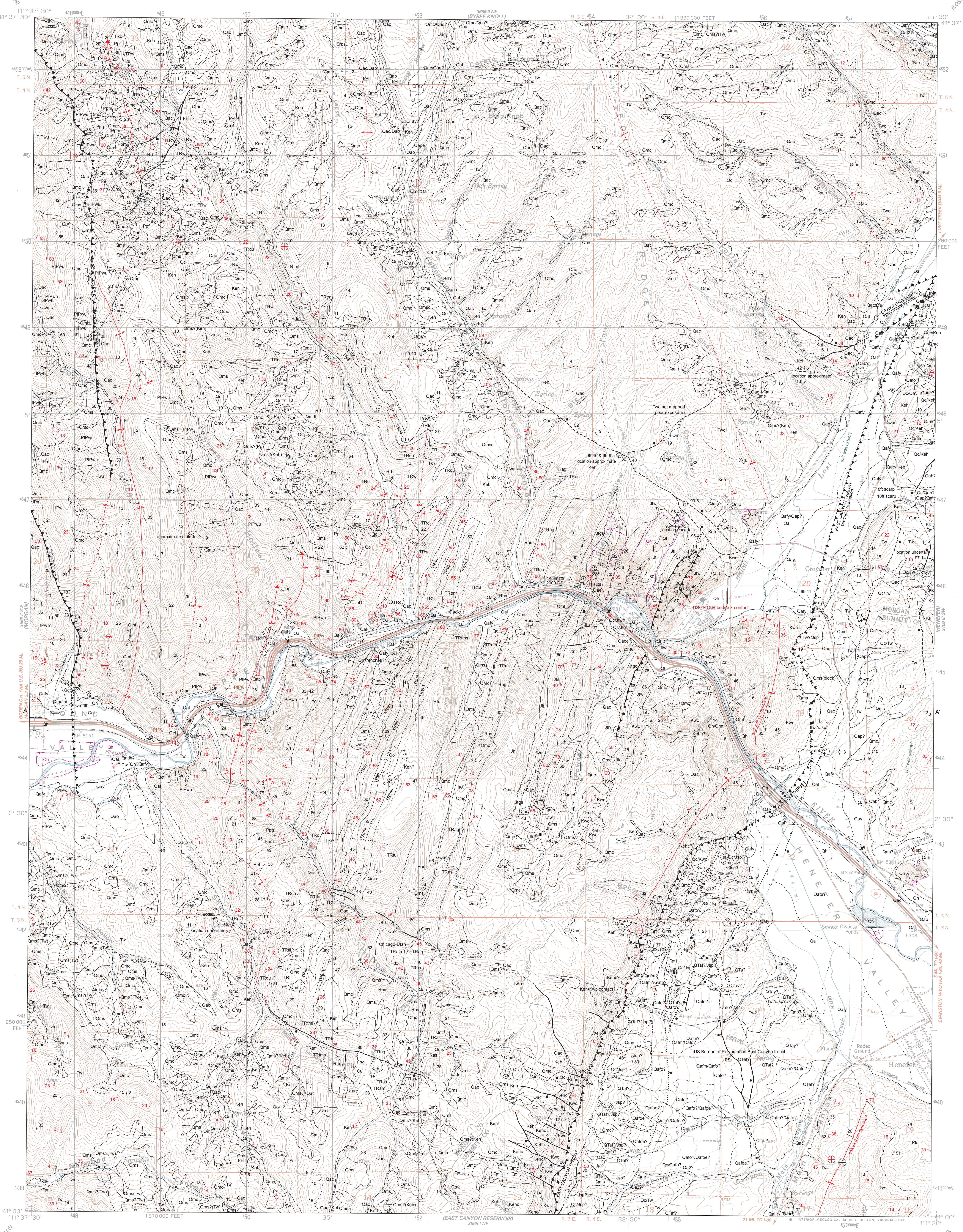
UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources



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11°16'
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 40 FEET
SUPPLEMENTARY CONTOUR INTERVAL 20 FEET

UTAH
QUADRANGLE LOCATION

Base from USGS Devils Slide 7.5' Quadrangle (1991)
Projection: UTM Zone 12
Datum: NAD 1927

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INTERIM GEOLOGIC MAP OF THE DEVILS SLIDE QUADRANGLE, MORGAN AND SUMMIT COUNTIES, UTAH

by

James C. Coogan, Jon K. King, and Greg N. McDonald

2018

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OPEN-FILE REPORT 691
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UTAH DEPARTMENT OF NATURAL RESOURCES
2018

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INTRODUCTION

The Devils Slide quadrangle is located northeast of Salt Lake City and southeast of Ogden, Utah (figure 1) along a national east-west transportation corridor (U.S. Interstate Highway 84 and the Union Pacific Railroad). The major geographic features in and near the quadrangle are Henefer and Round Valleys and the valleys of Lost Creek and Main Canyon Creek; East Canyon, which extends northward forming the valley of Main Canyon Creek; Durst Mountain to the west and north; the Weber River in Henefer and Round Valleys; and Upper Weber Canyon cut by the Weber River between Henefer and Round Valleys. The valleys of Lost Creek and Main Canyon Creek will be referred to as Lost Creek valley and Main Canyon Creek valley, respectively, hereafter in this report. Devils Slide is named after the two resistant, near vertical limestone beds south of Interstate Highway 84 in Upper Weber Canyon.

This is the third version of a large-scale geologic map of the Devils Slide quadrangle. Schick (1955) presented the first detailed map of the area in his thesis on Upper Weber Canyon, and Mullens and Laraway (1973) published a more complete bedrock map. For this study, Coogan mapped the bedrock, improving the stratigraphy and structure, and also mapped some Quaternary surficial deposits. McDonald mapped surficial deposits on the west margin of the quadrangle. King did additional mapping and standardized surficial units, and therefore is responsible for the Quaternary/surficial deposits; surficial deposits are generally not mapped where they are likely less than 6 feet (2 m) thick. King also added the upper tongue of the Dinwoody Formation and middle shale member of the Thaynes Formation; subdivided the Weber Sandstone like he did in the adjacent Morgan quadrangle (Coogan and others, 2015), although with uncertain accuracy; and locally subdivided the Park City and Phosphoria Formations north of the Weber River. Select field-measured attitudes from Mullens and Laraway (1973) are also included in red on the present map in areas where Coogan had limited access. Several of Mullens and Laraway's (1973) prospect locations and bedrock outcrops that were obliterated by highway construction are also shown in red on the present map. Coogan's work was prior to 2000, while most of McDonald's work was in 2003 and 2004. King's additions and changes were done irregularly from 2000 to 2012. The contacts for the extent of the quarrying for cement plant feed and other human disturbances (Qh) are as of September 1986, when the aerial photographs used to geologically map the Devils Slide quadrangle were taken. Only larger disturbances are mapped. The extent of more recent disturbances, taken from 2009 orthophotographs, are shown by purple lines. The cement plant quarry extent is about double the 1986 size and new disturbances are present near the golf course in Round Valley.

GENERAL GEOLOGY

In the Devils Slide quadrangle, Pennsylvanian through Permian marine sedimentary strata and Mesozoic (Triassic and Jurassic) rocks are exposed between Round and Henefer Valleys. These Paleozoic and Mesozoic strata are probably on the Cretaceous Crawford thrust sheet and are exposed in an east-dipping homocline that is locally complicated by Cretaceous folding, west-directed thrusts, and other faults. The homocline is cut by two west-directed(?) thrust faults north of Round Valley, two smaller west-directed thrusts near Devils Slide, and the west-directed East Canyon thrust west of Henefer Valley. The other (normal[?]) faults in these rocks, no matter the trend, are likely related to deformation during the Cretaceous and early Tertiary because these faults do not cut the Eocene-Paleocene Wasatch Formation. Cretaceous deformation created the Crawford thrust sheet, while Cretaceous and early Tertiary deformation created the Absaroka and Medicine Butte thrust systems farther to the east and reactivated thrust faults that formed earlier in the quadrangle (see figure 2). Mesozoic rocks and the Wasatch Formation are cut by Cenozoic extensional faults near Main Canyon Creek valley. Rotation of the homocline likely occurred during late Cretaceous to Eocene uplift of the Wasatch anticlinorium (culmination of Yonkee and others, 1997), rather than during middle to late Cenozoic normal faulting, because significant down-to-the-west normal faulting, in the form of a large valley, is not present to the east of the exposed homocline. This rotation also produced the overturned monoclines mapped to the west in the Morgan quadrangle (Coogan and others, 2015) and is the reason the direction of transport on the thrust faults is not easily deciphered. Mississippian and older units are likely present in the homocline in the subsurface beneath the Devils Slide quadrangle (see cross section) and are briefly described in the description of map and cross-section units.

Cretaceous conglomeratic rocks of the Weber Canyon Conglomerate and Evanston Formation are exposed on the east flank of the homocline, and unconformably overlie the older Paleozoic and Mesozoic rocks. These synorogenic conglomeratic rocks and the Cretaceous thrust sheets are unconformably overlain by the Cenozoic (Eocene and upper Paleocene) Wasatch Formation. The Weber Canyon Conglomerate is associated with Late Cretaceous movement on the Crawford thrust sheet and initial movement on the Absaroka thrust sheet to the east in Wyoming (figure 2). The younger Evanston and Wasatch strata were deposited during Late Cretaceous and early Tertiary reactivation (and uplift?) of the Willard thrust fault (north of map area) and Crawford thrust fault, and uplift of the Wasatch anticlinorium (figure 2). In the southwest part of the Devils Slide quadrangle, west-dipping Wasatch Formation strata are present on the east limb of the Morgan Valley syncline. The Wasatch Formation predates the formation of Morgan Valley, and Lost Creek and Main Canyon Creek valleys. The Oligocene(?) and Eocene Norwood Formation appears to "pinch out" near Lone Tree Canyon in the East Canyon Reservoir quadrangle and is not exposed to the north in the Devils Slide quadrangle; the Norwood may be present in the subsurface on the east side of Main Canyon Creek valley. The Norwood unconformably overlies the Wasatch Formation, "fills" Morgan Valley and the East Canyon graben in adjacent quadrangles, and is folded with the Wasatch Formation in the Morgan Valley syncline.

The Devils Slide quadrangle is geologically significant for its well-exposed Jurassic and Triassic strata, and late Cretaceous to Eocene synorogenic conglomerates (see for example DeCelles, 1994). Other than the Jurassic Twin Creek Limestone (Imlay, 1967) and Triassic Thaynes Formation (Smith, 1969), the Jurassic and Triassic strata in the quadrangle are little studied and warrant further work (see limited palynological data in appendix). The Twin Creek Limestone is the feed source for the cement plant at Devils Slide and is a reservoir rock for oil and gas fields near the Utah-Wyoming border. Asphaltum of uncertain origin was found in Quaternary deposits in the U.S. Bureau of Reclamation trench used to evaluate paleoseismicity in the East Canyon graben (Piety and others, 2010). Salt, likely NaCl (see Mansfield, 1927 p. 338), is present in the shallow subsurface in the Preuss Formation in Main Canyon Creek valley and to the south in the East Canyon graben (see for example Lamerson, 1982, p. 325). Water wells less than 300 feet (90 m) deep on the south margin of Henefer Valley (section 5, T. 3N., R. 4E. Salt Lake Base Line and Meridian [SLBM]) encountered salt (table 1, see Utah Division of Water Rights well drilling database for details). Phosphate is present in the Meade Peak Phosphatic Member of the Phosphoria Formation (map unit Ppm); see Cheney and others (1953), Cheney (1957), and Cheney and Sheldon (1959) for more information. Two trenches have been excavated across the Meade Peak Phosphatic Member south of U.S. Interstate Highway 84 east of Taggarts; it is not known if either of these trenches is that of Cheney and others (1953). The southern (and larger) trench seems to post-date the 1961 U.S. Geological Survey Morgan 15-minute topographic map and pre-date the 1967 aerial photographs McDonald used to map surficial deposits. The larger trench might be related to highway or railroad construction in Upper Weber Canyon rather than phosphate exploration. Minor excavations for coal and copper have also been made in the quadrangle (see for example Gloyn and others, 1995).

SURFICIAL DEPOSITS

Remnants of Pliocene and/or Pleistocene alluvial deposits are present in Main Canyon Creek valley and likely cap some terraces on the Wasatch Formation north of Upper Weber Canyon. Pre-Lake Bonneville Pleistocene alluvial and landslide deposits are present in the Devils Slide quadrangle. Late Pleistocene lacustrine, deltaic, and alluvial deposits related to Lake Bonneville are present in Round Valley, and post-Bonneville shoreline Quaternary (latest Pleistocene and Holocene) alluvial deposits are present in Henefer Valley and Lost Creek valley. Lake Bonneville likely extended into Upper Weber Canyon but did not reach Henefer or Lost Creek valleys, because the highest shoreline is about 5180 feet (1579 m) in Morgan Valley. Mass-movement deposits like landslides and rockfalls are probably the most significant Quaternary units in the quadrangle because of the potential threat to the transportation (railroad, highway, and pipeline) corridor through Upper Weber Canyon. Rockfalls have occurred even where obvious talus slopes are not visible (see McDonald, 2009). Note that no attempt was made to map landslides that post-date the September 1986 aerial photographs used to create the Devils Slide map. Ages (years) in the text and tables are from various methods and are the numbers reported in the original references.

Like in Morgan and Round Valleys, multiple alluviated surfaces are present in the Devils Slide quadrangle east of Round Valley and they seem to be in roughly the same height ranges as surfaces in Morgan and Round Valleys (table 2). The ages of alluvium, including terraces and fans, in the Devils Slide quadrangle are in part based on heights above present adjacent drainages (see table 3). This height approach was taken, rather than relating them to altitudes (including Lake Bonneville shorelines) or a single drainage (like the Weber River), because erosion over time has incised drainages, increasing the heights of alluvium above drainages, alluvial surfaces have slopes, and tributaries to the Weber River increase in altitude up their drainages. So the first surface next to a drainage could be ten to hundreds of feet above the Weber River or a particular altitude. Also, Lake Bonneville did not reach most of the Devils Slide quadrangle, many surfaces predate Lake Bonneville, and drainages were likely backfilled during the rise of Lake Bonneville. If correlated correctly, the surfaces in Morgan and Round Valleys are almost the same as those in the Devils Slide quadrangle that are upstream from several potential Weber River nick points (tight bends cutting Weber Sandstone near Taggarts and extensive Weber Canyon Conglomerate) in Upper Weber Canyon. The alluvial surface heights above Dry and Quarry Cottonwood Creeks are similar to those in Morgan and Round Valleys although these Creeks are upstream from tight bends in Weber Canyon and downstream from the nick point in the Weber Canyon Conglomerate. Due to this apparent correspondence of surfaces, King expanded the area of surface correlations to include the Lost Creek drainage (Lost Creek Dam, Peck Canyon, Francis Canyon) and the Henefer quadrangle (table 3) upstream from the Weber Canyon Conglomerate. Although the older map labels (Coogan, 2004a-c, 2010b) are not consistent with the newer maps (Coogan and others, 2015; this report), the surfaces are at about the same heights above adjacent drainages. Note that the correlations for the Lost Creek drainage and Henefer Valley in Coogan (2010b) have been revised (see table 3). The ages of the surficial deposits are uncertain and may extend through the Quaternary, whether the lower boundary is at 1.8 Ma, roughly the top of the Olduvai subchron normal paleomagnetism, or about 2.6 Ma, roughly the top of the normal paleomagnetism marking the top of the Gauss chron (Gibbard and Cohen, 2008).

Quaternary deposits are likely cut by extensional faults in Main Canyon Creek valley (see Piety and others, 2010) and are shown as dashed faults west of and in unit QTa on our map. Another scarp (10 to 18 feet [3–5 m] high) is present across late Pleistocene deposits (Qap) in Hay Hollow to the north in the Lost Creek drainage, but is not prominent in adjacent colluvial deposits that mantle bedrock. Alternatively, these scarps may be from dissolution of the salt welt under East Canyon; see Lamerson (1982, p. 325) and Yonkee and others (1997, figure 28-B) for more on the salt welt.

STRUCTURAL GEOLOGY

The folding and faulting in the area is complex; the timing from oldest to youngest is summarized here. The southwest end of the Crawford thrust fault is located just to the east in the Henefer quadrangle and its location, as mapped there (Coogan, 2010a), is based on the inferred northern extent of the Preuss salt welt. Salt and thrust movement interacted such that the thrust enters the salt, seems to disappear, and then reappears. For an example see Coogan and Yonkee (1984, figure 7) and think of the homocline in upper Weber Canyon as being the rocks of the Sublette Range and the syncline east of the Gulf well as being a faulted version of the Stevenson syncline, which is east of the Devils Slide quadrangle. The salt welt is thickest in East Canyon south of the Devils Slide quadrangle (see Lamerson, 1982, p. 325) and extends northward through Main Canyon Creek valley, Croydon, and Lost Creek valley. The inferred northern extent of the Preuss salt welt is placed at the northern ends of normal faults in the Devils Slide and Henefer quadrangles.

East of the Devils Slide quadrangle, the Stevenson syncline formed after deposition of the Cretaceous (Santonian-Coniacian) Echo Canyon Conglomerate (deposited during emplacement of the Crawford thrust sheet, figure 2) and prior to deposition of the latest Cretaceous Evanston Formation, possibly during early (Campanian) movement on the Absaroka thrust system (see figure 2; Yonkee and others, 1997, figure 30) and likely formed at the same time as the Coalville anticline (see Lamerson, 1982, p. 320–321), also east of the Devils Slide quadrangle. In the Devils Slide quadrangle, the mostly Campanian and coeval Weber Canyon Conglomerate displays widespread growth structures and records uplift of the east limb of the Wasatch anticlinorium in its clast composition. Weber Canyon Conglomerate deposition is synchronous with late slip on the Crawford thrust, early movement on the Absaroka thrust, initial development of the Henefer anticline (now known as the salt welt), and back-thrusting along the East Canyon thrust fault zone (figure 2). The location, thickness, and numerous angular unconformities in the Weber Canyon Conglomerate may be most indicative of repeated salt welt dissolution and movement providing the "hole" for deposition and rotation of beds.

The roughly east-west-trending normal faults and the north-south-trending, broad folds in the Eocene-Paleocene Wasatch Formation are likely the result of Eocene (Darby/Hogsback) thrusting (figure 2), with a leading edge to the east in Wyoming (Yonkee and others, 1997). The west-northwest-trending faults that cut the Cretaceous Evanston Formation in the Devils Slide quadrangle may have formed during Cenozoic extension (normal faults) or Darby/Hogsback-thrusting (tear faults). The abundance of such faults west of Main Canyon Creek valley and the observation that they "die out" away from the valley are the reason these west-northwest-trending faults are shown as normal faults on the map and are interpreted as being contemporaneous with valley development rather than being tear faults.

The roughly north-south-trending normal faults are likely due to post-thrust Cenozoic extension, either from Oligocene(?) and Eocene relaxation of the Cordilleran fold-and-thrust belt (collapse of Constenius, 1996) or from Miocene and younger Basin and Range extension (see for example Sullivan and others, 1988), or from both. Cenozoic extensional faulting occurred along at least the west side of Main Canyon Creek valley; the faulting on the east side of the valley and to the northeast of Croydon may or may not be due to salt dissolution. In particular, some offset in Main Canyon Creek valley and the East Canyon graben is due to relaxation of the Cordilleran fold-and-thrust belt (Constenius, 1996). This is indicated by Oligocene(?) and Eocene Norwood Formation fill to the south in the East Canyon graben (see Bryant, 1990). Miocene and younger Basin and Range extension may have also occurred in and along the East Canyon graben (see Piety and others, 2010).

The thickness of Tertiary fill (Wasatch Formation, with or without Norwood Formation and younger deposits) in the East Canyon graben is uncertain, but overall seems to increase to the south, possibly with increasing throw on the East Canyon fault zone. From seismic data and well bore sonic velocities, Coogan (July 18, 2007, digital communication to U.S. Bureau of Reclamation) showed about 4000 to 4500 feet (1220–1370 m) of Wasatch and about 800 feet (245 m) of Norwood south of the Devils Slide quadrangle and north of East Canyon Reservoir. From less precise gravity data (Quitzau, 1961), valley fill would be between about 4000 and 5000 feet (1200 and 1500 m) thick near Henefer and 5248 and 6500 feet (1600 and 2000 m) thick near East Canyon Reservoir, based on ~15 mgal and ~20 mgal differences multiplied by 80 and 100 meters of lower density valley fill per mgal, respectively (see data in Phelps and others, 1999 that crudely results in 90 meters per mgal). But low-density salt is present in the subsurface (Jps) so the valley fill is thinner, like Coogan (July 18, 2007, digital communication to U.S. Bureau of Reclamation) showed, or the 80 meters is correct. Quitzau (1961) did not model a profile for either area, but noted a 20 mgal decrease in the 2 miles (3.2 km) east of Devils Slide and a 12 mgal closure in gravity contours. His 20 mgal decrease east of Devils Slide is likely partly due to low-density salt (Jps) in the subsurface (see cross section).

MAP AND CROSS SECTION UNIT DESCRIPTIONS

SURFICIAL DEPOSITS

QUATERNARY

Qa **Alluvium, undivided (Holocene and Pleistocene)** – Sand, silt, clay, and gravel in stream and alluvial-fan deposits; variably sorted; variably consolidated; composition depends on source area and some source areas extend beyond map boundaries; deposits lack fan shape (Qaf) and are distinguished from terraces (Qat) based on upper surface sloping toward adjacent streams from sides of drainage, are mapped where fans and terraces are too small to show separately at map scale, or where relative age (height above adjacent drainage) of alluvium is uncertain; mapped on queried Qatp terrace above Henefer Valley where contact cannot be drawn between thin younger fans (Qafy) upslope and these older terrace deposits; 6 to 20 feet (2–6 m) thick.

Qay, Qa2?

Younger alluvium (mostly Holocene) – Like undivided alluvium, but unconsolidated; mapped on the margins of Round, Henefer, and Lost Creek valleys where not incised by active drainages, and stream and fan alluvium cannot be mapped separately; also up to ~20 feet (6 m) above south side of Round Valley indicating unit includes slightly older post-Provo shoreline regressive Lake Bonneville-age alluvium; revised from Qa1 shown in Pine Canyon in the Henefer quadrangle (see table 3; Coogan, 2010b); mapped as Qa2 (queried) where ~20 feet (6 m) above incised stream in Stephens Canyon; 6 to 20 feet (2–6 m) thick; likely post-dates late Pleistocene Lake Bonneville and is mostly Holocene.

Qapb, Qap, Qap?, Qab, Qab?

Lake Bonneville-age alluvium (upper Pleistocene) – Like younger alluvium, but unconsolidated to weakly consolidated, higher above present drainages, and appears to be related to shorelines of Lake Bonneville; suffixes indicate age with Qap and Qab together comprising Qapb where more exact age cannot be determined or alluvium of different ages cannot be shown separately at map scale; suffixes partly based on heights above adjacent drainages (see tables 2 and 3); Qap is related to the Provo and regressive shorelines of Lake Bonneville that are not present in the map area while Qab is related to the Bonneville shoreline (~5180 feet [1579 m]); Qab appears graded to the Bonneville shoreline as mapped in Round Valley, but this highest level of Lake Bonneville only reached Upper Weber Canyon so Qab elsewhere (as well as all deposits labeled Qap) are not adjacent to shorelines and direct correlation cannot be demonstrated; 6 to 20 feet (2–6 m) thick.

Qapb is mapped about 40 feet (12 m) above Quarry Cottonwood Creek and 10 to 20 feet (3–6 m) above Qap on the floor of Harris Canyon; Qapb revised from Qat2 shown in Henefer quadrangle (see table 3; Coogan, 2010b).

Qap is mapped in the bottom of drainages into Lost Creek and Henefer valleys where the deposits are elevated about 35 feet (11 m) above the adjacent floodplains in those valleys, including a broad unnamed drainage north of Henefer Valley; Qap also mapped east of the Lost Creek valley north of Wolf Den Canyon and queried under Qafy west of the

Lost Creek valley about 25 to 40 feet (8–12 m) above adjacent floodplain; Qap? mapped in Hay Hollow and Harris Canyon is revised from Qa1 (and stray Qal label) shown in the Henefer quadrangle (see table 3; Coogan, 2010b).

Qab? and Qab are mapped about 40 feet (12 m) and 35 feet (11 m) above Qap on the drainage floors in Hay Hollow and Harris Canyon, respectively; Qab in Harris Canyon is revised from Qat3 shown in the Henefer quadrangle (see Coogan, 2010b); queried Qab above Hay Hollow is revised from Qa2-3 (and stray Qat2 label) shown in the Henefer quadrangle (see Coogan, 2010b); the Harris Canyon Qab is 60 to 65 feet (18–20 m) above the adjacent floor of Henefer Valley; Qab? is mapped on first surface above Qatp? on west side of the Henefer Valley, and is queried because the height above the Weber River may be about 100 feet (30 m), the height of Qao (see table 3); Qab is mapped 60 to 70 (18–21 m) above Quarry Cottonwood Creek; Qab (queried) mapped 65 feet (20 m) above Pine Canyon is revised from Qat3 shown in the Henefer quadrangle (see Coogan, 2010b).

The Qab that is mapped ~80 to 95 feet (24–29 m) above Round Valley and 40 to 50 feet (12–15 m) above adjacent drainages at the mouth of Geary Hollow, with about 80-foot (24 m) thickness, appears unique. Based on heights above adjacent drainages, these deposits would be Qao, but similar alluvial deposits to the east near Phil Shop Hollow have a Bonneville shoreline cut into them and are much thinner. The lack of a Bonneville shoreline, thicknesses, and heights above drainages indicate the deposits could be a Bonneville shoreline fan-delta (see Coogan and others, 2015).

Qao, Qao?

Older alluvium (mostly upper Pleistocene) – Sand, silt, clay, and gravel on surfaces above and likely older than Lake Bonneville-age alluvium; deposits lack fan shape (Qaf) and are distinguished from terraces (Qat) based on upper surface sloping toward adjacent streams from sides of drainage; composition depends on source area; mapped 100 feet (30 m) above Quarry Cottonwood Creek and above Round Valley near Phil Shop Hollow; about 20 feet (6 m) above incised Bonneville shoreline near Phil Shop Hollow; queried Qao is mapped about 120 feet (37 m) above Dry Creek because this height overlaps with Qaoe, but the deposits are below nearby Qaoe.

Older alluvium is likely older than Lake Bonneville and the same age as Qafo (likely Bull Lake age; 95,000 to 130,000 yrs old—see Chadwick and others, 1997, and Phillips and others, 1997); see table 2 and note revisions from Coogan and King (2006) and King and others (2008). From work in the Henefer quadrangle (Coogan, 2010a) and the Devils Slide quadrangle, and age estimates in Sullivan and Nelson (1992) and Sullivan and others (1988), the older alluvium (Qao, Qafo, Qato) may encompass upper (pre-Bull Lake) and lower (Bull Lake) alluvial surfaces that are not easily recognized in Morgan Valley (see tables 2 and 3).

Qaoe, Qaoe?

Older eroded alluvium (middle and lower Pleistocene) – Like older alluvium but mapped on eroded remnants of surfaces located above the Bonneville shoreline, and above (and older than) pre-Lake Bonneville older alluvium (Qao and Qafo); Qaoe typically about 10 feet (3 m) thick, but appears ~120 feet (37 m) thick in one exposure west of Henefer Valley at Roberts Hollow and in queried exposures (Qaoe?) in Weber Canyon.

Qaoe is mapped 130 feet (40 m) above Quarry Cottonwood Creek and 150 feet (46 m) above Dry Creek; Qaoe? is mapped 190 feet (58 m) above Lost Creek valley in Wolf Den Canyon, and queried because it is shown as Qa4 (surface 5) in the Henefer quadrangle but only 60 to 80 feet (18–24 m) above the drainage in canyon; Qaoe is mapped as queried more than 140 feet (43 m) above the west side of Henefer Valley at and north of Roberts Hollow because actual height above Henefer Valley is uncertain and variable; Qaoe is mapped as queried where 135 and 160 feet (41 and 49 m) above the Weber River near the cement plant due to poor exposure and Qmc caps. In the Main Canyon Creek valley east of the graben, alluvium mapped above Main Canyon Creek is at the height boundary of Qaoe and QTa, but their mapped height above the Weber River would make the alluvium QTay, so the alluvium is labeled QTay?.

The thin colluvium capped surfaces (Qc and Qc/Qa on map) 220 feet (67 m) above Frank Hollow may be Qaoe or QTay; degraded terraces (surfaces with no mappable deposits) are present ~120 to 150 feet (37–46 m) and ~180 feet (55 m) (QTay?) above Lost Creek between Coal Hollow and Chokecherry Hollow, and ~195 feet (69 m) above Dry Creek.

The Pleistocene age for older eroded alluvium is uncertain, but west of the Weber River in the Morgan quadrangle, the deposits at similar heights above drainages were reported by Sullivan and others (1988) as being older than 730 ka [>780 ka, Bassinot and others, 1994], based on reversed paleomagnetism; however, their sample site is one of the highest alluvial remnants of Qaoe (>200 feet [60 m] up) and may be QTay.

Qal, Qal?

Stream alluvium and floodplain deposits (Holocene) – Sand, silt, clay, and gravel in channels, floodplains, and terraces less than 10 feet (3 m) above stream level; moderately sorted; unconsolidated; locally includes muddy, organic overbank and oxbow lake deposits; mapped along Weber River and Lost Creek; composition depends on source areas far beyond the Devils Slide quadrangle, but typically contains many quartzite cobbles recycled from the Wasatch Formation; mostly Holocene, but deposited after regression of Lake Bonneville from the late Pleistocene Provo shoreline; 6 to 20 feet (2–6 m) thick. Qal queried where may include alluvial-fan deposits.

Parts of the Weber River in upper Weber Canyon were moved during construction of Interstate Highway 84, so stretches of the river bed that are mapped as Qal, and are historical, could be mapped as human disturbances (Qh).

Qat, Qat2?, Qatp?, Qato?

Stream-terrace alluvium (Holocene and Pleistocene) – Sand, silt, clay, and gravel in terraces above floodplains; moderately sorted; variably consolidated; upper surfaces slope gently downstream; number and letter suffixes indicate relative ages and are from heights above adjacent drainages and follow those in Morgan Valley and Round Valley (see tables 2 and 3); the lowest/youngest terraces are Qat2 and are post Lake Bonneville and likely mostly Holocene in age; terraces labeled Qatp? are likely related to the Provo and slightly lower regressive shorelines of Lake Bonneville, although these shorelines are not present in the map area; unit Qato? is likely older than Lake Bonneville; Qat with no suffix used where age unknown or age subdivisions of terraces cannot be shown separately at map scale; Qat only mapped north of Wolf Den Canyon where height uncertain but likely no higher (older) than Qap; 6 to at least 20 feet (2–6+ m) thick.

Queried Qat2 is only mapped where it is 12 feet (4 m) above Tom Condies Creek in Pine Canyon and queried because it may be in the floodplain (Qal2) and the bench cannot be distinguished downstream in the Henefer quadrangle; queried Qatp is only mapped 30 feet (9 m) above the Lost Creek valley north of Wolf Den Canyon and 20 to 30 feet (6–9 m) above the Weber River in Henefer Valley and queried because it is the first terrace above the River and would typically be Qat2; queried Qato is mapped north of Wolf Den Canyon where it is 120 feet (36 m) above the Lost Creek valley and may be Qao or Qaoe; Qatp? in Henefer Valley is revised from Qat2 shown in the Henefer quadrangle (see Coogan, 2010b).

Qaf **Alluvial-fan deposits, undivided (Holocene and Pleistocene)** – Mostly sand, silt, and gravel that is poorly stratified and poorly sorted; variably consolidated; includes debris-flow deposits, particularly in drainages and at drainage mouths (fan heads); mapped where fan age uncertain or for composite fans where portions of fans with multiple ages cannot be shown separately at map scale; mapped along Lost Creek and Quarry Cottonwood Creek and near mouth of Phil Shop Hollow; toes of most of the fans in Upper Weber Canyon have been removed for roadbed construction, so their age cannot be readily/easily determined and therefore are labeled Qaf; generally less than 40 feet (12 m) thick.

Qafy, Qafy?

Younger alluvial-fan deposits (Holocene and uppermost Pleistocene) – Like undivided fans but unconsolidated, and younger fans impinge on present-day floodplains, divert active streams, and/or overlie low terraces; probably post-Lake Bonneville and mostly Holocene in age; mapped where they impinge on floodplains and terraces along Weber River in Round and Henefer Valleys and Upper Weber Canyon, as well as in Lost Creek valley; queried at mouth of Hay Hollow where may include other alluvial units; generally less than 40 feet (12 m) thick.

Qafpb, Qafpb?

Lake Bonneville-age alluvial-fan deposits (upper Pleistocene) – Like undivided alluvial fans but ~40 feet (12 m) above Lost Creek Valley; appear to be related to the Provo and/or Bonneville shorelines of Lake Bonneville; mapped north of Wolf Den Canyon; queried where only 25 feet (8 m) above north end of Henefer Valley because lower than adjacent Qap (35 feet [11 m] up), but appears to underlie Qap and may be related to Lake Bonneville transgression; unit less than 40 feet (12 m) thick.

Qafm, Qafm?

Pre-Lake Bonneville-age alluvial-fan deposits (upper Pleistocene) – Like older alluvial fans (Qafo?), but mantle Qafo? in graben in Main Canyon Creek valley and estimated age in U.S. Bureau of Reclamation trench (SW1/4SW1/4 section 5, T. 3 N., R. 4 E. SLBM) is older than Lake Bonneville and younger than Bull Lake glaciation (31–38 ka) (see table 3 and Piety and others, 2010); a surface on QTaf? and QTa? east of the graben can be traced upstream to Qafm/Qafo? and this surface is about 80 feet (24 m) above adjacent active drainage into Main Canyon Creek, a height on the boundary between Qab and Qao (see table 3). Queried because intermittent upward movement and dissolution of salt welt makes fan-age classification uncertain.

As exposed in the Bureau of Reclamation trench (plate 1), Qafm is overlain by Qafy on the downthrown side of the trenched fault and QTaf? is overlain by Qc on the upthrown side of the fault; but these younger units are so thin (<3 feet [1 m] and 3 feet [1 m] thick, respectively) that they are not mapped.

Qafo? **Older alluvial-fan deposits (mostly upper Pleistocene)** – Incised fans of mostly sand, silt, and gravel that are poorly stratified and poorly sorted; includes debris-flow deposits, particularly in drainages and at drainage mouths (fan heads); likely older than Lake Bonneville; queried in Wolf Den Canyon because 115 feet (35 m) above Lost Creek valley but only 40 feet (12 m) above creek in Wolf Den Canyon and height above Lost Creek is near boundary between Qafo and Qafoe; queried Qafo also mapped 135 to 140 feet (41–43 m) above Dry Creek in northwest margin of map area because this height is more like Qafoe in Morgan Valley (see table 2 and Coogan and others, 2015); generally less than 40 feet (12 m) thick.

Qafo is queried in the East Canyon graben because the deposits are not dissected and some deposits mantle Qafoe (see also unit Qafm above); this results in a reversal of typical height above adjacent drainages and only local incision. Our Qafo is roughly shown to the south by Bryant (1990) as Qgp (pediment gravel); farther south he showed Qoa (dissected alluvium) adjacent to the East Canyon fault, which may be the QTaf or Qafoe that we mapped in the Devils Slide quadrangle. We mapped queried Qafo under queried Qafm (Qafm?/Qafo?) east of the graben near Main Canyon Creek, where the height above the creek is at division of two surfaces (Qs3-4 and Qs4, table 3); see also unit Qafm above. These atypical deposits are likely the result of irregular upward movement and dissolution of salt in the East Canyon graben. As noted under Qao, Qafo may contain two ages (levels) of alluvial surfaces that are not easily recognized in Morgan Valley.

Qafoe? **Older eroded alluvial-fan deposits (middle and lower Pleistocene)** – Contain mostly sand, silt, and gravel that is poorly bedded and poorly sorted; typically in eroded fan remnants located above and apparently older than pre-Lake Bonneville older alluvial-fan deposits (Qafo) and lower relative to alluvial units QTa?, QTay, QTay?, and QTaf?; however in Main Canyon graben, Qafoe? actually overlies unit QTaf? and underlies Qafo?; this stacking indicates filling of the graben as it subsides and exposure due to periodic incision as the east side of the graben is breached by streams; thickness uncertain, may approach 80 feet (24 m); likely same age as Qaoe (>780 ka).

Qafoe? seems to be 120 feet (36 m) above the adjacent drainage in the Main Canyon graben but infilling of the graben makes this height ambiguous; for this reason, Qafoe? is not shown in the Devils Slide quadrangle in table 3.

Qac, Qac?

Alluvium and colluvium (Holocene and Pleistocene) – Unsorted to variably sorted gravel, sand, silt, and clay in variable proportions; includes stream and fan alluvium, colluvium, and, locally, mass-movement deposits too small to show at map scale; typically mapped along smaller drainages that lack flat bottoms; 6 to 20 feet (2–6 m) thick.

Some Qac deposits are "perched" on benches ~40 to 130 feet (12–40 m) above Quarry Cottonwood and Dry Creeks, and 55 to 80 feet (17–24 m) above the west side of the Lost Creek valley indicating the alluvium is at least partly Lake Bonneville age and older (see tables 2 and 3); similar benches are present in the Heiners Creek and Henefer quadrangles (see Coogan, 2010a-b); Qac is queried where it is ~250 feet (75 m) above Big Cottonwood Creek on the north edge of the Devils Slide quadrangle and may be QTay.

Qc, Qc?

Colluvium (Holocene and Pleistocene) – Unsorted clay- to boulder-sized material; includes material moved by slopewash and soil creep; composition depends on local bedrock and surficial deposits(?); some colluvium mapped on alluvial(?) surfaces about 65 to 220 feet (20–70 m) above Frank Hollow, but the surfaces may be beds in Keh; Qc queried above Quarry Cottonwood Creek and Phil Shop Hollow where it may be residual deposits on bedrock (Keh), and along tributary to Dry Creek where it may be Qmc; generally less than 20 feet (6 m) thick.

Qct **Colluvium and talus, undivided (Holocene and Pleistocene)** – Unsorted, clay- to boulder-sized angular debris (scree) at the base of and on steep, typically partially vegetated slopes; mapped in Round Valley north and south of Weber River on and at the base of steep Weber Sandstone exposures; forms debris cones north of the Weber River; also mapped in Weber Canyon on and at the base of several bedrock units; 6 to 20 feet (2–6 m) thick.

Qmc, Qmc?

Landslide and colluvial deposits, undivided (Holocene and Pleistocene) – Poorly sorted to unsorted clay- to boulder-sized material; mapped where landslide deposits are difficult to distinguish from colluvium (slopewash and soil creep) and where mapping separate, small, intermingled areas of landslides and colluvial deposits is not possible at map scale; locally includes talus, debris-flow, and flood deposits; typically mapped where landslides are shallow; also mapped where the blocky or rumpled morphology that is characteristic of landslides has been diminished or smoothed by slopewash and soil creep; composition depends on local sources; 6 to 40 feet (2–12 m) thick. These deposits may be as unstable as landslide units Qms, Qms1, Qmsy, and Qmso. Queried on north margin of map area and in Main Canyon Creek valley where may not include landslides and be Qac.

Qms, Qms?, Qms1, Qmsy, Qmso

Landslide deposits (Holocene and Pleistocene) – Poorly sorted clay- to boulder-sized material; includes slides, slumps, and locally flows and floods; generally characterized by hummocky topography, main and internal scarps, and chaotic bedding in displaced blocks; composition depends on local sources; morphology becomes subdued with time and amount of water in material during emplacement; thicknesses highly variable, but estimate up to about 20 to 30 feet (6–9 m) for small slides, and 80 to 100 feet (25–30 m) for larger landslides; divided into younger (mostly Holocene) and older (Pleistocene) deposits where possible (suffixes y and o, respectively). Qms queried where identification as landslide is uncertain. Contacts shown between landslides where deposits are different/distinct. Numerous landslides are too small to show at map scale and typically landslides less than 6 feet (2 m) thick have not been mapped.

Qms without a suffix is mapped where the age is uncertain (though likely Holocene and/or late Pleistocene), where portions of slide complexes are of different ages but cannot be shown separately at map scale, or where boundaries between slides of different ages are not distinct. Qms1 is mapped where scarps have not been revegetated, and the landslide is Holocene and may be historical. Qmsy is mapped where a landslide deflects the stream in upper Phil Shop Hollow.

Qmso is typically mapped where deposits are perched above present drainages, rumpled morphology typical of mass movements has been diminished, and/or younger surficial deposits cover or cut Qmso. Qmso is mapped above Quarry Cottonwood Creek where downslope the slide ends are "perched" about 300 feet (120 m) or more, as well as 80 and 110 feet (24 and 34 m) above the present drainage. The lower deposits are at the heights of Qao above Quarry Cottonwood Creek, and the higher deposits may be related to alluvium (unit QTa) in Morgan Valley that is likely older than 780 ka (see table 3 and Coogan and others, 2015, table 1). Older landslide deposits may be unstable, and are easily reactivated with the addition of water, be it precipitation, altered drainage, irrigation, or septic tank drain fields.

Qms(Tw), Qms?(Tw), Qms?(Keh), Qms?(Pp), Qms?(PIPw)

Block landslide and possible block landslide deposits (Holocene and upper and middle? Pleistocene) – Mapped where nearly intact block is visible in landslide (mostly block slide) with stratal strikes and dips that are different from nearby in-place bedrock; unit involved in landslide shown in parentheses, for example Qms(Tw); composition depends bedrock unit; see rock unit in parentheses for descriptions of blocks; thickness highly variable, up to about 20 to 30 feet (6–9 m) for small slides, and cross sections in nearby quadrangles show larger blocks are about 150 feet (45 m) thick. Qms queried, for example Qms?(Tw), where bedrock block may be in place, that is stratal strikes and dips in queried block are about the same as nearby in-place bedrock.

Qmdf, Qmdfh

Debris-flow deposits (Holocene and upper Pleistocene) – Mostly very poorly sorted sand, silt, clay, gravel, and cobbles in unstratified deposits characterized by rubbly surfaces and debris-flow levees with channels, lobes, and mounding; deposits in drainages typically form mounds, an indication of being more viscous Qmdf rather than being flat like Qac; many debris flows cannot be shown separately from alluvial fans because a consistent contact cannot be drawn between the debris flows and the fans that are at least partly comprised by debris-flow deposits; Qmdfh deposits are lobate debris accumulations and are mapped on active alluvial fans (Qafy) on the north side of Round Valley where debris flows in 1958 are documented; these historical debris flows are visually distinct from alluvial fans in Round Valley and contacts are based on lack of vegetation and fresh appearance of natural levees, channels, and debris; 0 to 40 feet (0–12 m) thick; mapped because of historical hazard, despite being less than 6 feet (2 m) thick.

Qmrf **Rockfall deposits (Holocene and Pleistocene)** – Unsorted, angular, block and finer debris at base of cliff in Triassic rocks south of Interstate Highway 84 (section 23, 26, T. 4N., R. 3E. SLBM) and north of the Interstate at base of cliff of Weber Sandstone (section 28, T. 4N., R. 3E. SLBM); the former may have been emplaced by a single event and the latter is at least partly historical since it is on an old highway roadbed; the cliffs have distinct scarps above the debris; estimate 0 to 40 feet (0–12 m) thick; mapped because of historical hazard, despite being less than 6 feet (2 m) thick.

Qmt **Talus (Holocene and Pleistocene)** – Unsorted, clay- to boulder-sized, angular debris (scree) at the base of and on steep, mostly unvegetated slopes; only larger debris fields can be shown at map scale; deposits include minor colluvium locally; likely less than 20 feet (6 m) thick.

Qadb? **Lake Bonneville transgressive and Bonneville-shoreline alluvial-fan and delta deposits (upper Pleistocene)** – Cobbly gravel, sand, silt, and clay deposited above (subaerial) and in Lake Bonneville (subaqueous) as lake transgressed to and was at the Bonneville shoreline; mapped at the mouth of Phil Shop Hollow where Bonneville shoreline is obscure so that line cannot be drawn between delta and fan; outside the map area, this unit is better sorted delta and lake deposits overlying poorly sorted alluvial-fan deposits; 6 to at least 40 feet (2–12+ m) thick.

Qh, Qh?

Human disturbances (Historical) – Mapped disturbances obscure original rocks or deposits by cover or removal; only larger disturbances are shown; includes rock removal and engineered fill, particularly along Interstate Highway 84 and Union Pacific Railroad, and disturbances from cement plant operations, as well as gravel pits and sewage-treatment facilities. Edges of disturbances that post-date the 1986 aerial photographs used to map the geology in this quadrangle are shown in purple and were added from and are visible on 2006 and 2009 orthophotographs of the quadrangle.

QUATERNARY AND TERTIARY

The change in the Quaternary-Tertiary boundary favored by Europeans from about 1.8 Ma, roughly the top of the Olduvai normal paleomagnetism subchron, to about 2.6 Ma, roughly the top of the normal paleomagnetism marking the top of the Gauss chron (Gibbard and Cohen, 2008), does not affect mapping and labeling of the following unconsolidated units because we do not have any paleomagnetic data. However, carving nearly a million years out of the episodically shrinking Pliocene means rocks we have listed as Pliocene in the Morgan quadrangle (Coogan and others, 2015), like the fanglomerate of Huntsville (Thv) and younger conglomeratic unit Tcy, may be Quaternary even though they are consolidated (rock). We have chosen to keep rocks (consolidated and/or lithified) as Tertiary and unconsolidated deposits as Quaternary and Quaternary/Tertiary to emphasize their erosional, geotechnical, and hydrological differences.

QTa?, QTay, QTay?

High-level alluvium (lower Pleistocene and/or Pliocene) – Gravel, sand, silt, and clay above Weber River terraces near Henefer, and in graben between East Canyon fault and Main Canyon Creek appear to be alluvial fans and gravel armored surfaces, but may include terrace deposits related to the Weber River; at least locally poorly sorted (see Eardley, 1944, p. 874); QTa? mapped with upper surface about 265 and 360 feet (80 and 110 m) above and next to Henefer Valley, because this height range is at the division of QTay and QTao in Morgan Valley; QTay? mapped about 200 and 220 feet (60 and 67 m) above Henefer Valley; QTay mapped above Qaoe at 200 and 240 feet (60–75 m) above Quarry Cottonwood Creek, with the former queried because height may indicate alluvium is unit Qaoe; the thin colluvium-capped surfaces (Qc and Qc/Qa on map) 220 feet (67 m) above Frank Hollow may be Qaoe or QTay; estimate QTa? at least 240 feet (75 m) thick in high bluffs next to Henefer Valley, and QTay? ~200 feet (60 m) thick to south where relief is lower and bluffs could be Qaoe (see also well 5, table 1).

QTaf? **High-level alluvial-fan deposits (lower Pleistocene and/or Pliocene)** – Red gravel, sand, silt, and clay, in graben east of East Canyon fault; fan material eroded from red conglomeratic Wasatch Formation (Tw) and Weber Canyon Conglomerate (Kwc), as well as sandy Preuss Redbeds (Jp, Jsp?); these red bedrock units, at least locally, shallowly underlie the red fans, making fan contacts difficult to map and fan identification uncertain, hence the query on the map unit; overlain downslope by units Qafoe and Qafo and upslope map unit locally includes thin, small younger (likely Holocene) alluvial fans (Qafy) that cannot be shown separately at map scale, have indistinct edges, and/or are less than 6 feet (3 m) thick; at least locally gravel-armored and poorly sorted (see Eardley, 1944, p. 874); estimate about 240 feet (75 m) thick in bluff along antithetic fault just to south in East Canyon Reservoir quadrangle. The surface on QTaf? and QTa? in Main Canyon Creek valley is not the Weber Valley surface of Eardley (1944, see, in particular, his plate 7) despite these units being part of his surface in Morgan Valley (see Coogan and others, 2015).

Our unit QTaf? was mapped as Wasatch Formation, with a down-to-the east normal fault, to the south by Bryant (1990); farther south Bryant (1990) showed Qoa (dissected alluvium) adjacent to fault, which may be our QTaf or Qafoe unit.

STACKED UNITS

Numerous stacked units are on this map. This is partly a result of the compromise between showing surficial deposits and bedrock on the same map. By stacked, we mean a thin covering of one unit over another, which is shown by the upper map unit (listed first) then a slash and then the underlying unit (for example Qc/Tw). The upper unit is typically a surficial deposit with the lower unit being rock (Q_/rx), but exceptions are present. We map the stacked units where it is important to show both units as they have potential geologic hazards and/or economic value (for example landslides or landslide-prone impermeable clayey bedrock units, and phosphate or sand and gravel). The upper unit is typically about 6 feet (2 m) thick and conceals but does not obscure the lower unit. This thickness was chosen because a building foundation would penetrate a thinner upper unit, particularly colluvium (Qc), making it a small factor in construction. We have not mapped most of the colluvium as it is thinner than 6 feet (2 m) and we can tell what is underneath. The exceptions to this approach are where the thin deposits obscure the geologic details of faulting, lithologies, and age relationships. The underlying unit in the stack has been identified based on exposures at the edges of the stacked unit and small exposure windows (gaps) or excavations in the cover that cannot be shown at map scale, and materials in the cover that came from the underlying unit.

Qh/Qmt

Surficial deposits over mass-movement deposits – These units were mapped because they inform the map user about potential geologic hazards; and in this case about talus and potential rockfalls that may impact the human disturbance.

Qmc/Qa, Qmc/Qao?

Mass-movement deposits over surficial deposits – These units were mapped because they inform the map user about overlying potential geologic hazards.

Qc/Tw, Qc/Keh, Qac/Keh, Qc/Kk, Qc/Jsp?, QTaf?/Jsp?

Surficial deposits over bedrock – The units were mapped because they inform the map user about potential geologic hazards due to the underlying landslide-prone and impermeable clayey bedrock.

Qac/Qa, Qac/Qab, Qac/Qao?, Qc/Qa, Qc/Qab?, Qc/Qafo?, Qc/QTay?, Qc/Kwc, Qc/Kwc?, Qc/Jtl?, Qc/Jtw?

Alluvial and colluvial deposits over other surficial deposits and bedrock – These units were mapped because they show where we are uncertain about which underlying unit is present (underlying unit queried), and/or where the overlying Qac and Qc may obscure the underlying materials or bedrock.

Tw?/Jsp, Tw?/Jsp?, Keh?/Pp

Bedrock over bedrock – Thin, typically easily weathered bedrock over other bedrock, which means the overlying "bedrock" may actually be surficial deposits; over the salt welts near Moab, Utah, units similar to stacked Jsp units are referred to as "caprock"; also units Tw, Keh, and Jsp are locally landslide prone.

Qafy/Qap?, Qafm/Qafo?, Qafm?/Qafo?, Qafo?/Qafoe?

Surficial deposits over surficial deposits – These units were mapped because they inform the map user about stratigraphic age-relation details seen in the field that went into the Quaternary correlation chart.

BEDROCK UNITS

TERTIARY

Tw, Tw?

Wasatch Formation (Eocene and upper Paleocene) – Typically red to reddish-brown sandstone, siltstone, mudstone, and conglomerate; conglomerate clasts typically rounded and derived from Precambrian (Neoproterozoic) and Paleozoic meta-sedimentary and sedimentary rocks, typically quartzite; lighter shades of red, yellow/tan, and light gray more common in uppermost Wasatch; basal conglomerate contains locally derived angular clasts where contact with underlying Mesozoic rocks is exposed and is less likely to be red; queried Wasatch (Tw?) has visible bedding, and is reddish strata northwest of Henefer and pale grayish strata on the divide between Lost Creek and Henefer Valleys that may be some other unit than the Wasatch, likely red Preuss Redbeds (Jp, Jsp), and light gray to tan Weber Canyon (Kwc), Hams Fork Member of Evanston Formation (Keh, Kehc), and/or Stump Formation (Jsp). Tw contains scattered oncolitic/algal limestone beds (see Mullens, 1971, p. 18; Mann, 1974) south of Weber Canyon and west of East Canyon fault zone. Tw locally includes landslides that are too small to show at map scale. The Wasatch Formation is at least locally prone to slope failures, because it is at least locally clay rich and poorly consolidated. Permeability in the Wasatch Formation is complicated due to clay content, limestone beds, and variable cementation that is so strong in some areas that quartzite clasts are broken through rather than around during fracturing. The variability is indicated by perched springs in the unit.

The age of the Wasatch Formation is based on the Eocene-Paleocene boundary used in Jacobson and Nichols (1982), which is likely the C24 paleomagnetic reversal (see Hicks and others, 2003). Other Eocene-Paleocene boundaries would put P6 (Paleocene) palynomorphs in the Eocene, and the P stands for Paleocene. Wasatch strata to the southeast in Salt Lake City 30 x 60-minute quadrangle contain P5-6 palynomorphs, but also the palynomorph *Platycarya platycaryoides* (Nichols and Bryant, 1990, sample D6052), which is Eocene (see Nichols, 2003). See also Jacobson and Nichols (1982) for Paleocene (P) biozones based on palynology, and upper Paleocene (P5 and P5-6) Wasatch samples (P3055-2A, 3B; P3387-2) taken to the south (their figure 7 updated with mapping by Bryant, 1990) and P5-P6 sample (P2833-1,2) from the Wasatch Formation in the Ogden 30 x 60-minute quadrangle (their figure 11 updated with mapping by Coogan and King, 2016). Wasatch strata to the northeast in the Meachum Ridge quadrangle contain upper Paleocene (P4-5) palynomorphs in sample 97-7 and Eocene palynomorphs in sample 97-13 that is above sample 97-7 (Coogan and King 2016, appendix table 1) with both containing recycled Maastrichtian and P1-2 palynomorphs; recycled since the P1-2 interval is in the unconformity that separates Paleocene (Tev) from Cretaceous (Keh) Evanston Formation (See Jacobson and Nichols, 1982).

The Wasatch Formation total thickness from the unfaulted Tn-Tw contact in the southeast part of the Morgan quadrangle to the Tw-Keh contact in the southwest part of the Devils Slide quadrangle is about 5000 to 6000 feet (1500–1800 m), as estimated by King using bedding dip (~20–25°), outcrop pattern, and topography. The Wasatch Formation may be thinner north of the Weber River because it is likely as much as about 2800 feet (800 m) thick near Herd Mountain, Bybee Knoll quadrangle. Thicknesses vary locally due to considerable relief on the basal erosional surface.

South of the map area, the total Wasatch thickness reportedly is as much as about 5000 feet (1525 m) with 4500 feet (1370 m) measured in an incomplete section in the southern Morgan Valley, Porterville quadrangle (Mann, 1974), south of the Weber River. However, the exact location of this measured section is uncertain; it appears to have started near the top of the Wasatch Formation near Whites Crossing (King reconnaissance mapping), but it may not have ended at the bottom of the Wasatch Formation. Also, Mann (1974) reported about 950 feet (290 m) of covered strata with schist boulder float at the base of his Wasatch section northwest of East Canyon Reservoir. However, boulder conglomerate with crystalline rock clasts is characteristic of the basal conglomerate of the Cretaceous Hams Fork Member of the Evanston Formation to the north near Devils Slide (see DeCelles, 1994).

Twc **Basal conglomerate of Wasatch Formation (upper Paleocene)** – Red-orange- and tan-weathering, cobble conglomerate, mainly containing Neoproterozoic and Cambrian quartzite clasts (DeCelles, 1994; see also Mann, 1974, site A, p. 75); forms prominent cliffs along the western tributaries of Lost Creek in Devils Slide quadrangle; likely more extensive than mapped because thinner exposures are poorly cemented and are likely masked by colluvium from adjacent mudstones; 0 to 400 feet (0–120 m) thick. Age based on P5-6 palynomorphs in Wasatch strata as shown by Nichols and Bryant (1990) and as noted above in unit Tw.

CRETACEOUS

Keh, Keh?

Hams Fork Member of Evanston Formation (Upper Cretaceous, Maastrichtian and Campanian) – Light-gray, brownish-gray, and tan sandstone, conglomeratic sandstone, and quartzite- and chert-pebble conglomerate, variegated gray, greenish-gray, and reddish-gray mudstone; coal locality is shown in Phil Shop Hollow by Mullens and Laraway (1964) (locations in section 3, T. 3 N., R. 3 E. SLBM are ours not theirs); palynology sample (P3903-2), stratigraphically above the coal and near the Wasatch Formation contact (not on our map because location is uncertain), is Maastrichtian-upper Campanian (Jacobson and Nichols, 1982, p. 740), although reported as latest Maastrichtian in Lamerson (1982, p. 324); a sample from the Causey Dam quadrangle (Mullens and Laraway, 1964) was reported as Late Cretaceous age (Lance Formation age [Maastrichtian]) (Leopold in Mullens, 1971, p. 13); up to about 600 feet (180 m) thick in Devils Slide quadrangle, not including basal conglomerate (Kehc, Kehc?). Regionally the same ages are derived from palynology (see Jacobson and Nichols, 1982; Coogan and King 2016, appendix tables 1 and 2). Queried on Thaynes Formation ridge where unit may be Wasatch Formation or surficial deposits, and queried along Quarry Cottonwood Creek and on Park City–Phosphoria Formation (Keh?/Pp) where unit may be surficial deposits. The Hams Fork is at least locally prone to slope failures due to high clay content and poor consolidation. Like unit Tw, permeability is variable.

Regionally, unconformably truncated and locally absent beneath the Wasatch Formation. In the hanging wall of the East Canyon thrust also unconformably truncated and locally absent, although King speculates that this may be an effect of movement of the salt welt rather than anything to do with the East Canyon thrust. Regionally the member thickens to the north, from 300 feet (90 m) at Echo Canyon Junction (to southeast of Devils Slide quadrangle) to 1200 feet (365 m) to the north near Lost Creek Dam (Coogan 2004b), and then thins to absence to the north below the angular unconformity at the base of the Wasatch Formation (Coogan, 2006a-b). The Member coarsens downward to the basal conglomerate (Kehc, Kehc?) that is mapped separately where possible.

This unit was named the Hams Fork Conglomerate Member by Oriel and Tracey (1970), but conglomerate in the name is dropped in the Ogden 30 x 60-minute quadrangle because strata are mostly sandstone and mudstone with only local basal conglomerate. Further, as demonstrated by the contained clasts (quartzite with lesser chert and limestone from Paleozoic rock), these geographically separate conglomerates have different source areas (compare Oriel and Tracey, 1970, p. 9 to DeCelles, 1994 and DeCelles and Cavazza, 1999, figure 10). Our Hams Fork unit has lithologies, in particular coaly beds and chert and quartzite granule and pebble beds like the lower member of Oriel and Tracey (1970), which underlies their Hams Fork Conglomerate Member. But, they reported that the lower member pinches out to the south (Oriel and Tracey, 1970, p. 6), north of our map area. Our basal conglomerate and their Hams Fork conglomerate likely have slightly different ages.

Kehc, Kehc?

Basal conglomerate of Hams Fork Member (Upper Cretaceous) – Tan, brownish-gray, and gray, cobble to boulder conglomerate with minor interbedded gray, carbonaceous mudstone; conglomerate contains greater than 80% Neoproterozoic and Cambrian quartzite clasts, but locally contains roughly 5% clasts of Triassic and Jurassic sandstone and rare Precambrian crystalline basement (schist and gneiss) clasts (DeCelles, 1994); regionally 0 to 400 feet (0–120 m) thick (see Coogan, 2004a-b; 2010a-b); west of East Canyon fault, Kehc is about 200 to 240 feet (60–70 m) thick on south margin of quadrangle and to north apparently is up to 400 feet (120 m) thick, with base not exposed and upper contact uncertain; appears to pinch-out in lower Echo Canyon to south in Coalville 7.5-minute quadrangle (Coogan, unpublished mapping) and to west above Powder Hollow in Devils Slide quadrangle.

Queried where earlier mapping by Coogan (unpublished) identified the unit as the basal conglomerate; but the Kehc-Keh contact was later removed by Coogan, and the conglomerates where placed in unit Keh. Based on aerial photograph and field observations (Kehc? looks like Kehc), King put the contact back on this map (Keh-Kehc?). The basal conglomerate (Kehc) is not mapped separately from Keh north of Weber River and may pinch out to the north because the distinctive cliff-forming strata of Kehc and Kehc? are not present at the base of Keh north of the river. The basal Hams Fork conglomerate is absent to the north in the Peck Canyon quadrangle along the regional basal angular unconformity (Coogan, 2004c). To the south Mann (1974) measured about 950 feet (290 m) of covered strata with Precambrian schist boulder float northwest of East Canyon Reservoir, but called it Wasatch Formation.

Kwc, Kwc?

Weber Canyon Conglomerate (Upper Cretaceous, Campanian and late Santonian) – Red, gray, and tan, boulder to cobble conglomerate with minor sandstone and mudstone interbeds; forms prominent cliffs; clasts from Tintic Quartzite, Weber Sandstone, Nugget Sandstone, Lodgepole Limestone, Park City Formation and Twin Creek Limestone (DeCelles, 1994) (list order not by age or abundance); contains progressive intraformational unconformities; overlies older rocks with angular unconformity; exposures continue south of Devils Slide quadrangle, west of East Canyon fault, and were shown by Bryant (1990) as Echo Canyon Conglomerate (his Ke); near cement plant about 1000 foot (300 m) thickness exposed in axis of syncline, with bottom not exposed, but does not appear much thicker between basal exposure on west limb of syncline and syncline axis; reportedly at least 1900 feet (580 m) thick near Devils Slide (DeCelles, 1994), but his figure 2 sketch map includes about 700 feet (215 m) of Hams Fork (Keh and Kehc) in his Weber Canyon Conglomerate.

Queried where Coogan did not label the outcrop and where colluvial cover (Qc/Kwc?) makes identification uncertain. East of the map area in the northwest limb of the Stevenson syncline the underlying older rocks include the Upper Cretaceous Echo Canyon Conglomerate, Henefer Formation, and Frontier Formation (see Coogan, 2010a-b); these Upper Cretaceous units are not present in the Devils Slide quadrangle.

Kk **Kelvin Formation (Lower Cretaceous, Albian and Aptian)** – More completely exposed to east in adjacent Henefer quadrangle (see Coogan, 2010b). Upper part mainly light-gray, tan, and light-reddish-gray, coarse-grained, cross-bedded sandstone and pebbly sandstone with abundant chert; interbedded with gray, tan, and minor reddish-gray and gray-green mudstone and siltstone; upper part up to 2300 feet (700 m) thick to south near Wanship (Eardley, 1944) and overlain by the Aspen Shale (Hale, 1960; Trexler, 1966), which is not present or not exposed near Henefer (see Coogan, 2010a-b). Lower one-third dominantly red-weathering, with reddish-gray and tan mudstone and siltstone; contains thin, discontinuous beds of nodular, blue-gray and lavender, micritic limestone (Morrison of some workers); gray and reddish-gray, coarse-grained, pebbly sandstone with reddish-gray, chert-pebble conglomerate toward base; exposed lower one-third reportedly up to 700 feet (210 m) thick (Eardley, 1944), but not clear where this thickness is exposed in his map area. Total Kelvin thickness east of Croyden at least 5700 feet (1740 m), with base not exposed (after Coogan, 2010a-b; since base and top not exposed near Henefer) due to fault truncation; based on topography, outcrop pattern, and bedding dip, King estimates thickness near Croydon as about 5600 to 6000 feet (1700–1800 m); about 6000 feet (1800 m) was penetrated in Gulf Richins well in East Canyon graben (section 32, T. 3N., R. 4E. SLBM), but Twin Creek Limestone thickness in same well (API 43-043-30256, Utah DOGM well and log files) is about twice its surface thickness of 2850 feet (870 m), possibly indicating Kelvin thickness in well is not stratigraphic thickness.

South of the map area along East Canyon Creek, Granger (1953) noted Weber and older quartzite clasts and a few Carboniferous limestone pebbles in the Kelvin; his uppermost conglomerate may not be part of the Kelvin. Farther south and to the east between Peoa and Wanship, Kelvin conglomerate clasts in four conspicuous beds were described as black, red, and yellow-colored chert in a lower bed, with a few quartzite pebbles that may be from Weber Sandstone in a second bed, and in an upper conglomerate bed where most of the large boulders were quartzite (Weber?) and the small pebbles were mostly chert. Some pebbles of Nugget Sandstone and Paleozoic limestone are present (see Eardley, 1944, p. 838).

JURASSIC

Jsp, Jsp?

Stump Formation and Preuss Redbeds, undivided (Upper and Middle Jurassic) – Mapped in small exposure south of Croydon and queried in large exposures in Main Canyon Creek valley; combined unit is about 1000 feet (300

m) thick to northeast at Toone Canyon, Lost Creek Dam quadrangle (Coogan, 2004b). The queried unit is reddish with some visible bedding that may or may not contain Stump Formation (note photogrammetric dips on map). The Jsp? unit grades into reddish clay, silt, and sand with only a hint of bedding that may be conglomerate-poor Wasatch Formation overlying residual Stump-Preuss deposits ("caprock") above the dissolving salt welt in Main Canyon Creek valley and the divide between Henefer Valley and Lost Creek valley (shown on map as Tw?/Jsp?). Palynomorphs from sample 99-11 are Jurassic but are not stage diagnostic (Coogan, 2010 a-b). However, the sample also contained Cretaceous morphotaxa (see Coogan and King, 2016, appendix table 1) that may have been recycled from or be from thin remnants of the Cretaceous Weber Canyon and Evanston Formations.

Stump Formation (Upper and Middle Jurassic) – Pale-red, yellow, gray, and green-gray shale and calcareous sandstone; at least locally green and glauconitic; about 100-foot- (30 m) thick covered interval of gray-green sandy soil represents the Stump at Toone Canyon (Coogan, 2004b) to the northeast; exposed Stump is 220 and 250 feet (67 and 76 m) thick about 25 miles (40 km) south of Devils Slide near Peoa and about 25 miles (40 km) north of Devils Slide near Walton Creek, respectively; underlying contact with Preuss is at least locally unconformable (Pipiringos and Imlay, 1979).

Jp, Jp?, Jps

Preuss Redbeds (Middle Jurassic) – Red and purplish-red sandstone, siltstone, and shale; poorly exposed; basal halite and anhydrite in subsurface (Jps); about 900 feet (270 m) thick to north at Toone Canyon (Coogan, 2004b), and 1196 feet (365 m) thick near Peoa (Thomas and Krueger, 1946) about 25 miles (40 km) away on north flank of Uinta Mountains; queried where may be Wasatch Formation or surficial deposits in Main Canyon Creek valley.

Subsurface thickness south of map area in the East Canyon graben is about 900 to 1250 feet (275–380 m), likely including Stump strata, which is about the same as surface thicknesses. An additional 0 to 700 feet (210 m) of saline strata was cut in the Gulf Richins well (API 43-043-30256, Utah DOGM; section 32, T. 3N., R. 4E. SLBM) and possibly as much as 6000 to 7500 feet (1800–2300 m) of salt was penetrated in the Amoco Franklin Canyon well (section 20, T. 3N., R. 4E. SLBM), but bed dips seem to indicate this well is in steeply dipping Preuss strata (see Lamerson, 1982, p. 325; API 43-043-30070, Utah DOGM well files). See Yonkee and others (1997, figure 28) for a complex interpretation of Franklin Canyon well.

Jtc **Twin Creek Limestone (Middle Jurassic)** – Mostly white- to gray-weathering, shaley limestone with some shale; mapped along back-thrust east of Powder Hollow; member descriptions from Coogan (2004b) to northeast in Lost Creek drainage where member thicknesses total ~2850 feet (870 m); similar, although incomplete, 2722-foot (825 m) thickness at Devils Slide, with member thicknesses (shown below) from Imlay (1967, p. 11, 13). Jtgl on cross section combines Jtgc and Jtl, while Jtrs combines Jtr and Jts. Potential groundwater source with variable permeability enhanced by cleavage noted in member descriptions; permeabilities and porosities in gas and oil fields near Evanston, Wyoming, are summarized in Chidsey (2016, table 4.1).

Jtgc **Giraffe Creek Member (Middle Jurassic)** – Gray, greenish-gray, and tannish-gray, calcareous sandstone and lime grainstone; forms ridges; total thickness about 225 feet (70 m) to northeast in Lost Creek drainage (Coogan, 2004b); 108-foot (35 m) exposed partial thickness at Devils Slide (Imlay, 1967), thrust truncated. Contact with underlying Leeds Creek Member is the most difficult to pick of member contacts in the Twin Creek Limestone; this has likely led to the disparate thicknesses reported for these members, particularly in subsurface.

Jtl, Jtl? **Leeds Creek Member (Middle Jurassic)** – Light-gray, thin- to very thick bedded, soft, clay-rich micritic limestone with tan silt partings; locally exhibits bedding-normal pencil cleavage; forms barren scree-covered slopes; 1000 to 1200 feet (300–365 m) thick to northeast in Lost Creek drainage (Coogan, 2004b); 1289 feet (393 m) thick at Devils Slide (Imlay, 1967). Queried where poorly exposed and member identification uncertain.

Jtw, Jtw?

Watton Canyon Member (Middle Jurassic) – Dark-gray, lime micrite (mudstone) and wackstone and minor oolite packstone; forms prominent ridges; locally exhibits bedding-normal stylolitic, spaced cleavage; about 400 feet (120 m) thick to northeast in Lost Creek drainage (Coogan, 2004b); 380 feet (115 m) thick at Devils Slide (Imlay, 1967). Queried where poorly exposed and member identification uncertain.

Jtb, Jtb?

Boundary Ridge Member (Middle Jurassic) – Gray, very thick bedded, ridge-forming, oolitic, lime grainstone to wackestone beds in middle and upper part that separate reddish and purplish siltstone and gray, silty limestone beds in middle and lower part; 100 to 250 feet (30–75 m) thick in Lost Creek drainage (Coogan, 2004b); about 100 feet (30 m) thick at Devils Slide (Imlay, 1967). Devils Slide (geographic feature) is in this unit and not in the Sliderock Member, which was named for Sliderock in Wyoming (see Imlay, 1967). Queried where poorly exposed and member identification uncertain.

Jtr, Jtr? **Rich Member (Middle Jurassic)** – Light-gray, thin- to very thick bedded, clay-rich, micritic limestone in upper part, and gray, lime wackestone in lower part; locally exhibits bedding-normal pencil cleavage; forms barren scree-covered slopes; about 500 feet (150 m) thick in Lost Creek drainage (Coogan, 2004b); 540 feet (165 m) thick at Devils Slide (Imlay, 1967). Queried where poorly exposed and member identification uncertain.

Jts **Sliderock Member (Middle Jurassic)** – Dark-gray, very thick bedded, lime wackestone in upper part and dark-gray, pelecypod and crinoid grainstone in lower part; forms small ridges; 100 to 227 feet (30–70 m) thick in Lost Creek drainage (Coogan, 2004b); 100 feet (30 m) thick at Devils Slide (Imlay, 1967); middle covered part at Devils Slide may be variegated siltstone and shaley sandstone exposed at Birch Creek (see Imlay, 1967).

Jtgs **Gypsum Spring Member (Middle Jurassic?)** – Red siltstone and sandstone, and gray, vuggy dolomite, with anhydrite in subsurface; up to 208 feet (65 m) thick at Devils Slide (Imlay, 1967). Despite its sharp upper and lower contacts (Imlay, 1967, p. 18), the Gypsum Spring is separated from overlying and underlying units by unconformities (see Imaly, 1980, figures 26–28). Where the Twin Creek is not present in Wyoming, the Gypsum Spring is a separate Formation (see Love and others, 1993), but Oriel (1969, p. 10) noted that the member in the Twin Creek does not include the entire Gypsum Spring Formation. See appendix for palynology data supplied by D.A. Sprinkel.

Isotopic dating of the Gypsum Spring in the Devils Slide quadrangle (see table 4 and Kowallis and others, 2011) implies a 10-million-year unconformity between the Pliensbachian Gypsum Spring and overlying Bajocian Twin Creek Limestone. For isotopic ages of Jurassic stage boundaries see for example Palfy and others (2000). The span of the overlying unconformity may be shorter if the tuff bed is not airfall (reworking of older material will make the unconformity seem larger) or the Jurassic stage boundaries are askew (see for examples Palfy and others, 2000, figure 3).

Jn **Nugget Sandstone (Lower Jurassic)** – Pale-grayish-orange, pinkish-tan, and locally off-white, well-cemented, cross-bedded, quartz sandstone; thickness here estimated by King (from outcrop pattern, dip, and topography) as about 1250 to 1360 feet (380–415 m); about 1100 feet (335 m) thick to northeast at Toone Canyon, Lost Creek Dam quadrangle (Coogan, 2004b); thickness of about 1500 feet (460 m) reported near Devils Slide by Eardley (1944) is about 10% too large. Potential groundwater source; permeabilities and porosities in gas and oil fields near Evanston, Wyoming, are summarized in Chidsey (2016, table 3.1).

South of the Uinta Mountains near Vernal, High and others (1969) and Sprinkel and others (2011) place less resistant, planar-bedded, reddish Triassic sandstone beds in the Nugget Sandstone that would be mapped, if present, as part of the Triassic Ankareh Formation in the Overthrust (fold-and-thrust) belt north of the Uinta Mountains in Utah, Wyoming, and Idaho. To the east in Wyoming, north of Colorado and east of Utah, as the Nugget thins and disappears, planar-bedded Nugget-like sandstones are interbedded (intertongued?) with shaly units that look like the Triassic Chugwater Group/Formation (Bell Springs unit of Pipiringos, 1968) and specifically the Jelm Formation. In Wyoming, this interbedded relationship is visible in the Rawlins Uplift and the age of the Bell Springs strata is conjecture (see Pipiringos, 1968).

TRIASSIC

Thickness estimates by King from outcrop pattern, bedding dip, and topography in the Devils Slide quadrangle.

Ꞧa **Ankareh Formation, undivided (Triassic)** – Shown on cross section and combines members Ꞧas, Ꞧag, and Ꞧam; see Kummel (1954) for a regional look at members of the Ankareh Formation.

Ꞧas **Stanaker Member or upper member (Wood Shale Tongue?) of Ankareh Formation (Upper Triassic)** – Bright orange-red shale, siltstone, and sandstone; locally micaceous; an estimated 600 feet (185 m) thick near Devils Slide and 680 feet (210 m) thick several miles south of Weber River; Schick (1955) reported 515-foot (155 m) exposed thickness near Devils Slide, but contradicted this thickness in his cross section; Mullens and Laraway (1964) showed about 750 feet (230 m) thickness in their cross section (including our ₮ag unit). In Lost Creek drainage called Wood Shale Tongue because Higham Grit, Timothy Sandstone, and Portneuf Limestone (all Idaho names) are present (see Coogan, 2004a).

₮ag **Gartra Grit(?) Member of Ankareh Formation (Triassic)** – Red, buff and gray, gritty micaceous sandstone reported; no greenish sandstone, conglomerate (granule or pebble), or limestone reported, lithologies indicative of the Higham Grit, Timothy Sandstone, and Portneuf Limestone; 43 to 76 feet (15–23 m) thick (Shinarump of Scott, 1954; Schick, 1955); Smith (1969) reported a 30-foot (9 m) thick, locally conglomeratic unit in the middle of the Ankareh and called it Gartra Grit. Unit may not be the Gartra; it may be the Higham Grit or Timothy Sandstone, part of the middle unit mapped to the northeast in the Lost Creek drainage (see Coogan, 2004a).

Middle unit to the northeast is about 200 feet (60 m) thick and, in contrast to Devils Slide, includes gray and greenish-gray, micaceous, quartz-granule sandstone at top (Higham Grit); middle greenish-gray, lithic-pebble conglomerate in middle, containing green siltstone clasts and rare fossil wood fragments (Timothy Sandstone Member of Thaynes Formation); and thin (2 feet [0.6 m]), gray and lavender, mottled limestone at base (Portneuf Limestone Member of the Thaynes Formation) (Coogan, 2004a).

If granule conglomeratic or gritty rocks are the only rock types present at Devils Slide, this unit should be called the Gartra Grit Member of the Ankareh and the units above and below are the upper (or Stanaker) and Mahogany Members of the Ankareh, respectively. Despite assertions that the Higham, Gartra, and Shinarump Conglomerate are equivalent units, each of these coarser units have their own geographic distribution (depositional area) and source area, as indicated by differing clasts (see Kummel, 1954; Stewart and others, 1972; and references above), and likely have their own timing following the Middle Triassic unconformity. Further, Thomas and Krueger (1946, p. 1273) indicated the conglomerate beds called Gartra have at least two different source areas.

₮am **Mahogany Member (Lanes Tongue?) of Ankareh Formation (Lower Triassic)** – Purple and brownish-red shale, siltstone, and sandstone (Coogan, 2004a, Lanes Tongue); an estimated 600 feet (185 m) thick near Devils Slide and 725 feet (220 m) thick several miles south of the Weber River. In Lost Creek drainage called Lanes Tongue because other units named in Idaho are present (see Coogan, 2004a).

Previously reported and shown thicknesses near Devils Slide vary widely, with 465-foot (140 m) exposed thickness reported by Schick (1955), with buff to gray siltstone and sandstone, but Schick (1955) contradicted this thickness in his cross section; to a 785-foot (240 m) thickness reported by Scott (1954); to about 850 feet (260 m) thick on the cross section of Mullens and Laraway (1964); and about 920-foot (280 m) thickness reported by Smith (1969).

Thaynes Formation (Lower Triassic) – Gray, silty limestone and calcareous shale and siltstone; estimated thickness of 1850 feet (565 m) (upper tongue of Dinwoody not included) from several miles south of Weber River in this quadrangle, similar to 1835-foot (560 m) thickness to northeast in Lost Creek drainage (note revision to Coogan, 2004a) that may or may not include the upper tongue of Dinwoody; 2200-foot (670 m) exposed thickness reported near Devils Slide (Eardley, 1944) likely includes upper tongue of Dinwoody. Scott's (1954) thicknesses at Devils Slide for the Thaynes, as well as the Ankareh, Dinwoody and Woodside, are mostly about 1.5 times thicker than what most workers have measured; at least some of Smith's (1969) member thicknesses are also too large.

Note that Kummel's (1954) members from about 70 miles (110 km) to the north near Bear Lake in Idaho are recognizable in this section and that most of these members are recognizable another 25 miles (40 km) to the southwest near Salt Lake City, Utah (see Mathews, 1931; Solien and others, 1979). Member descriptions after and thicknesses from Francis Canyon quadrangle, Lost Creek drainage (Coogan, 2004a) with estimated thicknesses from several miles south of the Weber River in the Devils Slide quadrangle. Members ₮tu and ₮tms are combined as unit ₮tus on cross section, while the Thaynes members below ₮tms are combined with the upper tongue of the Dinwoody Formation as unit ₮to on cross section.

₮tu **Upper calcareous siltstone member (Lower Triassic)** – Brownish-gray, thin-bedded, calcareous siltstone and thin-bedded, gray, fossiliferous limestone; an estimated 1035 feet (315 m) thick in Devils Slide quadrangle and about 1050 feet (320 m) thick in Francis Canyon quadrangle (note revision to Coogan, 2004a); Scott (1954, units 2–13) measured 1240 feet (380 m) while Smith (1969, units 161–225) measured about 1053.5 feet (321 m) of upper calcareous siltstone member.

Ŧtms, Ŧtms?

Middle shale member (Lower Triassic) – Gray, thin-bedded, calcareous, silty shale; queried where member identification uncertain; an estimated 115 feet (35 m) thick in Devils Slide quadrangle and about 100 feet (30 m) thick in Francis Canyon quadrangle; Scott (1954, unit 14 and possibly units 15–24) measured about 160 or possibly 285 feet (50–87 m), while Smith (1969, units 151–160) measured about 280 feet (85 m) of middle shale member. Coogan (2006a-b) lumped this member in his unit Ŧtu in the Horse Ridge and Dairy Ridge quadrangles.

Ŧtml **Middle limestone member (Lower Triassic)** – Gray, very thick to medium-bedded, fossiliferous limestone; forms prominent ridge; an estimated 230 feet (70 m) thick in Devils Slide quadrangle and about 110 feet (33 m) thick in Francis Canyon quadrangle. Scott (1954, unit 25) measured about 640 feet (195 m), while Smith (1969, units 139–150) measured about 120 feet (35 m) of middle limestone member; neither measurement seems correct.

Ŧtls **Lower shale member (Lower Triassic)** – Gray to brownish-gray, thin-bedded, calcareous siltstone to silty shale; lower half is likely reddish sandy siltstone of Decker Tongue of Ankareh Formation; unit Ŧtls an estimated 185 feet (55 m) thick in the Devils Slide quadrangle and about 375 feet (115 m) thick in Francis Canyon quadrangle, but poor exposures there may mean this reported thickness is too large; Scott (1954, unit 26) measured about 230 feet (70 m), while Smith (1969, unit 138 and lower part of unit 139, and Decker Tongue) measured about 140 feet (45 m) of lower shale member.

Ŧtll **Lower limestone member (Lower Triassic)** – Gray to grayish-brown, thick- to thin-bedded, fossiliferous limestone with *Meekoceras* ammonite zone at base; near Salt Lake City mapped with upper tongue of Dinwoody Formation (Ŧdu) as single unit with ammonite zone in the middle (see for example Solien and others, 1979); lower member an estimated 285 feet (85 m) thick in Devils Slide quadrangle; about 200-foot (60 m) thickness reported in Francis Canyon quadrangle (after Coogan, 2004a) and to north in Dairy Ridge quadrangle lower limestone member is 200 feet (60 m) thick (Coogan, 2006a); Scott (1954, units 27 and 28) measured about 315 feet (95 m) of lower limestone member of Thaynes, while Smith (1969, top of unit 120 through unit 135) measured about 270 feet (80 m).

Ŧdu **Upper tongue of Dinwoody Formation (Lower Triassic)** – Silty limestone and calcareous siltstone that is less resistant than overlying unit (Ŧtll) and is present below the *Meekoceras* ammonite zone; map unit an estimated 285 feet (85 m) thick in Devils Slide quadrangle; to north in Dairy Ridge quadrangle upper tongue of Dinwoody is 250 feet (75 m) thick and is greenish-gray and tan (Coogan, 2006a). Scott (1954, units 29 and 30) measured about 530 feet (160 m) of strata (Dinwoody tongue) below the ammonite zone, while Smith (1969, units 74 to most of 120) likely measured about 560 feet (170 m); both measurements are about twice as thick as our map thickness.

Ŧwd **Woodside and Dinwoody Formations, undivided (Lower Triassic)** – Only shown on cross section.

Ŧw **Woodside Shale (Lower Triassic)** – Dark-red, sandy shale and siltstone, with some sandstone; an estimated 500 feet (150 m) thick in Devils Slide quadrangle.

Other thicknesses reported near Devils Slide vary widely from 600-foot (180 m) thickness reported by Eardley (1944); to 755-foot (248 m) thickness reported by Scott (1954), although his figure 15 shows only about 600 feet (185 m) of Woodside with the rest being Dinwoody; to 800-foot (245 m) thickness shown by Mullens and Laraway (1964, cross section); and Smith (1969) reported about 990-foot (300 m) thickness but with about 135 feet (40 m) covered. The 384-foot (120 m) thickness reported at Salt Lake City is not red (Granger, 1953), so could all be upper tongue of Dinwoody (Ŧdu).

Ŧd **Dinwoody Formation (Lower Triassic)** – Greenish-gray and tan, calcareous siltstone and silty limestone; an estimated 300 feet (90 m) thick in Devils Slide quadrangle 500-foot (150 m) thickness shown by Mullens and Laraway (1964, cross section); Smith (1969) reported about 290 feet (88 m) of Dinwoody, but we are unsure that Smith's Dinwoody contacts are the same as those used on our map. Cheney and Sheldon (1959) described greenish-gray calcareous shale with a few beds of fossiliferous carbonate above the Franson Member of the Park City Formation at Devils Slide, but they called these 190 feet (58 m) of strata Woodside. Eardley (1944) apparently placed the Dinwoody strata in his overly thick upper division of the Park City Formation.

PERMIAN

Pp, Pp?

Park City and Phosphoria Formations, undivided (Permian) – Mapped north of Weber River where individual units cannot be consistently separated due to structural complexity; also used on cross section; queried where may be upper Weber Sandstone (Pℙwu). Total thickness near Taggarts 857 feet (260 m) but lower two units likely faulted (Cheney and others, 1953; Cheney, 1957). U.S. Geological Survey trench may be lower cut that is visible south of Weber River. Formations were also examined by Williams (1943), but his units do not fit well with Meade Peak and Grandeur Members used here.

Where possible divided into:

Ppf **Franson Member of Park City Formation (Permian)** – Interbedded gray to pinkish-gray to dark-gray, vuggy, cherty limestone, with lesser gray shale and calcareous sandstone; 242 feet (75 m) thick (Cheney and others, 1953; Cheney, 1957). Dark-gray and black, bedded chert of Rex Chert Member of Phosphoria Formation probably present. Williams (1943) noted 170 feet (52 m) of sandstone with chert (Rex) and 140 feet (43 m) of sandstone that probably make up this unit.

Ppm, Ppm?

Meade Peak Phosphatic Shale Member of Phosphoria (Permian) – Gray limestone, dark-gray to black, phosphatic siltstone and shale, and gray, calcareous sandstone; typically less resistant than overlying and underlying members; queried where member identification uncertain; 303 feet (90 m) thick (Cheney and others, 1953; Cheney, 1957). Williams (1943) noted 40 feet (12 m) of phosphate, 575 feet (175 m) of limestone and sandstone, and 8 feet (2.5 m) of basal phosphate; his thicknesses for the Park City and Phosphoria units, like those of Eardley (1944), are too large compared to our mapping.

Ppg, Ppg?

Grandeur Member of Park City (Permian) – Light-gray, thick-bedded, calcareous to dolomitic sandstone with gray chert nodules; queried where member identification uncertain; 312 feet (95 m) thick (Cheney and others, 1953; Cheney, 1957). Williams (1943) noted 65 feet (20 m) of limestone and 65 feet (20 m) of sandstone, with underlying 230 feet (70 m) of sandstone that is partly conglomeratic and contains intraformational breccia (flat-pebble conglomerate); both conglomerates are atypical of the Grandeur, as is the reddish coloration noted by Williams (1943, p. 597).

PERMIAN AND PENNSYLVANIAN

Pℙw, ℙwl, ℙwl?, Pℙwu

Weber Sandstone (Lower Permian and Pennsylvanian) – Gray, indurated, quartzose sandstone with dolomite and siltstone in lower part; where possible King divided Weber into ℙwl (lower) with distinct regular bedding and Pℙwu (upper) with less distinct bedding; lower unit queried (ℙwl?) west of back-thrust and north of Round Valley where complex structure makes it difficult to determine if any of the upper unit is present, and ℙwl-Pℙwu contact queried where separation of units is even more difficult. Reportedly 2260 to 3300 feet (690 to 975 m) thick near Morgan (after Williams, 1943; Eardley, 1944; Bissell and Childs, 1958; Mullens and Laraway, 1973); but, these thicknesses are likely from near the Weber River, so are likely from complexly folded strata and are across a back-thrust. King's estimated thickness of ~2600 feet (790 m) (from outcrop pattern, dip, and topography) is from about 2 miles (3.2 km) north of Weber River where two monoclines are present but Weber strata are not thrust faulted. See Williams (1943, p. 598) for fossils. Likely at least partly non-marine eolian (see Fryberger, 1979).

The lower Weber (ℙwl) may be units 1–3 of Eardley (1944) and *Fusulina*-bearing and older strata of Bissell and Childs (1958); both about 1000 feet (300 m) thick. The lower Weber does not appear to be the Desmoinesian and older strata of Welsh and Bissell (1979, p. Y18 and Y23) because Bissell (1964) identified Desmoinesian *Wedekindellina* sp. fusulinids to within 378 feet (115 m) of the top of the Weber (rounded to 400 feet). Since Bissell (1964) noted Permian *Schwagerina* sp. fusulinids in the uppermost Weber, the disconformity of Welsh and Bissell (1979, p. Y22) is not at the ℙwl-Pℙwu contact or the back-thrust in upper Weber (Pℙwu) in the Devils Slide quadrangle.

PENNSYLVANIAN

IPm **Morgan Formation (Pennsylvanian)** – Reddish brown-weathering sandstone, siltstone and limestone that grade northward into light-gray lower part of Weber Sandstone, as seen to west in adjacent Morgan quadrangle, and "pinching" out to north in southern Durst Mountain quadrangle (Coogan and King, 2006); thrust faulted into Weber rather than intertongued, also seen to west in adjacent Morgan quadrangle (Coogan and others, 2015); only exposed along thrust fault on west margin of Devils Slide quadrangle; likely unconformably overlies Round Valley Limestone (see Eardley, 1944 p. 832–833); 0 to ~1000 feet (0–300 m) thick in Morgan area (Eardley, 1944; Bissell and Childs, 1958; Mullens and Laraway, 1973) (see also Williams, 1943, although he missed the Round Valley Limestone). The type Morgan is Desmoinesian (see Sadlick, 1955); also see Williams (1943) for fossils.

Blackwelder (1910) described the contact between the Morgan Formation and underlying Round Valley Limestone (his Morgan-Mississippian limestone) as an unconformity with red strata that bear clasts of the underlying limestone and chert over a cavernous weathered surface of limestone. This description is significant enough that Eardley (1944, p. 832–833) quoted Blackwelder (1910) and we include it here because it implies karst development. This contact relationship explains the rapid thinning of the Morgan to the north (it was not deposited everywhere above the unconformity). We note that this contact is similar to the Amsden-Madison contact in Wyoming (though the Amsden and Madison are older) (see for example Mallory, 1967; Sando, 1974).

SUBSURFACE UNIT DESCRIPTIONS

Descriptions of concealed units on cross section are from exposures to west in the Durst Mountain and Morgan quadrangles (Coogan and King, 2006; Coogan and others, 2015).

PENNSYLVANIAN?

IPmr **Morgan and Round Valley Formations, undivided (Pennsylvanian)** – See description above for Morgan Formation.

Round Valley Limestone (Pennsylvanian and possibly Mississippian) – Mostly light-gray, fine-grained limestone with regular bedding; about 375 to 400 feet (115–120 m) thick near Morgan (Sadlick, 1955; Crittenden, 1959, p. 70; Mullens and Laraway, 1973).

MISSISSIPPIAN

Mdo **Doughnut Formation, undivided (Upper Mississippian)** – Includes upper member of limestone and siltstone that is about 300 feet (90 m) thick on Durst Mountain (Crittenden, 1959, p. 70, his units 3–6; Mullens and Laraway, 1973; Coogan and King, 2006), and lower (shale) member of siltstone, black shale, and limestone that is an estimated 200 feet (60 m) thick on Durst Mountain (see also Crittenden, 1959, p. 70, his unit 2).

Mh **Humbug Formation (Upper Mississippian)** – Tan- to reddish weathering, interbedded calcareous to dolomitic, quartzose sandstone, and sandy limestone and dolomite; lower part contains more sandstone and is less resistant than upper part; estimated total thickness 700 feet (215 m) on Durst Mountain (Coogan and King, 2006); see also Crittenden (1959, p. 70, his unit 1).

Mde **Deseret Limestone (Mississippian)** – Limestone, dolomite, and sandstone, with dark, less-resistant, shaly, phosphatic strata at base (Delle Phosphatic Shale Member); about 500 feet (150 m) thick in Morgan quadrangle (Mullens and Laraway, 1973) and estimated on Durst Mountain (Coogan and King, 2006).

Ml **Lodgepole Limestone (Lower Mississippian**) – Gray, fossiliferous limestone and lesser dolomitic limestone, locally cherty; estimate thickness as 650 feet (200 m) on Durst Mountain (Coogan and King, 2006; Coogan and others, 2015); reported thicknesses about 650, 755, and 800 feet (200, 230, and 245 m) (Eardley, 1944, Madison near Morgan; Williams, 1943, Madison at Weber Canyon; Mullens and Laraway, 1973, near Morgan, respectively).

DEVONIAN

Db **Beirdneau Sandstone (Devonian)** – Reddish-tan to tan to yellowish-gray, calcareous sandstone and siltstone, some silty to sandy dolomite and limestone, and lesser intraformational (flat-pebble) conglomerate; less resistant than adjacent units; estimate thickness as 200 feet (60 m); field thickness in Durst Mountain quadrangle of about 300 feet (90 m) (Coogan and King, 2006); reported thicknesses near Morgan about 185 and 230 feet (55 and 70 m) (Eliason, 1969; Three Forks of Mullens and Laraway, 1973, respectively); like the Hyrum, Eliason (1969) measured the Beirdneau where both formations appear to be at their thinnest on Durst Mountain. A bed of brownish-gray dolomite, resembling Hyrum Dolomite, is present in middle part of Beirdneau to northeast on the Crawford thrust sheet in Horse Ridge quadrangle (Coogan, 2006b), and a thin (~10–20 feet [3–6 m]) bed seems to be present on Durst Mountain as well, although the color is slightly different (see Coogan and King, 2006; Coogan and others, 2015).

Dhw **Hyrum and Water Canyon Formations, undivided (Devonian)**

Hyrum Dolomite (Devonian) – Brownish-gray and gray dolomite and minor limestone; more resistant at top and bottom with center of less resistant beds that grade laterally into reddish, dirty carbonate like the Beirdneau Sandstone; this gradation created problems in mapping Db-Dh contacts and faults cutting these units, and estimating thicknesses; estimate thickness as 250 to 450 feet (75–140 m) on Durst Mountain (Coogan and King, 2006); reported thickness of about 136 feet (40 m) (Eliason, 1969) is too thin relative to adjacent units and Eliason (1969) measured the Hyrum where it appears to be at its thinnest on Durst Mountain; unconformably overlies Water Canyon Formation.

Water Canyon Formation (Devonian) – Light-yellow-gray to medium-gray, interbedded calcareous sandstone and silty to sandy dolomite and limestone, with sandstone below carbonate and a distinctive very light gray, yellow-weathering dolomite at top; less resistant than underlying and overlying unit; estimate 200 feet (60 m) thick on Durst Mountain (Coogan and King, 2006); see also Eardley (1944), his Cambrian units 9–12 are 155 feet (47 m) thick in total; only about 100 to 150 feet (30–45 m) thick to northeast on leading edge of Willard thrust sheet (Coogan, 2006a-b).

SILURIAN AND ORDOVICIAN

Missing on Durst Mountain, along with all or most(?) of St. Charles Formation equivalent strata (uppermost Cambrian), due to thinning over Tooele arch and/or Stansbury uplift (see Hintze, 1959 and Rigby, 1959, respectively). Note that about 15 miles (25 km) to the northwest in Ogden Canyon, 1000 feet (300 m) of Ordovician and upper Cambrian strata are present (Fish Haven, Garden City, and St. Charles Formations), as is part of the Bloomington Formation between the Nounan and Maxfield. The Nounan and Maxfield are also thicker in Ogden Canyon, although the Ophir and Tintic are about the same thickness (see Yonkee and Lowe, 2004).

CAMBRIAN

Cn **Nounan Formation (Upper and Middle Cambrian)** – Medium-gray, typically thick-bedded dolomite and some limestone; estimate 350 to 400 feet (105–120 m) thick on Durst Mountain (see Coogan and King, 2006); see also Eardley (1944), his Cambrian units 6, 7, and 8 are 315 feet (95 m) thick in total. Underlying Bloomington Formation not present on Durst Mountain.

Cm **Maxfield Limestone (Middle Cambrian)** – Limestone and calcareous siltstone; estimate thickness as 300 feet (90 m) on Durst Mountain (Coogan and King, 2006); at least 280-foot (80 m) thickness inferred from Eardley (1944, Cambrian units 3–5), that is, at least to top of his limestone edgewise (flat-pebble) conglomerate; not consistently divisible into members; much thicker to west in Wasatch Range (see Yonkee and Lowe, 2004). Cambrian limestone (Cl) of Mullens and Laraway (1973) includes Maxfield and upper shale member of Ophir Formation.

Co **Ophir Formation, undivided (Middle Cambrian)** – Consists of upper and lower gray to olive-gray, variably calcareous and micaceous to silty argillite to slate with intercalated gray, silty limestone beds, and middle gray, micritic limestone. Highly deformed in most outcrops causing highly variable apparent thicknesses, but estimate at least 440 to 725 feet (135–220 m) thick on Durst Mountain (Coogan and King, 2006; Coogan and others, 2015). Ophir of Eardley (1944) and Mullens and Laraway (1973) is only the lower argillite member and their lower marker bed is likely the middle limestone member.

Ct **Tintic Quartzite (Middle and Lower? Cambrian)** – Tan, very well-cemented quartzite; conglomeratic in lower half with Precambrian quartzite pebbles and cobbles; basal 50 to 100 feet (15–30 m) is arkosic conglomerate derived from unconformably underlying Farmington Canyon Complex material; Eardley (1944) reported about 1000-foot (300 m) thickness at Durst Mountain.

PROTEROZOIC

Xfc **Farmington Canyon Complex (lower Proterozoic)** – Micaceous schistose and gneissic crystalline rocks with small bodies of amphibolite and pegmatite, variously called dikes and pods; Barnett and others (1993) reported the various isotopic ages of the complex in the Wasatch Range and concluded it is latest Early Proterozoic (about 1700 Ma) in age; more detailed information on the complex in the Wasatch Range is available in Bryant (1988) and Yonkee and Lowe (2004).

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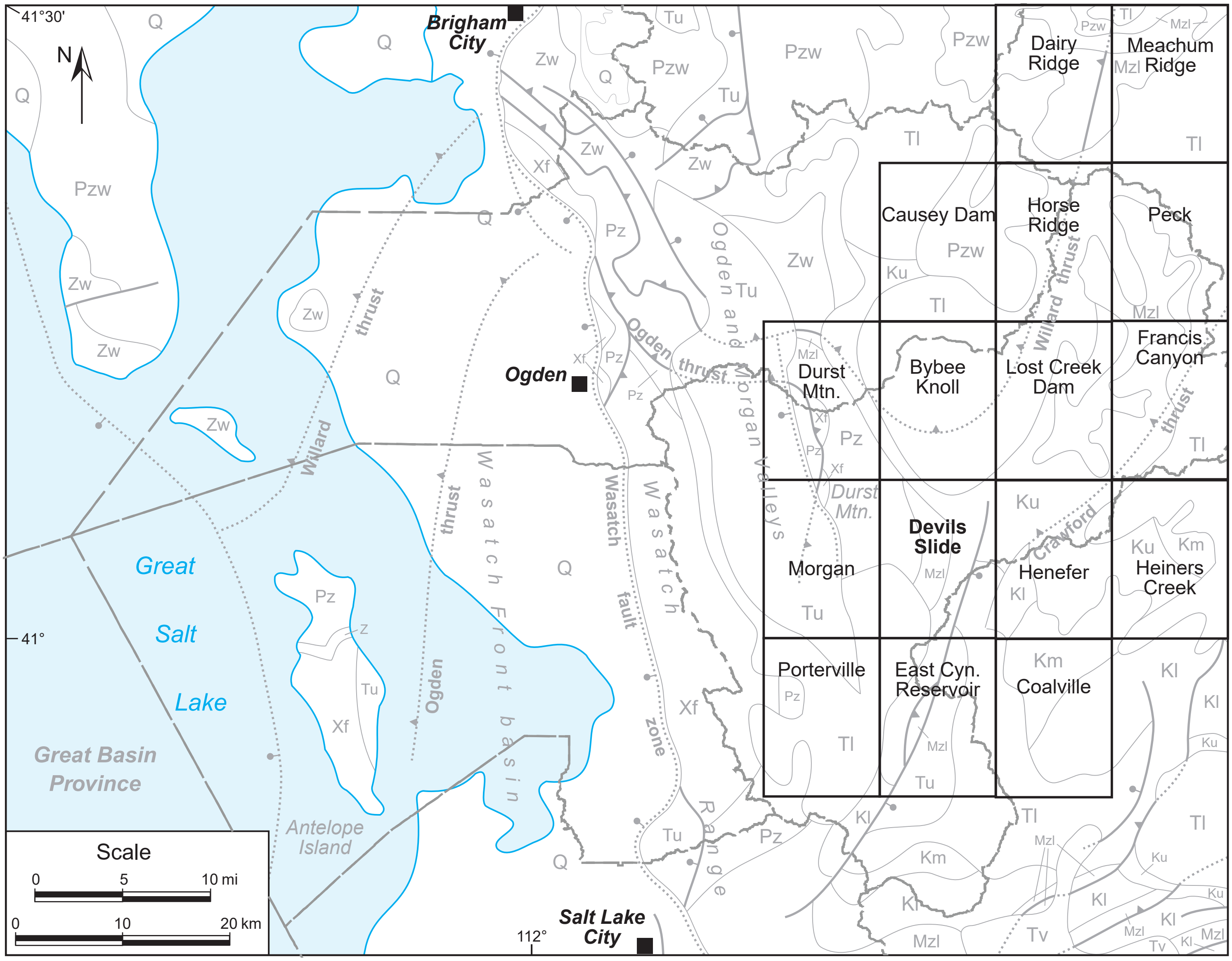


Q Quaternary deposits
Tu Tertiary, upper
Tl Tertiary, lower
Tv Tertiary volcanics
Ku Cretaceous, upper
Km Cretaceous, middle
Kl Cretaceous, lower
Mzl Mesozoic, lower
Pz Paleozoic
Pzw Paleozoic, Willard thrust sheet
Zw Late Proterozoic, Willard thrust sheet
Xf Farmington Canyon Complex

Figure 1. Generalized geologic map (modified from Yonkee and others, 1997) showing adjacent quadrangles and those noted in text. Geologic maps of the Dairy Ridge (Coogan, 2006a), Horse Ridge (Coogan, 2006b), Lost Creek (Coogan, 2004b), Francis Canyon (Coogan, 2004a), Henefer (Coogan, 2010b), Durst Mountain (Coogan and King, 2006), and Morgan (Coogan and others, 2015) quadrangles have been published.

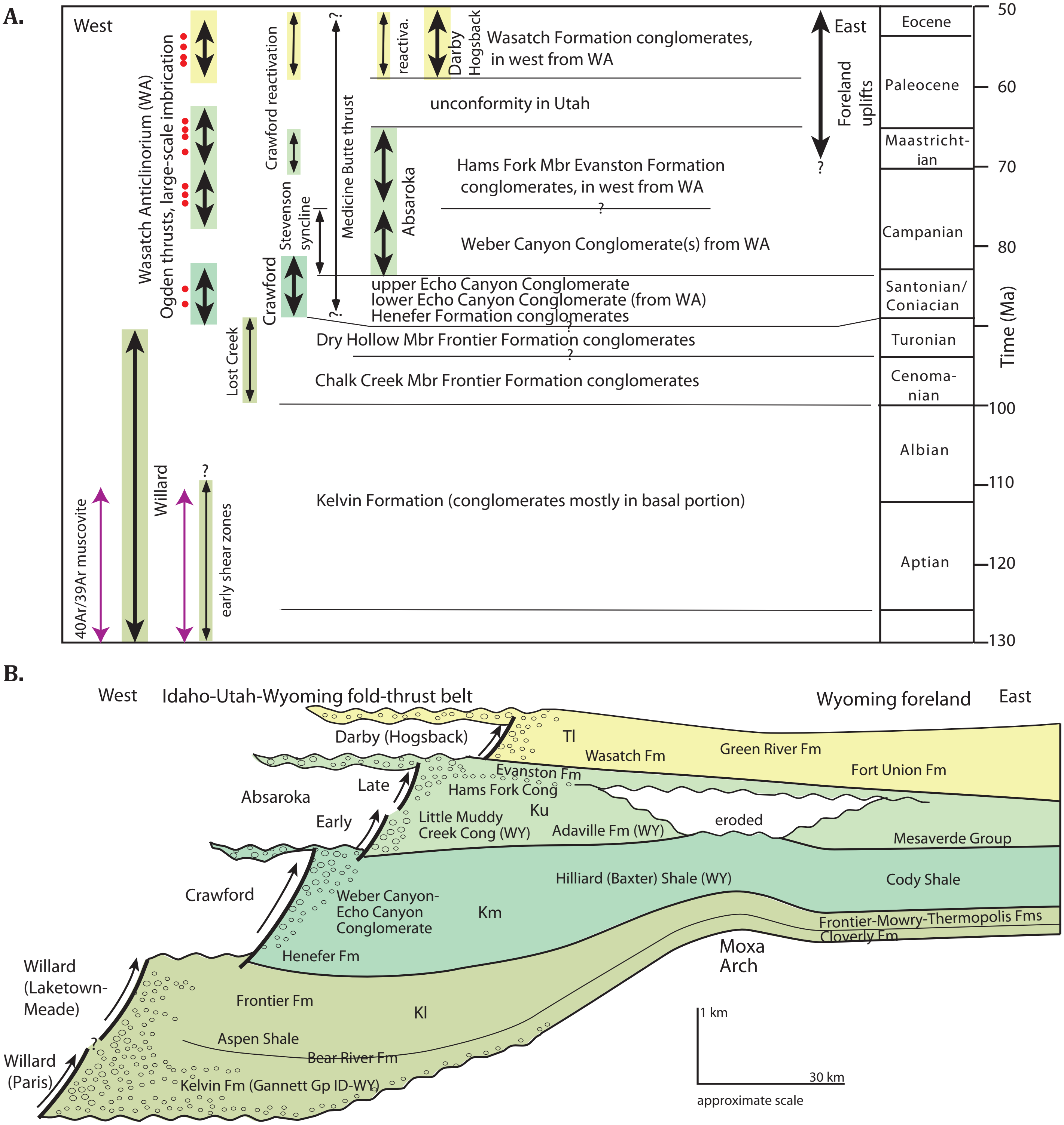


Figure 2. History of thrusting in the Idaho-Utah-Wyoming fold and thrust belt (modified from Yonkee and Weil, 2011; who modified Wiltschko and Dorr, 1983 for A, and Royse and others, 1975 for B). A) Ages of thrusting and synorogenic strata from this compilation and Coogan (2010a-b, appendix). Apatite fission-track ages (red dots) from Naeser and others (1983) and Burtner and Nigrini (1994). Argon-Argon ages from Yonkee and others (1989). B) General thicknesses and names of synorogenic strata in relation to major thrusts from Utah and Wyoming going into the southern Green River Basin. Note that conglomeratic intervals (ellipses) are east and west of associated thrusts, and Cretaceous divisions are informal. Lower Cretaceous strata (Kl) are thickest in the foredeep associated with movement on the Willard-Paris-Laketown (Meade) thrusts. Middle Cretaceous strata (Km) record movement on the Crawford thrust and regional subsidence, indicated by thick shales. Upper Cretaceous strata (Ku) record two episodes of movement on the Absaroka thrusts, along with the uplift of and erosion over the Moxa Arch. Paleocene and Eocene strata (Tl) record movement on the Darby-Hogsback thrust. Thrusts get younger to the east, with limited reactivation and uplift along older thrusts and the Wasatch Anticlinorium (WA).

Table 1. Geologically significant water wells in the Devils Slide quadrangle, from data in Utah Division of Water Rights well drilling database.

Map no.	Cadastral location - feet (ft) from, section, township (T) and range (R)	Total depth in feet (ft)	Interpretation of drillers logs ft=feet
1	N 602ft, W 968ft of E1/4 corner, section 20, T. 4N., R. 4E.	126	Unit Keh at 79 ft or less
2	N 850ft, W 1442ft of SE corner, section 20, T. 4N., R. 4E.	150	Penetrated fault and unit Kwc that are mapped to west
3	N1250ft, W 950ft of SE corner, section 29, T. 4N., R. 4E.	420	Quaternary and unit Tw above 310 ft, unknown unit(s) below
4	70 rods (1155ft?) E, 15ft N of SW corner, section 32, T. 4N., R. 4E.	319	Salt at 250 ft
5	N 403ft, E 102ft of W1/4 corner, section 5, T. 3N., R. 4E.	785	No salt reported, but salt may have been obscured by rotary drilling below 286 ft. Completed above 286 ft, likely in unit QTa?, with perforations above 80 ft likely in unit QTay?
6	S 1865ft, W 65ft of N1/4 corner, section 5, T. 3N., R. 4E.	143	Red shale (unit Jp?) at 106 ft, salt at 141 ft
7	S 3037ft, W 2546ft of NE corner, section 5, T. 3N., R. 4E.	135	Salt at 135 ft

Table 2. Heights of alluvial deposits above adjacent active drainages in Morgan and Round Valleys, and apparently Henefer and Lost Creek Valleys. Heights are from the Morgan, Durst Mountain, Snow Basin, and Peterson quadrangles (see Coogan and others, 2015), as well as the Devils Slide quadrangle. Younger ages (<20 ka) from Lake Bonneville history in C-14 years (see Oviatt and others, 1992). See Chadwick and others (1997) and Phillips and others (1997) for “Bull Lake” and Qaoe ages (cosmogenic ages). Other age estimates from Sullivan and others (1988) and Sullivan and Nelson (1992).

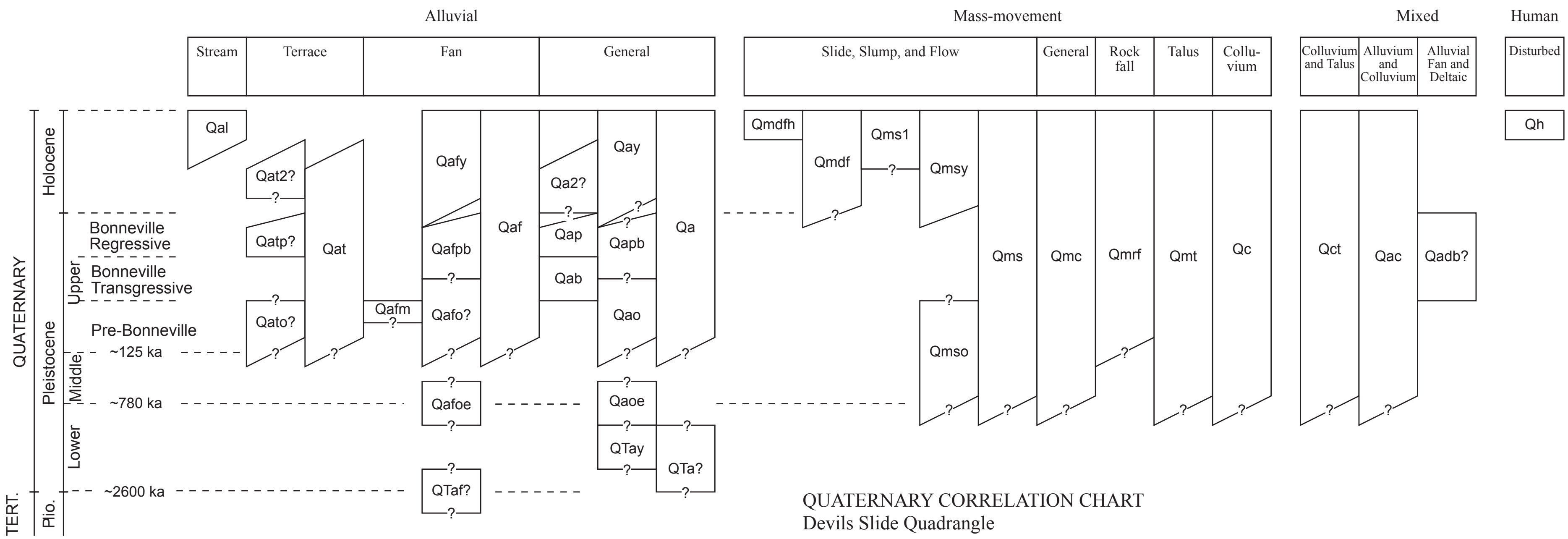
Unit(s)	Feet (m) above drainage	Age (ka=1000) years	Comments
Qal, Qay, Qafy	at to slightly above	<~13 ka	Post Lake Bonneville
Qa2	~15 feet (5 m)	<~13 ka	Younger age limit uncertain, post Lake Bonneville
Qat2	~10 to 20 feet (3-6 m)		
Qaf2	~20 to 40 feet (6-12 m)		
Qap	15 to 40 feet (5-12 m)		
Qatp	20 to 30 feet (6-9 m)	~13-15 ka	Provo shoreline occupation, Lake Bonneville
Qafp	~30 to 45 feet (9-14 m)		
Qab	40 to 90 feet (12-27m)		sites >50 feet (15 m) may be part of unit Qfdb
Qafb	~45 to 55 feet (14-17 m)	~15-20 ka	Bonneville shoreline occupation, Lake Bonneville
Qfdb	~50 to 100 feet (15-30 m)		fans that go into lake and become deltas
Qao	~70 to 120 feet (20-37 m)	~95-130 ka	“Bull Lake” glaciation-related deposits
Qato	~100 feet (30 m)		
Qafo	~70 to 120 feet (20-37 m)	~98-155 ka	amino acid ages, also >70-100 ka soil carbonate age
			≥ 400 ka amino acid age is possible if two alluvial surfaces
Qaoe	120 to 230 feet (35-70 m)	>247ka	>780 ka paleomag age, but paleomag may be on QTay;
Qafoe	~120 to 200 feet (35-60 m)		suspect marine oxygen isotope stage 16
QTay	~215 to 450 feet (66-137 m)	>780 ka	note height overlap with Qaoe
QTao	~320 to 800 feet (100-240 m)	>780 ka	
QTaf	~230 to 300 feet (70-90 m)	>780 ka	may be upstream equivalent of QTay
	~320 to 1000 feet (100-300 m)	>780 ka	may be entirely Pliocene

Table 3. Alluvial surfaces and deposits in Devils Slide quadrangle compared to those in Henefer quadrangle (Henefer and Lost Creek valleys) (Coogan, 2010b), Lost Creek drainage (Lost Creek Dam, Francis Canyon, and Peck Canyon quadrangles) (Coogan, 2004a-c) and Morgan Valley (Durst Mountain, Snow Basin, Peterson, and Morgan quadrangles) (Coogan and King, 2006; King and others, 2008; Coogan and others, 2015); for Round Valley - see Morgan Valley units. Heights are feet above adjacent active drainages.

Surface	Height above, feet	Devils Slide quad units	Henefer quad units	Lost Creek drainage units	Morgan Valley units
2	10-20	Qat2?, Qa2?	Qa2, Qat2	Qat2, Qaf2	Qa2, Qat2
2-3	20-30, 40?	Qap, Qatp?, Qafpb?	Qa2-3, Qat2 [Qatp?]	Qaty, Qaf2?	Qap, Qatp, Qaf2
3	40-60	Qab, Qafpb, Qapb	Qa3, Qat3	Qat3, Qaty?	Qab, Qafb
3-4	60-80	Qab, Qafm	Qa3, Qat3 [Qab], Qaf3?	Qat3, Qaf3	Qab, Qfdb
4	80-100	Qafm, Qao, Qmso	Qa4 (lower), Qaf3 [Qaf4]	Qa3, Qaf3?	Qao, Qafo
4-5	100-120	Qao, Qato?, Qafo?, Qmso	Qa4 (upper)	Qao	Qao, Qato, Qafo
5	120-150	Qaoe, Qao?, Qato?, Qafo?	Qa4?		Qaoe, Qafoe
6	160, 170?	Qaoe?	Qa5	Qa5?, Qat4, Qaf4	Qaoe, Qafoe
6-7	170-220	QTay, QTay?	Qa5?	Qa5	Qaoe, Qafoe
7	220 & 240	QTay, QTa?, QTaf?			QTay, QTaf?
8	300?	Qmso			QTa, QTaf
9?	>320	QTa?			QTao, QTaf

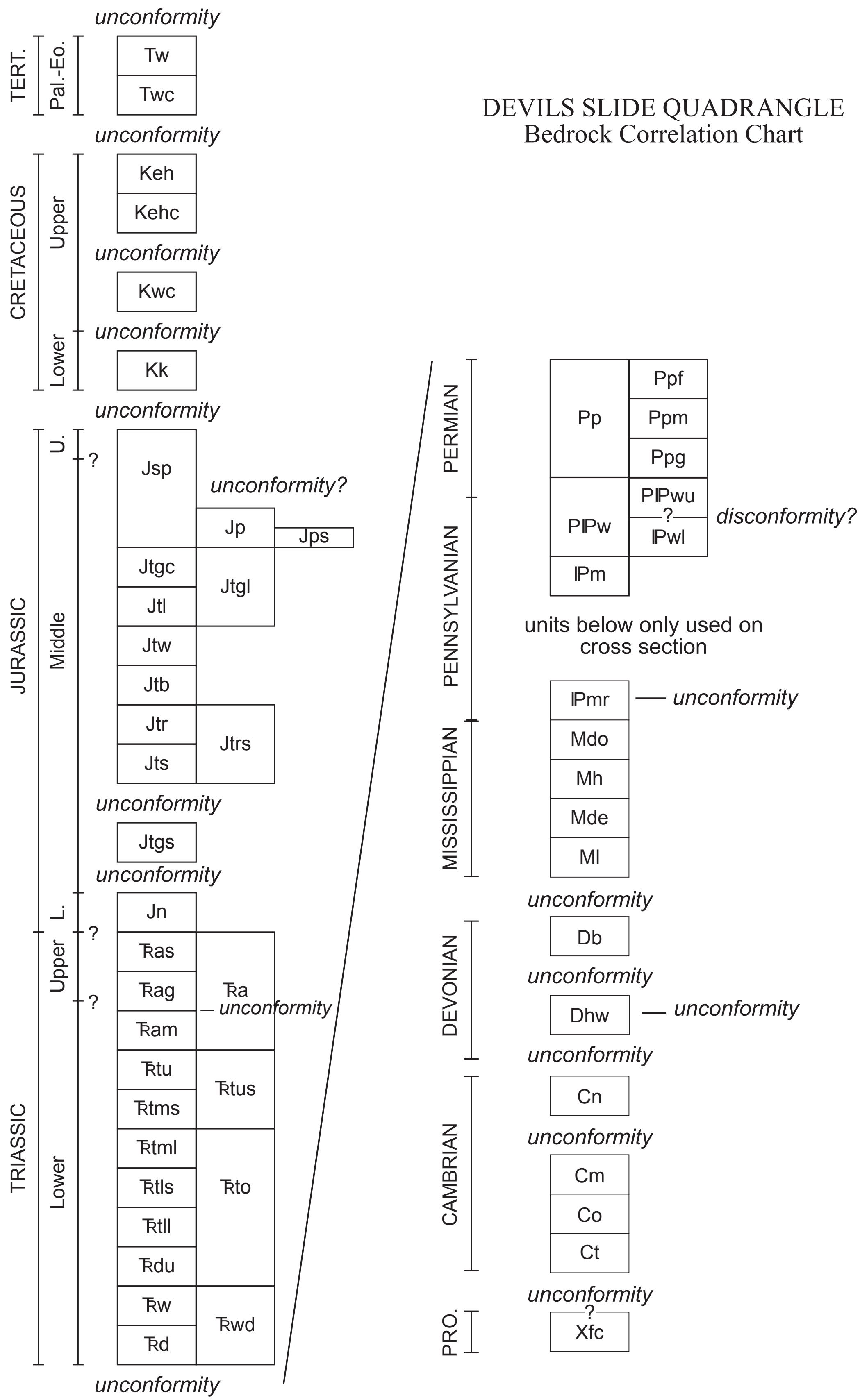
Table 4. Preliminary geochronologic results for Gypsum Spring Formation/Member (Jtgs) samples in Devils Slide quadrangle reported in abstract of Kowallis and others (2011). Toarcian and Aalenian stages missing, indicating an unconformity between these samples and overlying Bajocian-stage Twin Creek Limestone samples. Data provided by Doug Sprinkel of the Utah Geological Survey, but lithology changed to tuff (lithified) from ash (unconsolidated, unlithified). Locations are in WGS84 decimal degrees. Sample DS-040709-4 not plotted on map because no analysis performed.

Sample No.	Map Mbr	Latitude	Longitude	Lithology	Analysis	Age Ma	Error ±Ma	Stage
2000-DS-1	Jtgs	41.066529	-111.549277	Tuff	Ar/Ar sanidine	184.6	0.2	Pliensbachian
DS-040709-1A	Jtgs	41.066535	-111.549278	Tuff	U-Pb zircon	184.3	2.3	Pliensbachian
DS-040709-4		41.066531	-111.549263	Tuff	no crystals recovered			



QUATERNARY CORRELATION CHART
Devils Slide Quadrangle

DEVILS SLIDE QUADRANGLE
Bedrock Correlation Chart



LITHOLOGIC COLUMN - Devils Slide quadrangle

AGE	UNIT SYMBOL		GEOLOGIC UNIT	THICKNESS FEET	THICKNESS METERS	SCHEMATIC COLUMN	OTHER INFORMATION
Q	Q-various		Alluvium and mass movements	0-100?	0-30?		
TERTIARY P	QT		Alluvium, gravel	0-400?	0-120?		
TERTIARY Pal.-Eo.	Tw		Wasatch Formation	~0-5000	~0-1500		
TERTIARY Pal.-Eo.	Twc		basal conglomerate	0-400	0-120		
CRETACEOUS	Keh		Hams Fork Member of Evanston Formation	0-600	0-180		
CRETACEOUS	Kehc		basal conglomerate	0-400	0-120		ANGULAR UNCONFORMITY
CRETACEOUS	Kwc		Weber Canyon Conglomerate	0-1900	0-580		ANGULAR UNCONFORMITY
CRETACEOUS	Kk		Kelvin Formation	3000+	915+		
JURASSIC	Jsp		Stump Sandstone	220-250	67-76		Not in contact; but UNCONFORMITY
JURASSIC	Jp		Preuss Redbeds	~900	~270		UNCONFORMITY Additonal 0 to at least 700 feet (0-215 m) of salt in subsurface
JURASSIC	Jtgc	Twin Creek Limestone	Giraffe Creek Member	225	70		
JURASSIC	Jtl	Twin Creek Limestone	Leeds Creek Member	1000-1300	300-395		
JURASSIC	Jtw	Twin Creek Limestone	Watton Canyon Member	400	120		
JURASSIC	Jtb	Twin Creek Limestone	Boundary Ridge Member	100	30		
JURASSIC	Jtr	Twin Creek Limestone	Rich Member	500-540	145-165		
JURASSIC	Jts	Twin Creek Limestone	Sliderock Member	100	30		UNCONFORMITIES
JURASSIC	Jtgs	Twin Creek Limestone	Gypsum Spring Member	210	65		
JURASSIC ?	Jn		Nugget Sandstone	1250-1360	380-415		
TRIASSIC	Ŧas		Stanaker Mbr (Wood Shale T.?) of Ankareh Fm	600-680	185-210		Wood Shale Tongue to north
TRIASSIC	Ŧag		Gartra Grit Member of Ankareh Formation	30-75	9-23		Timothy Ss, & Portneuf Ls Mbrs, and Higham Grit not present UNCONFORMITY
TRIASSIC	Ŧam		Mahongany Mbr (Lanes T.?) of Ankareh Fm	600-725	185-220		Lanes Tongue to north
TRIASSIC	Ŧtu	Thaynes Fm	upper calcareous siltstone member	~1035	~315		
TRIASSIC	Ŧtms	Thaynes Fm	middle shale member	~115	~35		
TRIASSIC	Ŧtml	Thaynes Fm	middle limestone member	~230	~70		Includes Decker Tongue of Ankareh Formation
TRIASSIC	Ŧtls	Thaynes Fm	lower shale member	~185	~55		
TRIASSIC	Ŧtll	Thaynes Fm	lower limestone member	~285	~85		*Meekoceras* sp. ammonite
TRIASSIC	Ŧdu		Dinwoody Formation, upper tongue	~285	~85		
TRIASSIC	Ŧw		Woodside Shale	~500	~150		
TRIASSIC	Ŧd		Dinwoody Formation	~300	~90		UNCONFORMITY**?**
PERM.	Pp: Ppf		Franson Member of Park City Formation	240	75		
PERM.	Pp: Ppm		Meade Peak Shale Member of Phosphoria Fm	300	90		Phosphatic
PERM.	Pp: Ppg		Grandeur Member of Park City Formation	310	95		
PERM. / PENN.	P₽w: P₽wu —?— ₽wl		Weber Quartzite	~2600	~790		Back thrust and folding instead of disconformity?
PENN.	₽m		Morgan Formation	0-1000	0-300		See Morgan quadrangle (UGS OFR 643) for subsurface strata

Diagram is schematic - no fixed thickness scale

GEOLOGIC SYMBOLS
Devils Slide quadrangle

Contact, dashed where approximately located, dotted where concealed; queried where existence uncertain

Contact (purple), human disturbance that post dates 1986 aerial photographs used in geologic mapping

Contact (red), concealed due to human disturbance; location from Mullens and Laraway (1964)

Salt welt extent, concealed

Fault, dashed where approximately located, dotted where concealed, sense of movement unknown

Normal fault, bar and ball on downthrown side, dashed where approximately located, dotted where concealed; arrow and number indicate photogrammetric dip on fault; arrow on cross section shows sense of offset

Thrust fault, teeth on upper plate, dotted where concealed; arrow and number indicate photogrammetric dip on fault; arrow on cross section show sense of offset; bar and ball indicates later normal fault offset, shown with double-headed arrow on cross section; dashed on cross section where approximately located; query on cross section indicates existence uncertain,

Lineament, fold axis or fault, but offset uncertain

Major folds, for clarity projected under thin surficial deposits

Anticline hinge-zone trace, dashed where approximately located, dotted where concealed, arrow shows plunge

Syncline hinge-zone trace, dashed where approximately located (very approximate for broad syncline in Tertiary units and unit Keh), dotted where concealed, arrow shows plunge

Overturned synform hinge-zone trace, dashed because approximately located

Overturned antiform hinge-zone trace, dashed because approximately located

Monocline (flexure) hinge zone trace, dashed where approximately located, arrow shows plunge

Monocline, anticlinal bend on left, synclinal bend on right

Lake Bonneville shoreline

Bonneville (about 5180 feet [1579 m])

Mass-movement scarp

Strike and dip of bedding (attitudes in red from Mullens and Laraway, 1964)

50 45 50 Upright (top known from bedding indicators on right)

65 75 85 Overturned (top known from bedding indicators on right)

Vertical

Horizontal

45 75 Photogrammetric, upright on left; overturned on right

70 Strike and dip of cleavage

1 Borehole, selected; see table 1

Adit

Prospect, with prospective material (in red from Mullens and Laraway, 1964)
coal
Cu = copper

Trench, PO4 = Phosphate, PS = Paleoseismic Study

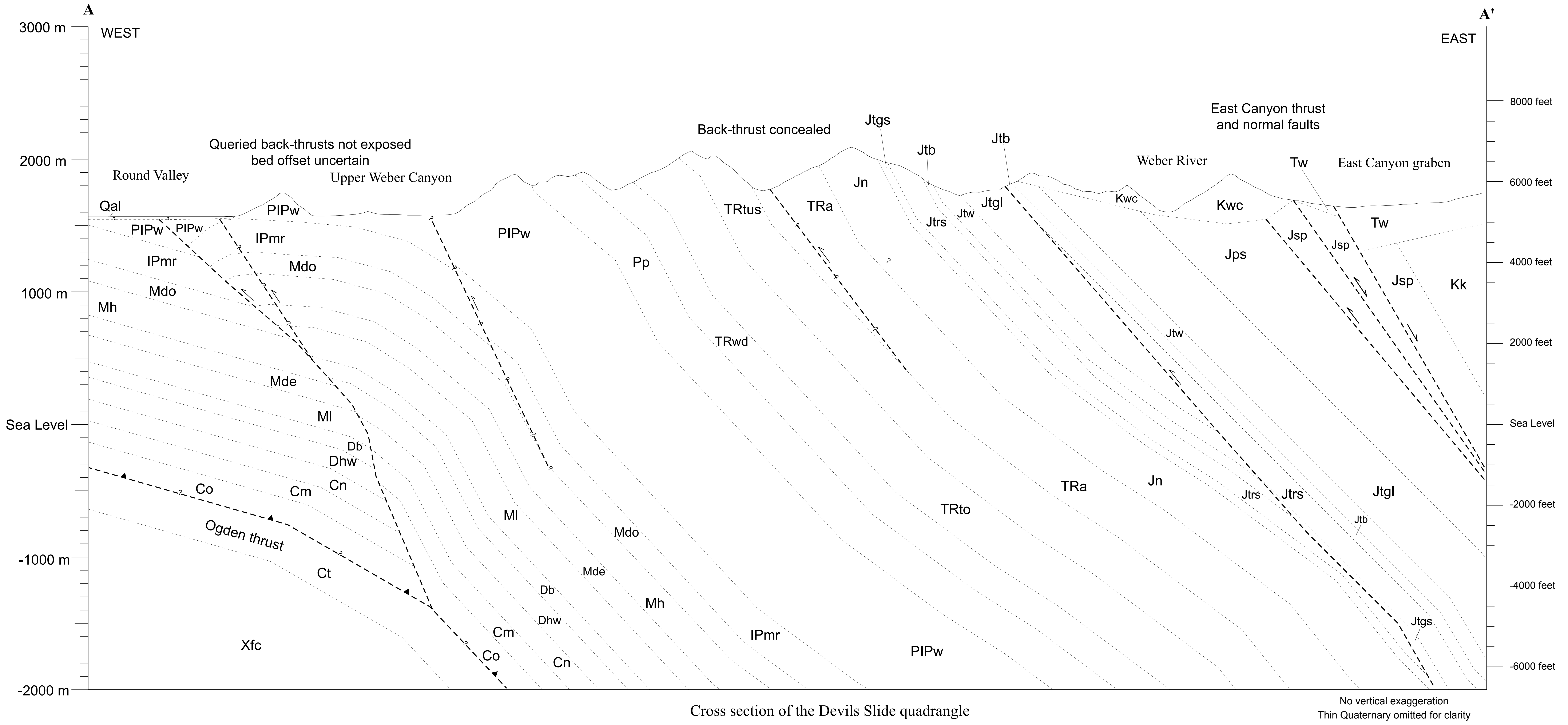
Sample location

DS092603-1 Palynology; see Appendix

2000-DS-1 Isotopic dating; see table 4

Q_/ Thin Quaternary unit over another unit (for example Qc/Jtc in Weber Canyon near Devils Slide)

Qms(block)
Qms?(Tw) Landslide with nearly intact rotated blocks of unit in parentheses; for example Qms(Tw); queried where blocks may be in place.



Cross section of the Devils Slide quadrangle

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APPENDIX

This appendix contains the preliminary palynological results of Twin Creek Limestone samples from the Devils Slide quadrangle analyzed by Dr. Gerald Waanders and are provided with locations and units by Doug Sprinkel of the Utah Geological Survey (written communications, March 30, 2010 and December 12, 2012). Locations are in WGS84 decimal degrees. Barren samples are not plotted on map.

Map no.	Sample No.	Map Mbr	Age/Stage	Lithology	Latitude	Longitude	lower Sprinkel unit	upper Sprinkel unit
	DS-063003-1		barren	Limestone	41.066529	-111.549301	8 (Jgs)	
	DS-063003-3		barren	Mudstone	41.066527	-111.549211	10 (Jgs)	
	DS-063003-4		barren	Limestone	41.066531	-111.548979	15 (Jgs)	
1	DS-063003-5	Jts	Bajocian to Bathonian	Limestone	41.067222	-111.547778	20 (Jts)	
2	DS-063003-6	Jts	Bajocian to Bathonian	Limestone	41.067222	-111.547500	21 (Jts)	
3	DS-092603-1	Jtr	Jurassic undiff.	Limestone	41.068314	-111.545721		7 (Jtr)
4	DS-092603-2	Jtw	Jurassic undiff.	Siltstone-Mudstone	41.068333	-111.544620		18 (Jtb)
5	DS-092603-3	Jtw	Bajocian to Bathonian	Limestone	41.068258	-111.544342		22 (Jtw)
6	DS-092603-4	Jtw	Bajocian to Bathonian	Limestone	41.067464	-111.544489		28 (Jtl)
	DS-092603-5		barren	Limestone	41.066718	-111.542778		21 (Jtw)
7	DS-102403-1	Jtl	Bathonian	Limestone	41.066726	-111.542216		32a (Jtl)
8	DS-102403-2	Jtl	Bathonian	Limestone	41.066393	-111.540965		32c (Jtl)
9	DS-102403-3	Jtgc	Callovian	Mudstone	41.064431	-111.539400		32d (Jtl)

Jts=Sliderock Member
Jtr=Rich Member
Jtw=Watton Canyon Member
Jtl=Leeds Creek Member
Jtgc=Giraffe Creek Member

Gerald Waanders
Consulting Palynologist

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March 17, 2004

TO: Mr. Douglas A. Sprinkel
Utah Geological Survey
1594 West N. Temple, Suite 3110
P. O. Box 146100
Salt Lake City, Utah 84114-6100

RE: Palynology analysis of outcrop samples received from Doug Sprinkel: DS063003-1, -2, -3, -4, -5, -6, DS092603-1, -2, -3, -4, -5, DS102403-1, -2, -3.

PO#308415; SS#04176

PALYNOLOGY REPORT

Twenty-five samples were processed and analyzed for palynomorphs. A list of the taxa found and their relative abundances is provided for each sample examined (R=rare, F=frequent, C=common and A=abundant). An estimate of the kerogen content (total organic recovery), paleoenvironment and age is also indicated.

9. DS063003-1, Unit 8, Gypsum Springs.

Barren of Palynomorphs

Kerogen Content: 100% Woody/Inertinite

T.A.I: Indeterminate

AGE: Indeterminate

ENVIRONMENT: Indeterminate

10. DS063003-2, Unit 88, Volcanic ash, Gypsum Springs

Paly. analysis of 25 Miscellaneous outcrop samples received from Doug Sprinkel.

Barren of Palynomorphs

Kerogen Content:	100% Woody/Inertinite
T.A.I:	Indeterminate
AGE:	**Indeterminate**
ENVIRONMENT:	**Indeterminate**

11. DS063003-3, Unit 10, Gypsum Springs

Barren of Palynomorphs

Kerogen Content:	100% Woody/Inertinite
T.A.I:	Indeterminate
AGE:	**Indeterminate**
ENVIRONMENT:	**Indeterminate**

12. DS063003-4, Unit 15, Limestone.

Barren of Palynomorphs

Kerogen Content:	100% Woody/Inertinite
T.A.I:	Indeterminate
AGE:	**Indeterminate**
ENVIRONMENT:	**Indeterminate**

13. DS063003-5, unit 20, Rich?

Spores and Pollen:

Araucariacites australis	(R)
Cerebropollenites mesozoicus	(R)
Callialasporites dampieri	(R)
Classopollis classoides	(R)

Paly. analysis of 25 Miscellaneous outcrop samples received from Doug Sprinkel.

Exesipollenites tumulus	(R)
Perinopollenites elatoides	(R)
Undifferentiated Bisaccates	

Microplankton:

Barbatacysta verrucosum	(R)
Leptodinium subtile	(R)
Tasmanites sp.	(A)

Kerogen Content: 70% Amorphous, 20% Cuticular and 10% Woody

T.A.I: 2.5

AGE: **Bajocian to Bathonian**

ENVIRONMENT: **Nearshore Marine, Lagoonal/Estuarine**

14. DS063003-6, unit 20, Rich?

Spores and Pollen:

Araucariacites australis	(F)
Cerebropollenites mesozoicus	(F)
Callialasporites dampieri	(R)
C. triangulus	(R)
Classopollis classoides	(R)
Corrugatisporites amplectiformis	(R)
Deltoidospora spp.	(C)
Exesipollenites tumulus	(R)
Klukisporites pseudoreticulatus	(R)
Undifferentiated Bisaccates	(A)

Microplankton:

Barbatacysta verrucosum	(F)
Microforaminifera linings	(R)
Tasmanites sp.	(C)
Tythodiscus sp.	(R)

Kerogen Content: 40% Amorphous, 10% Cuticular and 50% Woody

T.A.I: 2.5

AGE: **Bajocian to Bathonian**

Paly. analysis of 25 Miscellaneous outcrop samples received from Doug Sprinkel.

ENVIRONMENT: Nearshore Marine, Lagoonal/Estuarine

15. DS092603-1, unit 7, Rich (upper resistant bed).

Spores and Pollen:

Araucariacites australis	(C)
Callialasporites dampieri	(R)
Cerebropollenites mesozoicus	(R)
Classopollis spp.	(R)
Deltoidospora spp.	(F)
Exesipollenites tumulus	(R)
Leptolepidites psarosus	(R)
Undifferentiated Bisaccates	(R)

Kerogen Content: 85% Amorphous, 5% Cuticular and 10% Woody

T.A.I: 2.5

AGE: Jurassic (Undifferentiated)

ENVIRONMENT: Restricted Marine/Lacustrine

16. DS092603-2, unit 18, Boundary Ridge.

Spores and Pollen:

Araucariacites australis	(R)
Cerebropollenites mesozoicus	(R)
Classopollis spp.	(R)
Exesipollenites tumulus	(F)
Undifferentiated Bisaccates	(R)

Kerogen Content: 20% Amorphous, 50% Cuticular and 10% Woody

T.A.I: 2.5

AGE: Jurassic (Undifferentiated)

ENVIRONMENT: Estuarine/Deltaic

17. DS092603-3, unit 21, Boundary Ridge/Watton Canyon?

Spores and Pollen:

Paly. analysis of 25 Miscellaneous outcrop samples received from Doug Sprinkel.

Araucariacites australis	(C)
Callialasporites dampieri	(R)
Cerebropollenites mesozoicus	(R)
Classopollis spp.	(R)
Deltoidospora spp.	(R)
Exesipollenites tumulus	(R)

Microplankton:

Barbatacysta verrucosum	(C)
Durotrigia filipicatum	(R)
Lithodinia jurassica	(R)

Kerogen Content: 20% Cuticular and 80% Woody

T.A.I: 2.5

AGE: Bajocian to Bathonian

ENVIRONMENT: Nearshore Marine, Lagoonal/Estuarine

18. DS092603-4, unit 22, Watton Canyon.

Spores and Pollen:

Araucariacites australis	(R)
Callialasporites dampieri	(F)
C. triangulus	(F)
Cerebropollenites mesozoicus	(R)
Classopollis spp.	(C)
Deltoidospora spp.	(F)
Exesipollenites tumulus	(A)
Undifferentiated Bisaccates	(F)

Microplankton:

Barbatacysta verrucosum	(C)
Korystocysta pachydermum	(R)
Tasmanites sp.	(R)

Kerogen Content: 50% Amorphous, 25% Cuticular and 25% Woody

T.A.I: 2.5

AGE: Bajocian to Bathonian

Paly. analysis of 25 Miscellaneous outcrop samples received from Doug Sprinkel.

ENVIRONMENT: Nearshore Marine, Lagoonal/Estuarine

19. DS092603-5, Unit 28, Watton Canyon.

Barren of Palynomorphs

Kerogen Content: 5% Cuticular and 95% Woody

T.A.I: 2.5

AGE: Indeterminate

ENVIRONMENT: Fluvial/Deltaic

20. DS102403-1, Leeds Creek

Spores and Pollen:

Araucariacites australis	(R)
Cerebropollenites mesozoicus	(F)
Callialasporites dampieri	(R)
C. triangulus	(R)
Classopollis classoides	(A)
Deltoidospora spp.	(R)
Exesipollenites tumulus	(R)
Phyllocladidites sp.	(R)
Rugubivesiculites sp.	(R)
Undifferentiated Bisaccates	(F)

Microplankton:

Barbatacysta verrucosum	(F)
Chlamydophorella sp. (*Sentusi.*, Van Pelt)	(R)
Epiplosphaera reticulata	(R)
Leptodinium subtile	(R)
L. subtile subsp*. pectinigerum*	(R)
Tasmanites sp.	(C)
Valensiella ovula	(R)

Kerogen Content: 20% Amorphous, 30% Cuticular and 50% Woody

T.A.I: 2.5

AGE: Bathonian

Paly. analysis of 25 Miscellaneous outcrop samples received from Doug Sprinkel.

ENVIRONMENT: Nearshore Marine Shelf

21. DS102403-2, Leeds Creek.

Spores and Pollen:

Araucariacites australis	(R)
Cerebropollenites mesozoicus	(R)
Callialasporites dampieri	(R)
Classopollis classoides	(R)
Corrugatisporites amplectiformis	(R)
Deltoidospora spp.	(R)
Exesipollenites tumulus	(R)
Undifferentiated Bisaccates	(R)

Microplankton:

Barbatacysta verrucosum	(F)
Chlamydophorella sp. (*Sentusi.*, Van Pelt)	(R)
Ctenidodinium continuum	(R)
C. ornatum	(R)
Durotrigia filipicata	(R)
Gonyaulacysta jurassica	(R)
G. sp.	(R)
Epiplosphaera reticulata	(A)
Korystocysta pachydermum	(R)
Leptodinium subtile	(R)
Microforaminifera linings	(F)
Rynchodiniopsis cladophora	(F)
Tythodiscus sp.	(C)
Valensiella ovula	(F)
V. vermiculata	(R)

Kerogen Content: 20% Amorphous, 20% Cuticular and 60% Woody

T.A.I: 2.5

AGE: Bathonian

ENVIRONMENT: Open Marine Shelf

22. DS102403-3, near top of Leeds Creek.

Spores and Pollen:

Paly. analysis of 25 Miscellaneous outcrop samples received from Doug Sprinkel.

Acanthotriletes sp.	(R)
Araucariacites australis	(R)
Cerebropollenites mesozoicus	(R)
Callialasporites dampieri	(A)
C. triangulus	(R)
C. trilobatus	(R)
Cingulatisporites sp.	(R)
Classopollis classoides	(A)
Deltoidospora spp.	(A)
Exesipollenites tumulus	(R)
Foraminisporis wonthaggiensis	(R)
Foveotriletes canalis	(R)
Klukisporites pseudoreticulatus	(R)
Podocarpidites sp.	(R)
Punctatosporites sp.	(R)
Trilobosporites jurassica	(R)
Undifferentiated Bisaccates	(C)

Microplankton:

Barbatacysta verrucosum	(F)
Chlamydophorella sp. (*Sentusi.*, Van Pelt)	(R)
Durotrigia filipicata	(R)
Endoscrinium galeritum	(R)
Gonyaulacysta jurassica	(R)
Leptodinium subtile	(F)
Lithodinia deflandrei	(R)
Microforaminifera linings	(R)
Pareodinia ceratophora	(R)
Tasmanites sp.	(R)

Kerogen Content: 5% Amorphous, 20% Cuticular and 75% Woody

T.A.I: 2.5

AGE: Callovian

ENVIRONMENT: Nearshore Marine Shelf

Analysis By:

Gerald Waanders

Gerald Waanders
Consulting Palynologist

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April 17, 2009

TO: Mr. Douglas A. Sprinkel
Utah Geological Survey
1594 West N. Temple, Suite 3110
P. O. Box 146100
Salt Lake City, Utah 84114-6100

RE: Palynology analysis of 3 Gypsum Spring outcrop samples from the Devils Slide Section.

PO#: 312021

PALYNOLOGY REPORT

Three samples were processed and analyzed for palynomorphs. The samples were all barren of palynomorphs. HCl reactions, total organic recoveries, kerogen contents, T.A.I.'s (Thermal Alteration Indices) and paleoenvironments are provided below.

1. DS040709-21b; Gypsum Spring collected 1.5 m above ash dated at 184 Ma, UTM: 0453759 easting, 4546398 northing.

Barren of Palynomorphs

HCl Reaction: Strong

Total Organic Recovery: Poor

Kerogen Content: 30% Amorphous, 20% Cuticular and 50% Woody

T.A.I: 0.4-0.5% Equivalent R_0

AGE: Indeterminate

ENVIRONMENT: Nearshore Restricted Marine/Lacustrine

RE: Palynology analysis of 3 Gypsum Spring outcrop samples from the Devils Slide Section.

2. DS040709-2; Gypsum Spring, collected 23 m below ash dated at 184 Ma, UTM: 0453833 easting, 4546304 northing.

Barren of Palynomorphs.

HCl Reaction: Very Strong

Total Organic Recovery: Good

Kerogen Content: 100% Amorphous

T.A.I: 0.4-0.5% Equivalent R_0

AGE: Indeterminate

ENVIRONMENT: Restricted Marine/Lacustrine

3. DS040719-3; Gypsum Spring, collected in bed immediately below ash dated at 184 MA, UTM: 0453851 easting, 4546288 northing.

Barren of Palynomorphs:

HCl Reaction: Weak

Total Organic Recovery: Trace

Kerogen Content: 10% Amorphous, 20% Cuticular, and 70% Woody

T.A.I: 0.4-0.5% Equivalent R_0

AGE: Indeterminate

ENVIRONMENT: Floodplain/Deltaic

Analysis By:

Gerald Waanders