is unconformably overlain by younger block and ash flow tuff (Tvby), and so predates Eocene-Oligocene volcanism; mapped at the head of Tickville Gulch where it is as much as about 200 feet (60 m) thick; age uncertain, but likely Late Cretaceous to early Tertiary.*

unconformity

PENNSYLVANIAN and MISSISSIPPIAN

Oquirrh Group (Upper Pennsylvanian to Upper Mississippian) − *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) as redefined by Swensen (1975a) to include upper and lower plate rocks of the Midas thrust and lower plate rocks of the North Oquirrh thrust; some researchers (see, for example, Laes and others, 1997) include Lower Permian strata in the Oquirrh Group, but we prefer to restrict the group to the Upper Mississippian and Pennsylvanian West Canyon, Butterfield Peaks, and Bingham Mine Formations pending formal redefinition of the group; these three formations are incompletely exposed in the Tickville Spring quadrangle due to faulting and cover by Eocene to Oligocene volcanic rocks; 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).*

IPou Bingham Mine and Butterfield Peaks Formations, undivided (Upper to Middle Pennsylvanian) − *Yellowish-brown quartzitic sandstone and calcareous sandstone exposed near the entrance to Rose Canyon and in Dry Canyon; undivided due to limited exposure and extensive Tertiary volcanic cover.*

IPobm Bingham Mine Formation (Upper Pennsylvanian [Virgilian - Missourian]) − *Brown-weathering, fine-grained quartzitic sandstone and calcareous sandstone, and several medium-gray, fine-grained sandy and cherty limestone intervals (some mapped as limestone marker beds [ls]) in the northeast part of the quadrangle; the lower part of the formation, including the Jordan and Commercial Limestones, are apparently concealed by the upper plate of the Beef Hollow thrust and thus not exposed in the west Traverse Mountains; upper contact is not exposed; an incomplete section of the Bingham Mine Formation is about 5000 to 6000 feet (1500-1800 m) thick in the Tickville Spring quadrangle; the formation is about 7300 feet (2200 m) thick in the Oquirrh Mountains (Tooker and Roberts, 1970).*

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 quartzitic or 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 east of Tickville Gulch and north of Butterfield Canyon mapped separately as limestone 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 contains irregularly shaped black chert nodules and ribbon chert; commonly grade upward to finer grained, platy weathering limestone and argillaceous limestone; sample JN110502-2 – from southwest of Beef Hollow in the Jordan Narrows quadrangle, part of the same upper Butterfield Peaks limestone interval (ls) mapped in sections 25 and 36, T. 4 S., R. 2 W. (Biek, 2005) – yielded a single Idiognathodus species conodont, most likely* I. delicatus *(Desmoinesian); upper conformable contact not exposed in Tickville Spring quadrangle, but is exposed above Yosemite Gulch in the southwest part of the Copperton 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.*

IPMowc West Canyon Limestone (Lower Pennsylvanian to Upper Mississippian [Morrowan – Chesterian]) − *Medium-light-gray to medium-gray, thin- to thick-bedded, fine- to medium-grained limestone, sandy limestone, and fossiliferous limestone; locally laminated with brown-weathering silt and very fine grained sand; fossils include crinoid columnals, brachiopods, bryozoans, rugose corals, and fusulinids; lower and upper contacts are gradational and conformable and correspond to a change from predominantly carbonate strata of the West Canyon Limestone enclosed by predominantly clastic strata of the Manning Canyon Shale and Butterfield Peaks Formation, respectively; well exposed east of Tickville Gulch and north of West Canyon; the West Canyon Limestone is 1450 feet (442 m) thick at its type locality in West Canyon (Nygreen, 1958), and Tooker and Roberts (1970) measured 1436 feet (438 m) in this same area, but Davis and others (1994) reported a thickness of 1007 feet (307 m) in the southern Oquirrh Mountains and Biek (2004) measured 1025 feet (313 m) of West Canyon Limestone at Lake Mountain; earlier, thicker measurements likely reflect inclusion of gradational strata enclosing the Manning Canyon and Butterfield Peaks Formations.*

MISSISSIPPIAN

Mmc Manning Canyon Shale (Upper Mississippian) − *Cross section only; exposed immediately west of the Tickville Spring quadrangle in West Canyon where it is involved in a landslide near the junction of West Canyon and City Canyon; age from Davis and others (1994); see McFarland (1955) and Biek (2005) for unit description; about 1100 feet (340 m) thick in the Oquirrh Mountains (Tooker, 1999).*

Great Blue Limestone (Upper Mississippian) − *Divided into three members, ascending: Lower limestone member; middle Long Trail Shale Member; and upper limestone member; age from Gordon and others (2000); regionally the formation is about 2500 feet (760 m) thick (Gordon and others, 2000).*

Mgb Great Blue Limestone, undivided – *Cross section only.*

Mgbu Upper limestone member − *Medium- to very thick bedded, bluish-gray limestone, locally cherty and