INTERIM GEOLOGIC MAP OF THE CO-OP CREEK QUADRANGLE, WASATCH COUNTY, UTAH

by

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Introduction

The Co-op Creek quadrangle is about 25 miles (40 km) east-northeast of Provo, Utah, and is in the Strawberry River drainage basin above Strawberry Reservoir (figure 1). Bedrock exposures in the quadrangle provide a glimpse of the Charleston-Nebo thrust system through a cover of later Tertiary strata and Quaternary deposits, and provide a geologic link between Permian and Mesozoic rocks exposed to the northwest in the Wasatch Mountains and rocks of similar age to the east on the southwest flank of the Uinta Mountains. The thrust faults and associated folds formed during the Late Cretaceous to Eocene Sevier orogeny, and Maastrichtian (latest Cretaceous) to middle Eocene synorogenic conglomerates were deposited in the Co-op Creek quadrangle during this contractional deformation (see Constenius and others, 2003, and Horton and others, 2004, for regional summaries). Strawberry Valley is superimposed on this deformation and appears to partly be a middle Tertiary "collapse" basin that contains volcanic sedimentary rocks, like the Bear River Valley near the Utah-Wyoming border and Morgan Valley, Utah (see Constenius, 1996). Later normal faulting is indicated by Quaternary (late Pleistocene and possibly Holocene) fault scarps on the east margin of Strawberry Valley in the southeast part of the quadrangle (see also Nelson and Martin, 1982). Other potential geologic hazards are indicated by the numerous landslides in clay-rich Cretaceous and Tertiary strata.

The Permian and Mesozoic rocks in the Co-op Creek quadrangle are complexly folded and faulted with much attenuation and apparent thickening of strata. This has complicated attempts to measure stratigraphic sections and to identify the formally named geologic units in these strata.

The thrust faults exposed in the Co-op Creek quadrangle are splays off the Charleston thrust (see plate and figure 2). From west to east they are the Strawberry River thrust, an unnamed thrust splay of the Strawberry River thrust, and the Willow Creek back thrust west of the syn-thrust Willow Creek syncline, and the Shingle Mill Hollow thrust and Co-op Creek thrust east of the Willow Creek syncline. Except for the unnamed thrust and Willow Creek back thrust, the names of the thrusts and fold are those used by Welsh (1981). Later normal faulting has reversed movement along portions of the Strawberry River thrust fault, such that back-tilting is readily apparent along the trace in the northwest part of the quadrangle (see Qac in small valley on map). The concealed trace of the combined Co-op Creek-Shingle Mill Hollow thrust faults is likely near the eastern trace of the Strawberry normal fault zone, with the normal faulting cutting rocks younger than these thrust faults (units TKc, Tuc) and soling down into the combined faults, with reversal of movement along the thrust.

The Co-op Creek and Shingle Mill Hollow thrusts in the Co-op Creek quadrangle and the Currant Creek back thrust, exposed to the east in the Jimmies Point quadrangle, form a triangle zone with an unexposed thrust-fault flat (decollement) likely in the basal Twin Creek Formation below these quadrangles (see figure 2). This flat thrust fault is likely the Charleston thrust fault.

Elevations in the Co-op Creek quadrangle are high enough that glaciation took place during the Pleistocene and possibly in the Holocene. Astin (1977, p. 20) recognized possible

glacial deposits in the Tut Creek area (his Currant Creek Feeder Canal). Regionally, the middle and late Pleistocene glaciations are known as Bull Lake and Pinedale, respectively (see for example Chadwick and others, 1997). Glacial features are better developed in the adjacent Heber Mountain, Wolf Creek Summit, and Jimmies Point quadrangles (see Constenius and others, 2006). The recognition of glacial features and deposits in all these quadrangles is complicated by landslide, slump, and flow in the Cretaceous and Tertiary clay-rich rocks that are at these high elevations. It is difficult to separate low-relief, cirque headwalls from landslide scarps and much glacial material appears to have been transported in mass-movements after glacial deposition. A scarp with higher relief than most high-elevation scarps in these quadrangles is present in the northeast part of the Co-op Creek quadrangle and is shown as a queried cirque headwall, with queried glacial deposits located downslope east of the headwall. Other queried glacial deposits are mapped among landslide deposits in a shallower basin north of the queried headwall. A few moraines have been mapped on the east margin of the Co-op Creek quadrangle, but whether these moraines are Bull Lake or Pinedale age is uncertain. Questionable glacial deposits are located topographically above and adjacent to some of these moraines and might be Bull Lake in age. Younger glacial deposits, likely lower and possibly middle Holocene deposits (see Madsen and Currey, 1979), appear to occupy cirques along the boundary between the Jimmies Point and Co-op Creek quadrangles.

The Co-op Creek quadrangle has potential mineral and energy resources. The Meade Peak Member of the Permian Phosphoria Formation is a potential source of phosphate and associated metals (see for example Love, 1967, 1984) and could be a source rock for oil and gas. Cretaceous coal-bearing strata, a possible methane source, are exposed to the east in the Jimmies Point quadrangle (see also Doelling, 1972) and locally in the Mesaverde Formation in the Co-op Creek quadrangle (Astin, 1977), and are likely extensive beneath younger cover in the Co-op Creek quadrangle (see figure 2). Astin (1977, p. 18 and 32) reported dead oil in a shell bed in the Mancos Shale and fetid odors or dead oil in several other formations, but did not identify any locations. We mapped the Dakota Formation, which contains several coquina shell beds, in the area that Astin (1977) mapped as Mancos Shale. As shown in figure 2, Cretaceous oil and gas source rocks are present in subsurface in the area. The "Chinese wax mine" to the west (see Ritzma, 1975) in the adjacent Twin Peaks quadrangle is indicative of oil migration out of lower Tertiary oil shales, which are present in the Green River Formation near Strawberry Reservoir, but the oil migration pathway is uncertain.

This map and report are part of work by the Utah Geological Survey to geologically map the Provo 30- x 60-minute quadrangle (Constenius and others, 2006). This open-file report was made to provide detail that could not be shown at the smaller scale of the Provo 30- x 60-minute map, and on the map of Coogan and Constenius (2001) of the Co-op Creek and nearby quadrangles. In addition, our geologic mapping of the Co-op Creek quadrangle is different from previous work (see figure 3). Previous relatively detailed mapping of the quadrangle was by Bissell (1952) for a paper on regional geology. Astin (1977) published a report on the Co-op Creek quadrangle for an M.S. thesis at Brigham Young University, but concentrated on bedrock geology and had understandable difficulty identifying some Triassic red beds. Welsh (1981) released a detailed map of Paleozoic and Mesozoic bedrock in the Co-op Creek quadrangle, but did not map other parts of the quadrangle.

Most of the mapping of the Co-op Creek quadrangle in this report was done in 1999 and 2000 by Coogan and Constenius (2001). Coogan focused on the Permian, Mesozoic, and Tertiary rocks and Quaternary deposits in the northeast part of the quadrangle, while Constenius worked on the southwest part of the quadrangle. Coogan and Constenius (2003, unpublished) later drew a cross section through the Co-op Creek and Jimmies Point quadrangles that is reproduced here as figure 2, with corrected Mesaverde and Mancos formation thicknesses and Strawberry River Valley geology. Additional work was done later by Constenius and King, mostly in 2008, 2009, and 2010. In particular, Constenius worked out the geology involved with Permian and Pennsylvanian rocks along the Strawberry River, and the Uinta Formation and older Tertiary rocks. King examined and remapped the Quaternary geology in the quadrangle, as needed.

Map Unit Descriptions

(Units with * shown only in cross section figure)

Quaternary

Qal Stream and floodplain alluvium (Holocene) - Sand, silt, clay, and gravel in channels and floodplains; composition depends on source area; 0 to 20 feet (0-6 m) thick and likely thickest along Strawberry River.

Qat2,3, Qato

Stream-terrace alluvium (Holocene and Pleistocene) - Sand, silt, clay, and gravel in terraces above floodplains of Strawberry River and Left Fork of Currant Creek, and in much higher (older), gently dipping terraces (Qato) (or fans?) above Co-op and Pass Creeks and Sleepy Hollow; number and letter suffixes apply to local drainages with multiple terrace levels, with lowest (youngest) terraces labeled 2 and likely Holocene and upper Pleistocene; Qat3 terraces, above Qat2, are ~40 feet (12 m) above upper Strawberry River; regionally Qat2 surfaces are typically 10 to 35 feet (3-11 m) above adjacent drainage while Qat3 surfaces are typically 35 to 60 or more feet (11-18+ m) above adjacent drainage; Qato is typically ~120 feet (35 m) above Sleepy Hollow and ~200 feet (60 m) above upper Co-op and Pass Creeks; 0 to 45 feet (0-14 m) thick.

Terraces that do not have mappable deposits are present west of upper Co-op Creek; edges of these terraces are shown by a gray dash-dot line. These surfaces are less than 40 feet (12 m) and 40 to 80 feet (12-25 m) above the creek south of the normal fault, and are 100 to 120 feet (30-35 m) above the creek north of the normal fault, similar to Qafm and Qato.

Qaf, Qaf1?, Qafy, Qaf3

Alluvial-fan deposits (Holocene and Pleistocene) - Mostly sand, silt, and gravel that is poorly stratified and poorly sorted; deposited mainly by debris flows at drainage mouths; Qaf used where fans are Holocene and upper Pleistocene, and for some fans of uncertain

age(s); generally less than 40 feet (12 m) thick.

Qafy fans impinge on Qal indicating they are at least partly Holocene in age. Qaf1? fans are inset into Qafy fans in southeast part of quadrangle and next to Hobble Creek; inset indicates they are even younger Holocene features; queried because the age difference between Qaf1 and Qafy may only be local. Qaf3 alluvial fans are similar in appearance to Qafy fans but are incised by active drainages (see Qac in drainages east of Quaternary fault scarps in southeast part of quadrangle) and Qafy fans appear inset into Qaf3 fans; Qaf3 fans are ~40 feet (12 m) above upper Co-op Creek and Sleepy Hollow, but are below Qato along these drainages. Qaf3 fans are also located along the Strawberry River and Hobble Creek ~40 feet (12 m) above inset Qafy fans; Qaf3 fans are likely related to Pinedale-age (upper Pleistocene) glaciation (see Nelson and Martin, 1982).

Qafm Intermediate-level alluvial-fan deposits (upper and middle Pleistocene) - Deposits similar to Qaf3 but fan surfaces are more dissected than and above Qaf3 fans; Qafm fans are located between Quaternary fault strands in the southeast part of the quadrangle; they are deeply incised by and are ~80 feet (25 m) above active drainages; they are not as high above active drainages as Qato terraces; may be related to Bull Lake-age glaciation (Little Valley lake cycle); 0 to about 50 feet (0-15 m) thick.

Qa Alluvium, undivided (Quaternary) - Sand, silt, clay, and gravel in mixed stream and alluvial-fan deposits; composition depends on source area; mapped where fans impinge on stream terraces less than 20 feet (6 m) above upper Co-op Creek, upper Strawberry River and mouth of Bjorkman Hollow; shown as undivided unit because a contact can not be drawn between the fans and terraces; Qa used because terrace/fan level is indeterminate or where alluvium of different levels is too small to show separately at map scale; 0 to 20 feet (0-6 m) thick.

Qac Alluvium and colluvium (Quaternary) - Includes clay- to boulder-size sediment of stream and fan alluvium, colluvium, and, locally, mass-movement deposits too small to show separately at map scale; 0 to 20 feet (0-6 m) thick.

Qc Colluvium (Quaternary) - Includes slopewash and soil creep; composition depends on local bedrock; generally less than 20 feet (6 m) thick.

Qm Mass-movement deposits, undivided (Quaternary) - An area of raised relief that is thicker than most colluvium, but does not appear to be talus or a landslide; several mass-movement processes may contribute to deposit and it may be an older eroded landslide; 0 to 40 feet (12 m) thick.

Qmc Mass movement and colluvial deposits, undivided (Quaternary) - Includes landslides and areas of slopewash and soil creep; mapped in areas of subdued morphology where landslides and colluvial deposits can not be shown separately at map scale; composition

depends on local sources; 0 to 40 feet (12 m) thick.

Qms, Qmsy, Qmso

Landslides (Quaternary) - Poorly sorted clay- to boulder-sized material; generally characterized by hummocky topography, main and internal scarps, and chaotic bedding in displaced bedrock; includes slide, slump, and locally flow deposits; morphology becomes subdued with age and the amount of water in the deposits; locally includes small wet depressions in which younger sediment has accumulated; divided into relatively younger (Holocene) and older deposits where possible (suffixes y and o, respectively); Qmsy label is based on fresher appearance of scarps; bedrock units most susceptible to mass movements include the Keetley Volcanics (Tk, Tkt), volcaniclastic rocks of Strawberry Valley (Tvc), Uinta Formation (Tuc and Tucb), Currant Creek Formation (TKc), and clay-rich Mesozoic rocks (Kmv, TRa); glacial deposits (various Qg units) are also highly susceptible; thicknesses highly variable.

Qmg Mass-movement and glacial deposits, undivided (Holocene and upper Pleistocene) - Glacial deposits (see unit Qg description) in displaced landslide masses; locally includes small wet depressions in which younger sediment has accumulated; up to 300 feet (90 m) thick in adjacent quadrangles, but thickness in map area uncertain.

Qg, Qgm, Qg?, Qgm?

Glacial deposits, undivided (Holocene and upper and middle Pleistocene) - Includes till (moraine deposits) and outwash of various ages, but likely mostly Pinedale age; till is non-stratified, poorly sorted clay, silt, sand, cobbles, and boulders and is mapped as Qgm (moraines) where distinct shapes of vegetated lateral moraines are visible above Pass Creek; outwash is stratified and variably sorted, but better sorted and bedded than till due to alluvial reworking; Qgm? as mapped above Tut Creek may be two lateral moraines; Qg deposits above Pass Creek appear to be moraine and outwash; all glacial deposits locally include mass-movement deposits too small to show separately at map scale; estimate 0-150 feet (0-45 m) thick. Qg queried above Pass Creek where glacial origin uncertain due to gently sloping upper surface, and position next to sloping terraces and above Qgm; might be Bull Lake in age.

Qgy? Younger glacial deposits (Holocene and possibly uppermost Pleistocene) - Non-stratified, poorly sorted clay, silt, sand, cobbles, and boulders deposited in non-vegetated cirque basins along boundary between Co-op Creek and Jimmies Point quadrangles; deposits derived from conglomeratic and clay-rich Tertiary bedrock (units TKc and Tucb); characterized by sharp non-vegetated moraines with very poor soil development in east-facing cirque in Jimmies Point quadrangle; queried in Co-op Creek quadrangle due to lack of recognizable moraines in north-facing cirque; 0 to 50 feet (0-15 m) thick in Jimmies Point quadrangle.

Qh Human disturbance (Historical) - Two gravel pits along Hobble Creek, the larger is

recontoured and reclaimed; the smaller is not recontoured. As shown on the topographic base map, a quarry is present in the Oquirrh Formation where sample KNC060106-14 was taken.

Tertiary

Tk Keetley Volcanics (Oligocene[?] - upper Eocene) - Volcanic breccia and conglomerate in upper part, interbedded volcanic conglomerate and minor light-gray tuffaceous sandstone in lower 300 feet (90 m); volcanic clasts are andesite to rhyodacite; conglomerate has light-orange and gray, coarse sandstone matrix and locally contains orthoquartzite, sandstone, and limestone boulders to pebbles; tuffaceous sandstone is light gray, coarse grained to pebbly, and trough cross-bedded; sample KNC92799-5 from the north margin of Co-op Creek quadrangle yielded an $^{40}Ar/^{39}Ar$ hornblende plateau age of 40.45±0.18 Ma, but this is far older than the nearby underlying Tkt dated at 37 Ma by Constenius and others (2003); 0 to more than 1400 feet (0-425+ m) thick (this report).

Tkt Keetley Volcanics, basal tuffaceous unit (Oligocene[?] - upper Eocene) - Very light-gray to greenish-gray tuff and tuffaceous sandstone and pebbly sandstone; rarely exposed; sample KNC92799-6 from the northern margin of the Co-op Creek quadrangle yielded an $^{40}Ar/^{39}Ar$ hornblende plateau of 37.25±0.14 Ma (Constenius and others, 2003 in table), implying the older date on the overlying Keetley is from reworked material; another sample (KNC6901-1), from near Peoa, Utah, yielded an $^{40}Ar/^{39}Ar$ age of 38.20±0.11 Ma (Constenius and others, 2003); 0 to about 200 feet (0-60 m) thick (this report).

Tvc Volcaniclastic rocks of Strawberry Valley (Oligocene[?] - upper Eocene) - Upper part is tan to orange and gray conglomerate and coarse-grained sandstone; conglomerate contains quartzite cobbles to small boulders with sandstone, limestone, and volcanic clasts locally present. Lower part is light-gray, boulder to cobble conglomerate with quartzite and andesite to rhyodacite clasts in a coarse to pebbly sandstone matrix; interbedded with light-gray, coarse-grained, cross-bedded, tuffaceous sandstone; sample KNC92899-2 from the south central portion of the Co-op Creek quadrangle yielded an $^{40}Ar/^{39}Ar$ biotite plateau of 37.73±0.28 Ma (Constenius and others, 2003 in table); Tvc correlative northward, with additional volcanic material, into Keetley Volcanics, with similar Ar/Ar ages, and possibly correlative southward to Moroni Formation, but older than nearby strata called Moroni Formation (samples KNC71194-5, KNC101701-1, and KNC101701-4 from Billies Mountain quadrangle yielded $^{40}Ar/^{39}Ar$ ages of 34.68±0.09, 34.86±0.09, and 37.18±0.38 Ma, respectively, by Constenius and others, 2003); at least 1500 feet (457 m) thick, with top not exposed (this report).

Tucb Uinta Formation, boulder conglomerate (middle Eocene) - Red-brown and gray, thick- to very thick-bedded conglomerate, commonly stained red by weathering of interbedded, thin, red-brown and brick red mudstone; extremely coarse clastic unit comprised mainly of cobbles and boulders, some boulders 3 to 10 feet (1-3 m) in diameter; quartzite clasts derived from Pennsylvanian-Permian Oquirrh Formation predominate, with Precambrian

Uinta Mountain Group, Cambrian Tintic Quartzite, Pennsylvanian Weber Formation, Permian Park City Formation, Triassic Thaynes Formation, and Jurassic Twin Creek Limestone lithic clasts locally present in the Red Ledge (eastern Co-op Creek Quadrangle) and White Ledge (southeast Wolf Creek Summit Quadrangle) areas; sandstone occurs as minor intercalated lenses of coarse- to very coarse-grained, brick-red to red-brown sandstone; mudstone is brick red to red brown and forms thin partings between ledges of conglomerate; partings of bentonite are found at White Ledge locality; unit found above elevation of ~8800 feet (2680 m) capping landscape prominences in the Twin Peaks, Co-op Creek, and Wolf Creek Summit quadrangles; overlies conglomerate member of Uinta Formation (Tuc); preserved thickness ranges from about 500 to 900 feet (150-275 m). Preliminary U-Pb zircon ages from the White Ledge, Wolf Creek Summit quadrangle are about 39 Ma.

Tuc Uinta Formation, conglomerate (middle Eocene) - Red-brown, tan and gray, thick- to very thick-bedded pebble to cobble conglomerate interbedded with minor sandstone, commonly stained red by weathering of interbedded, thin, red-brown mudstone; quartzite clasts predominantly derived from Pennsylvanian-Permian Oquirrh Formation; sandstone is subordinate to conglomerate and occurs as intercalated lenses of coarse- to very coarse-grained, brick-red to red-brown sandstone; mudstone is brick red to red brown and forms thin partings between ledges of conglomerate; interfingers with the main body of the Uinta Formation to the south in the Strawberry Reservoir NW and NE quadrangles; up to 1500 feet (460 m) thick.

Older Eocene rocks are not exposed in Co-op Creek quadrangle, and may or may not be present in subsurface in the quadrangle. The middle Eocene Green River Formation is exposed to south in Strawberry Reservoir NW quadrangle, but northern extent is uncertain. To the west, the Green River Formation is progressively truncated and is completely removed by erosion in the Two Tom Hill quadrangle (see figure 1) along the basal Uinta Formation unconformity. Because the lower Eocene Colton and Flagstaff Formations pinch out to the north (see Constenius and others, 2006), they are likely not present or very thin in subsurface in the Co-op Creek quadrangle. The following descriptions for these older Eocene rocks are abridged from Constenius and others (2006).

The upper Green River Formation is sandstone, siltstone, mudstone, marlstone, and rare oil shale; sandstone is occasionally coarse grained to conglomeratic. The middle Green River Formation is mostly mudstone, siltstone, and fine- to medium-grained sandstone in the upper part, and the lower part is dominantly oil shale and marlstone. The lower Green River Formation is shale and mudstone as very thick beds separated by marlstone, and also contains claystone and sandstone; oil shale is common near base.

The Colton Formation is calcareous sandstone interbedded with microcrystalline limestone and mudstone. The Flagstaff Limestone is thick-bedded, microcrystalline limestone interbedded with marlstone and calcareous mudstone; and medium- to coarse-grained sandstone increases in abundance up section.

TKc Currant Creek Formation (Paleocene and Upper Cretaceous, Maastrichtian) - Includes: gray- to tan-weathering, thick-bedded, boulder to cobble conglomerate, dominated by well-rounded, quartzite clasts from Oquirrh Formation; gray, yellowish-gray, and minor red, thick-bedded, coarse-grained sandstone and pebble conglomerate; and gray, very light-gray and variegated siltstone; poorly exposed; unconformably overlies Mesaverde Formation; about 4800 feet (1460 m) thick near Currant Creek (Bissell, 1952), Jimmies Point quadrangle and reported by Walton (1964) as at least 4000 feet (1200 m) in same area.

Kmv Mesaverde Formation (Upper Cretaceous) - Light-gray, white, and tan, thick-bedded, cross-bedded, coarse-grained sandstone, gray siltstone, and dark-brownish-gray, carbonaceous shale and coal; poorly exposed in isolated outcrops in this quadrangle; best exposures near Currant Creek Reservoir, Jimmies Point quadrangle; Bissell (1952) measured 5165 feet (1575 m) near Coal Mine Hollow, Jimmies Point quadrangle. Thins to east and contains more coastal deposits, interfingering with marine Mancos Shale (see Molenaar and Wilson, 1993).

Km* Mancos Shale, main body (Upper Cretaceous) - Not exposed in Co-op Creek quadrangle, but likely underlies extensive landslide deposits in northeast part of map area (see gap between Frontier exposures to the north and Mesaverde exposures on the south). To east in Jimmies Point quadrangle unit consists of dark-gray bentonitic shale with minor gray limestone (marlstone); gray, fine-grained silty sandstone; estimated 1680 feet (510 m) thick by Bissell (1952) near Currant Creek Reservoir, Jimmies Point quadrangle, and thickens to east (see Molenaar and Wilson, 1993).

Kf Frontier Formation (Upper Cretaceous) - Light-gray, white, and tan, thick-bedded, medium-grained sandstone interbedded with dark-gray siltstone, shale, dark-brownish-gray, carbonaceous shale and minor coal in upper part; top not exposed and bottom poorly exposed in Co-op Creek quadrangle, but contains an oyster coquina marker bed in the lower 50 feet (15 m); extensively burrowed in the middle; in Jimmies Point quadrangle, map unit appears to include lower Mancos Shale, a non-resistant zone below two resistant beds in the Frontier Formation (do not know which resistant bed is sandstone coquina); about 700 feet (215 m) thick (this report); Bissell (1952) measured 660 feet (200 m) of Frontier and 95 feet (29 m) of lower Mancos Shale near Currant Creek Reservoir, Jimmies Point quadrangle.

Kml Mancos Shale, lower (Upper Cretaceous) - Dark-gray, non-resistant and poorly exposed shale; mapped by King adjacent to Frontier Formation in northeast part of Co-op Creek quadrangle above Mowry Shale; outcrop width about that of underlying Mowry, so estimate lower Mancos is about 90 feet (27 m) thick. On ortho-photograph on north margin of Jimmies Point quadrangle, a dark-gray non-resistant zone is visible below two resistant beds in lower third of Jimmies-Point Frontier map unit, and Frontier-Mowry contact can not be mapped because it is in the non-resistant zone and the Mowry lacks its

characteristic silvery color.

Kmm Mancos Shale, Mowry Shale Tongue (Lower Cretaceous) - Dark-gray, silvery weathering, platy to blocky, fissile, siliceous shale in lower part, with abundant teleost fish scales; upper part contains non-fissile, greenish-gray claystone; Bissell (1952) measured 88 feet (27 m) of Mowry near Currant Creek Reservoir, Jimmies Point quadrangle.

Kd Dakota Formation (Lower Cretaceous) - Sandstone, white to tan, very thick bedded, cross-bedded, with extensive quartz veins; interbedded with gray and variegated siltstone; bottom not exposed in Co-op Creek quadrangle; more resistant than underlying and overlying units; regionally thickens northward from about 200 to 400 feet (60-120 m) thick (this report); Bissell (1952) measured 180 feet (55 m) of Dakota to the north in the Heber Mountain quadrangle.

KJcm* Cedar Mountain and Morrison Formations, undivided - Not exposed in Co-op Creek quadrangle, but shown on figure 2 and poorly exposed to east in Jimmies Point quadrangle and to north in Heber Mountain and Wolf Creek Summit quadrangles; reportedly 2650 feet (810 m) thick in southeast Heber Mountain quadrangle (Morrison of Bissell, 1952); but may be only about 1500 feet (460 m) thick (see Huddle and McCann (1947a,b).
Cedar Mountain (Lower Cretaceous) - Regionally, variegated greenish-gray, red-brown, and lavender mudstone interbedded with gray, red, and buff coarse- to fine-grained sandstone and siltstone; minor nodular limestone and conglomerate.
Morrison (Upper Jurassic) - Interbedded greenish-gray and light-red siltstone; medium-grained, pinkish-gray sandstone; and pinkish-gray, quartz- and chert-pebble conglomerate with pebbly sandstone in thick, fining-upward, trough-cross-stratified beds.

Js* Stump Formation (Middle Jurassic) - Not exposed in Co-op Creek quadrangle but shown on figure 2. To east in Jimmies Point quadrangle contains lower light-gray, medium-bedded, calcareous sandstone, and upper gray to green-gray, thick-bedded, ridge-forming, bioclastic limestone and sandy limestone, with thickness uncertain due to faulting and tight folding; about 250 feet (75 m) thick to north in Wolf Creek Summit quadrangle (this report). Curtis of Huddle and McCann (1947a,b) and Bissell (1952).

Jp* Preuss Formation (Middle Jurassic) - Not exposed in Co-op Creek quadrangle but shown on figure 2. To east is oldest unit exposed in Jimmies Point quadrangle, where it contains red, brownish-red, purplish-red, and minor light-gray, thin- to medium-bedded sandstone and siltstone; thickness uncertain in Jimmies Point quadrangle due to faulting and tight folding; about 750 feet (230 m) thick to north in the Wolf Creek Summit quadrangle (this report). Entrada of Huddle and McCann (1947a,b) and Bissell (1952).

CO-OP CREEK THRUST SHEET (Mesozoic units also shown on figure 2 east of Co-op Creek thrust)

Jtu Twin Creek Formation, upper members (Middle Jurassic) - Not divided because upper Twin Creek Giraffe Creek, Leeds Creek, and Watton Canyon Members are structurally attenuated and top not exposed where present between thrust faults in northern Co-op Creek quadrangle; estimated undeformed thickness is about 650 feet (198 m) from regional relationships. See also Imlay (1967) for descriptions and thicknesses to east along Duchesne River.

Giraffe Creek and Leeds Creek Members - Regionally, thinly interbedded, light-gray to light-greenish-gray, soft, shaley limestone and platy weathering, light-gray to tannish-gray, fine-grained, calcareous sandstone; sandstone increases upward; a 15-foot-thick (5 m) gypsum bed lies in the middle of the two members; together these members are about 500 feet (150 m) thick to northeast of Co-op Creek thrust in Wolf Creek Summit quadrangle (this report).

Watton Canyon Member - Dark-gray, medium- to thick-bedded, lime micrite to wackestone with oolites and pelecypod fragments; resistant ridge former; micrites display a characteristic spaced, bedding-normal fracture; about 120 feet (35 m) thick to northeast of Co-op Creek thrust in Wolf Creek Summit quadrangle (this report).

Jtl Twin Creek Formation, lower members (Middle Jurassic) - Not mapped separately because lower Twin Creek Boundary Ridge, Rich, Sliderock, and Gypsum Spring Members are structurally attenuated and base not exposed where present between thrust faults in northern Co-op Creek quadrangle; estimated undeformed thickness is about 230 feet (70 m) feet from regional relationships. See also Imlay (1967) for descriptions and thicknesses to east along Duchesne River.

Boundary Ridge Member - Red to purplish-red shale and siltstone, and minor, gray siltstone; recessive and poorly exposed; about 65 feet (20 m) thick to northeast of Co-op Creek thrust in Wolf Creek Summit quadrangle (this report).

Rich, Sliderock, and Gypsum Spring Members - Light-gray, soft, shaly limestone in upper part; dark-gray, thick-bedded, bioclastic limestone in middle, and thin (5-foot thick [1.5 m]) purple shale at base; about 160 feet (50 m) thick to northeast of Co-op Creek thrust in Wolf Creek Summit quadrangle (this report).

Jn Nugget Sandstone (Lower Jurassic) - Reddish-orange, orange, and pink, massive-weathering, cross-bedded, moderately cemented to friable, noncalcareous, well-rounded, fine- to medium-grained sandstone, with common frosted grains; about 1260 feet (385 m) thick to northeast of Co-op Creek thrust in Wolf Creek Summit quadrangle (this report), but incompletely exposed in Co-op Creek quadrangle; upper and lower contacts not exposed in Co-op Creek quadrangle; Navajo of some previous workers.

TRa Ankareh Formation, undivided (Upper and Lower Triassic) - Mapped between thrust faults in north part of Co-op Creek quadrangle; upper and lower contacts not exposed; rocks similar to unit TRal (see below); at least 300 feet (90 m) thick. Also used as cross-

section unit east of Co-op Creek thrust and about 1250 feet (380 m) thick where exposed in Wolf Creek Summit quadrangle.

TRal Ankareh Formation, lower member (Lower Triassic) - Dull-red, reddish-brown and purplish-red, thin-bedded mudstone, siltstone, and medium- to thin-bedded, fine-grained sandstone; minor purplish gray and gray mudstone and siltstone; siltstone is locally micaceous; green reduction spots common; the brecciated, light-red sandstone near the base of unit is probably not the conglomerate (middle) member (compare to unit 50 of Smith, 1969), because the underlying unit, TRat, is too thin to be the entire lower Ankareh member and TRat+TRal has about the thickness of the lower member where it is not complexly folded (see following for 350+300 about=800 feet); in the Co-op Creek quadrangle, map unit TRal is on the Co-op Creek thrust sheet and is at least 300 feet (90 m) feet thick (this report); Smith (1969) reported 668 feet (204 m) of lower Ankareh exposed near Willow Creek west of the axis of the Willow Creek syncline in the Co-op Creek quadrangle, but his contacts are not those used on this map; the lower Ankareh member is about 800 feet (245 m) thick to northeast in Wolf Creek Summit quadrangle (this report). Because only the lower contact of TRal (with TRat) is exposed, the middle conglomerate member and upper member of Ankareh are likely not exposed along the Willow Creek syncline, though they may be obscured by trees south of Willow Creek.

Upper and conglomerate (middle) members of Ankareh total about 390 feet (120 m) thick northeast of Co-op Creek thrust in Wolf Creek Summit quadrangle (this report), though Bissell (1952) measured 520 feet (159 m) in the same area. To northeast, the upper member is lithologically like the lower member (and map unit TRal); upper is red, purplish-red, and reddish-gray, thin-bedded mudstone, siltstone, and fine-grained sandstone; lower is red and purple siltstone and shale, and purplish-gray, calcareous siltstone that is thin bedded throughout and poorly exposed; the conglomerate member is gray to white, brownish weathering, very thick bedded, cross-bedded, coarse-grained sandstone and pebble conglomerate that is 40 feet (12 m) thick (this report); possibly equivalent to the Gartra Grit Member and called Shinarump by some previous workers (for example Bissell, 1952).

TRat Lower Ankareh Formation and upper Thaynes Formation, undivided (Lower Triassic) - Greenish-gray and very light-gray, calcareous sandstone with green clay intraclasts in upper part; white, thinly laminated, well-indurated, calcareous sandstone and micaceous sandstone in lower part; unit contains rocks that are transitional between typical lower Ankareh and upper Thaynes lithologies, possibly indicative of intertonguing shown by Kummel (1954, figure 21) or attenuation due to tight folding; about 350 feet (107 m) thick. Lower Ankareh member to northeast of Co-op Creek thrust in Wolf Creek Summit quadrangle is poorly exposed, red and purple siltstone and shale, and purplish-gray, calcareous siltstone, and is thin bedded throughout (this report). Also unit 5 of Bissell's (1952) Thaynes reads like Ankareh. Unit TRat looks partly reddish and non-resistant like the Ankareh on aerial photographs and looks at least locally attenuated (King, this report).

TRtw Thaynes and Woodside Formations, undivided (Lower Triassic) - Used on figure 2 east of Co-op Creek thrust.

TRtu Thaynes Formation, upper member (Lower Triassic) - Dark-gray, bioclastic, lime grainstone; weathers medium blue gray; forms two prominent ridges separated by thin-bedded, dark-gray, silty limestone; about 300 feet (91 m) thick (this report); see also Bissell (1952, his unit 4). Smith's (1969) upper Thaynes is 372 feet (113 m) thick on the west limb of the Willow Creek syncline, but he likely used different upper and lower contacts than those shown on this map. His 166 feet (50.5 m) of red Decker Tongue of Ankareh directly underlies his upper Thaynes (see also unit 3 of Bissell, 1952).

TRtl Thaynes Formation, lower member (Lower Triassic) - Mainly dark-brownish-red, thin- to medium-bedded, calcareous siltstone with rare zones of dark-gray, blue-gray weathering, bioclastic grainstone resembling unit TRtu in lower part; about 1000 feet (300 m) thick (this report). Thaynes is typically greenish- to brownish-gray and more limestone rich, so map unit may be intertongued Thaynes and Ankareh lithologies (see Kummel, 1954, figure 21). Bissell's (1952) Thaynes measured section units 1-3, including Decker Tongue of the Ankareh (his unit 3), total 930 feet (283 m) thick, while Smith (1969) only measured ~600 feet (180 m) of comparable strata.

TRw Woodside Formation (Lower Triassic) - Dark-red to red-brown shale and siltstone; poorly exposed; forms strike valleys; about 500 feet (150 m) thick (this report); Smith (1969) measured 420 feet (130 m) near Willow Creek and 710 feet (215 m) on the east limb of the Willow Creek syncline. Nearby 780 feet (238 m) thick in the Amoco Cottonwood Canyon well (API 43-049-30007), Rays Valley quadrangle (calculated using 5° dip) (Constenius, 2008).

Pp* Park City and Phosphoria Formations, undivided (Permian) - Used on figure 2 east of Co-op Creek thrust; reportedly 425 to 450 feet (130-140 m) thick near northeast corner of Wolf Creek Summit quadrangle (see Bissell, 1952), so thinner than thrust sheet exposures.

Ppf Park City Formation, Franson Member (Permian) - Dolostone; light tannish gray and light-brown; weathers very light tannish gray to white; very thick bedded; silty to sandy; with small, quartz-filled vugs and light-gray, white, and tan and brown chert as nodules and stringers; commonly highly fractured to brecciated; minor white to light-gray anhydrite and shale; about 650 feet (200 m) thick in Willow Creek area (this report); Bissell (1952, units 3-5) measured 585 feet (178 m), while Cheney and others (1953) measured 547 feet (167 m), and Welsh (1981, Sinbad and Plympton units) measured about 730 feet (222.5 m). Nearby 660 feet (203 m) thick (Sinbad and Plympton units on Welsh [1981] log) in the Amoco Cottonwood Canyon well, Rays Valley quadrangle (calculated using 6° dip) (Constenius, 2008).

Ppm Phosphoria Formation, Meade Peak Phosphatic Member (Permian) - Dark-gray to black, fissile, siliceous shale, lesser pelletoidal phosphatic shale and phosphatic limestone and dolomite that weather to a bluish cast and some thin-bedded, medium-gray siltstone with brown and gray laminations; poorly exposed, forms benches and swales with siliceous shale and siltstone chips as float; about 190 to 225 feet (70 m) thick in Willow Creek area; Bissell (1952, unit 2) measured 225 feet (68.5 m), while Cheney and others (1953) measured 187 feet (57 m), and Welsh (1981) measured about the same. Nearby 305 feet (93 m) thick in Amoco Cottonwood Canyon well, Rays Valley quadrangle (Welsh, unpublished log), calculated using 6° dip, though may be structurally thickened by small-scale faulting and folding (Constenius, 2008).

Sample from near Willow Creek has low thermal maturity of Ro 1.1 (Coogan and Constenius, 2003).

Ppg Park City Formation, Grandeur Member (Permian) - Dominantly dolostone in upper two-thirds that is medium to dark gray, weathers very light gray, is very thick bedded, and is fine to medium crystalline, with dispersed, white chert nodules; lower part is medium-gray, gray-weathering, shelly, dolomitic lime wackestone; both parts thick bedded, with dark-gray, 0.4- to 0.8-inch-thick (1-2 cm) chert layers; about 685 feet (210 m) thick in the Willow Creek area; Bissell (1952, unit 1) measured 685 feet (209 m), while Cheney and others (1953) measured 683 feet (208 m), and Welsh (1981) measured about the same. Nearby 788 feet (240 m) thick (calculated using 6° dip) where drilled in the Amoco Cottonwood Canyon well, Rays Valley quadrangle (Constenius, 2008).

PIPw* Weber Sandstone/Quartzite (Lower Permian and Pennsylvanian) - Used on figure 2 east of Co-op Creek thrust; roughly the thinner marine shelf equivalent of the rocks in the Oquirrh Basin, including the Diamond Creek, Kirkman, and Oquirrh Formations. About 1500 to 1600 feet (460-490 m) thickness exposed to east along Duchesne River (Bissell, 1952).

Pdc Diamond Creek Sandstone (Lower Permian) - Light-gray, tan and orangish-red-brown, very thick bedded and trough cross-bedded, very fine to medium-grained, friable sandstone, with thin-bedded, light-gray, calcareous sandstone interbeds; poorly exposed, forms swale between Grandeur and Kirkman carbonate ribs; about 450 feet (140 m) thick in the Willow Creek area (Welsh, 1981), and Astin (1977) reported 78 meters (256 feet) in same area but he may have missed the upper contact; Bissell (1952) measured 165 feet (50 m), but this is too thin compared to outcrop width. Nearby, 480 feet (146 m) penetrated in Diamond Fork anticline (after Welsh, 1981); 1273 feet (388 m) thick were drilled in the Amoco Cottonwood Canyon well, Rays Valley quadrangle (calculated using 6° dip) (Constenius, 2008).

Pk Kirkman Limestone (Lower Permian, Leonardian and Wolfcampian) - Very light gray, gray and very dark gray, thick- to medium-bedded, nonlaminated to thinly laminated, dolomitic limestone; intraformational breccia makes up upper two-thirds of Kirkman in

Wasatch Range and consists of dark-gray to black, gray-weathering beds of rotated, thinly laminated, limestone clasts, and lighter gray beds of nonlaminated, dolomitic limestone; contains rare, thin beds of red-weathering, gray, slabby-weathering, sandy limestone; strong fetid odor when broken; anhydrite at base of unit; white calcite veins common; brecciation in upper 2/3 may be due to dissolution of saline beds that do not survive exposure; age from Clark (2009); thickness varies from 97 to 375 feet (30-115 m) on east side of the Strawberry River valley (this report); Bissell (1952) measured 375 feet (115 m) and Astin (1977) 108 meters (354 feet), while Welsh (1981) reported more than about 200 feet (60 m), thrust truncated, near Willow Creek. Nearby 190 or 300 feet (60 or 90 m) penetrated in Diamond Fork anticline, Billies Mountain quadrangle, depending on contact with underlying Granger Mountain Member (after Welsh, 1981, text and log, not dip adjusted); and 325 feet (100 m) thick (calculated using 6° dip) were drilled in the Amoco Cottonwood Canyon well, Rays Valley quadrangle (Constenius, 2008).

Saline strata are interval of detachment/decollement in region, such that rocks above may be complexly folded and faulted while rocks below are little deformed.

Pogm Oquirrh Formation, Granger Mountain Member (Permian, Wolfcampian) - Gray, tan-weathering, limy, very fine grained sandstone and siltstone; minor beds with black films (track and trail markings?); interbedded with gray, dolomitic sandstone, dolomite, and light-gray limestone; lower part of unit extended east into this quadrangle from Twin Peaks quadrangle; upper part of unit in Co-op Creek quadrangle, not far below contact with Kirkman and east of Strawberry River, is fault truncated; 2813 feet (857 m) of Granger Mountain penetrated by Cottonwood Canyon #1 well, Rays Valley quadrangle (Constenius, 2008); 8200 to 10,255 feet (2500 to 3125 m) thick on Wallsburg Ridge west of map area (after Baker, 1976, using contacts of Constenius and others, 2006; Welsh, 1981; respectively).

Pogml Oquirrh Formation, Granger Mountain Member, limestone unit (Permian?, Wolfcampian?; Pennsylvanian, Virgilian) - Unit locally present at bottom of Granger Mountain Member; contact extended east into quadrangle from Twin Peaks quadrangle; consists of ledge- and cliff-forming limestone intervals separated by slope-forming, yellowish-brown, calcareous siltstone interval with a few limestone interbeds; limestone is gray, medium to thick bedded, fossiliferous, and locally cherty; up to about 500 feet (150 m) thick in Center Creek quadrangle (Biek and others, 2003).

IPowr Oquirrh Formation, Wallsburg Ridge Member (Pennsylvanian, Virgilian-Missourian) - Light-gray to yellowish-brown, thick-bedded, fine- to medium-grained quartzite and sandstone; feldspathic to siliceous (orthoquartzite); quartzites commonly have conchoidal fracture; locally thinly laminated to cross-bedded; includes rare, silty and sandy, gray limestone interbeds; age from Baker (1976); about 3700 feet (1130 m) thick to northwest in Center Creek quadrangle (Biek and others, 2003), about 6400 feet (1950 m) thick farther to west in Wallsburg Ridge quadrangle (after Baker, 1976, using contacts of Constenius and others, 2006), 5280 feet thickness shown by Welsh (1981), and possibly

over 8000 feet (2450 m) thick to west in Wasatch Range (after Baker, 1947, 1973).

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quadrangles, and Wallsburg Ridge quadrangle), 4 surface measured sections (Bear Canyon, Wallsburg Ridge, Charleston, and Willow Creek), and 2 well logs (Sun Diamond Fork #2 and Mountain Fuel Supply Thistle Dome #1), plus additional figures. [copies in Utah Geological Survey files]

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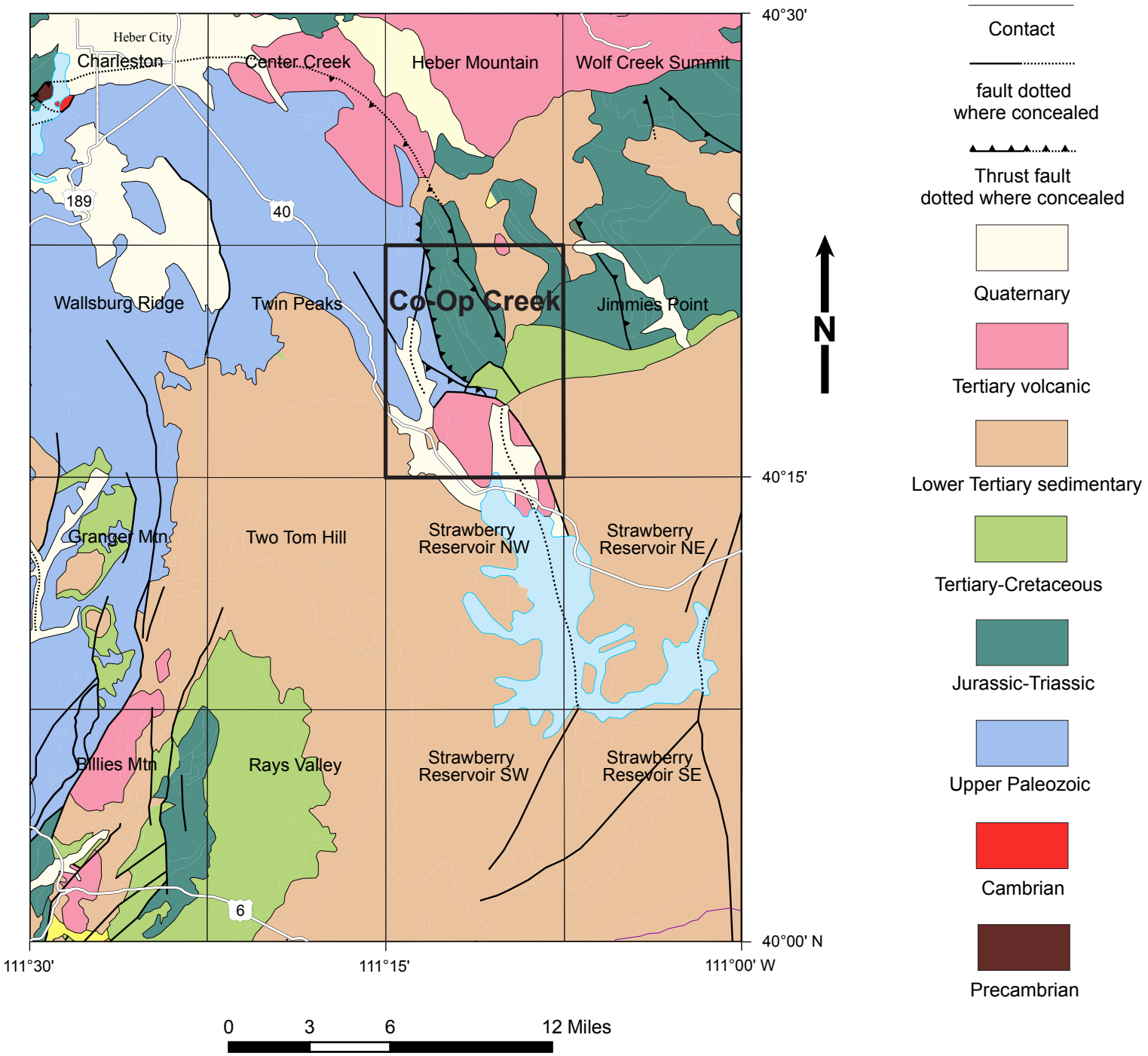


Figure 1. Geologic index map for the Co-op Creek (bold) and adjacent quadrangles, central Utah.

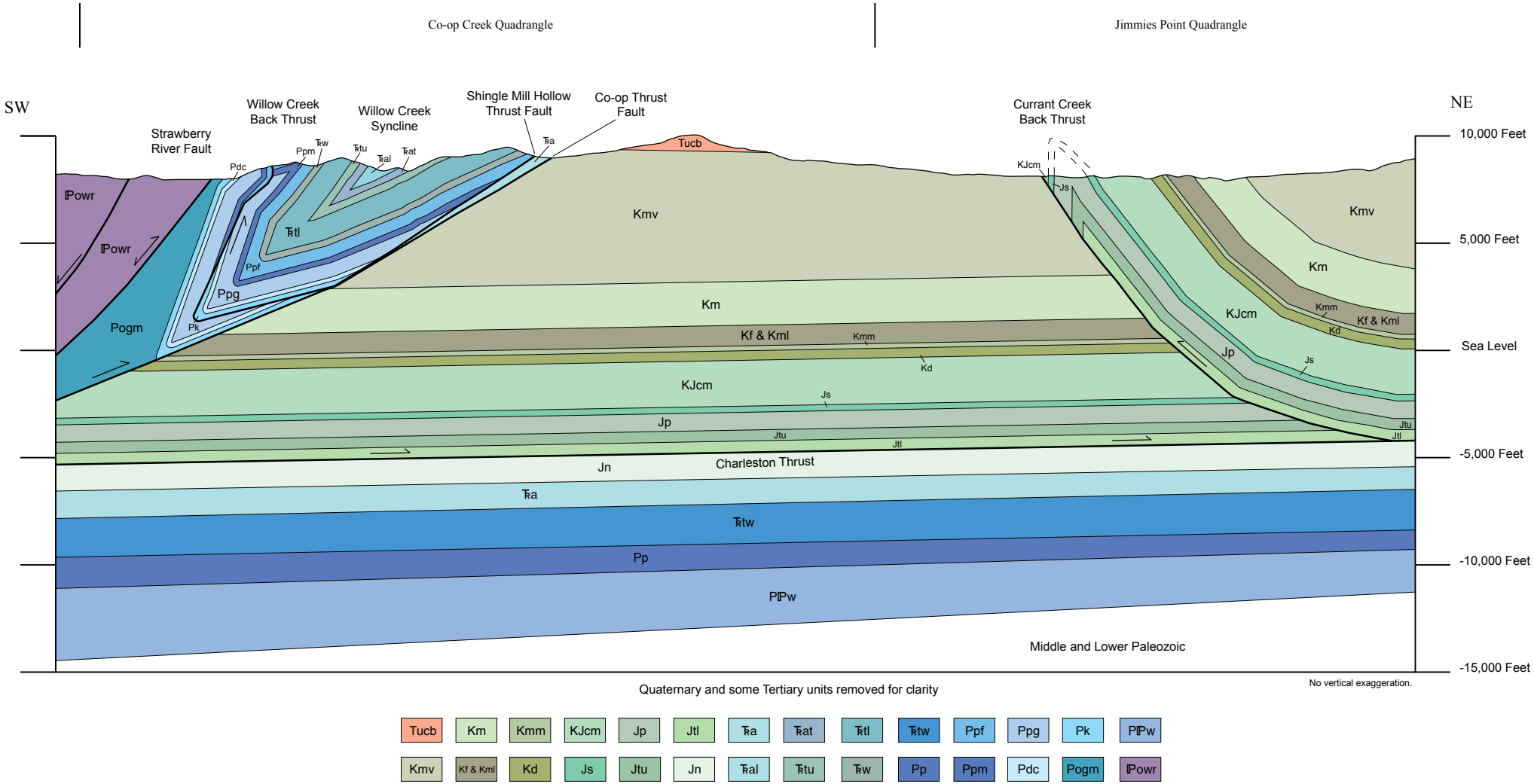


Figure 2. Simplified cross section of the Co-op Creek and Currant Creek area, Wasatch County, Utah. See lithologic column for unit symbols.

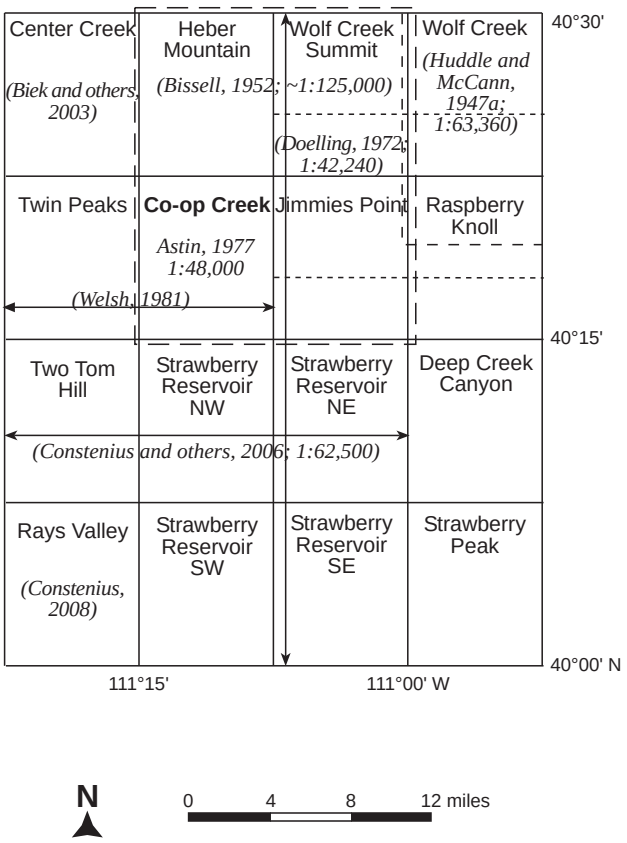


Figure 3. Index to previous relatively detailed geologic mapping in the Co-op Creek (**bold**) and adjacent quadrangles, Utah (*authors and dates in italics, see references; scale 1:24,000 unless otherwise shown*).

TABLE 1. Summary of $^{40}Ar/^{39}Ar$-age analyses from the Co-op Creek quadrangle (**bold**) and the area of the Provo 30' x 60' quadrangle (modified from Deino and Keith, 1997; Constenius and others, 2003; Christiansen and others, 2007; and UGS and NMGRL, 2007). Latitude and longitude (in NAD27) corrected for samples in Provo 30' x 60' quadrangle and ages corrected for analyses funded by STATEMAP.

Sample number	Unit	Latitude	Longitude	Age+2sd (Ma)	Mineral	Type of analysis
SP-3303	Mosida basalt	40° 10' 39.3"	111° 58' 25.0"	19.47±0.14	groundmass	furnace step-heating$
SP-4003	Mosida basalt	40° 09' 2.2"	111° 59' 22.4"	19.65±0.17	groundmass	furnace step-heating$
Tick 28*	Tvtw	40° 26' 28"	112° 05' 27"	32.12±0.14	plagioclase	single crystal Argon-ion step-heating
SP-3205	Tsp, breccia mbr	40° 09' 1.6"	111° 59' 38.3"	33.73±0.65	groundmass	furnace step-heating$
KNC72393-1T	Tvte	40° 28.834'	111° 38.664'	34.4±1.4	biotite	single crystal Argon-ion step-heating
KNC7894-44*	Moroni	39° 56.867'	111° 30.983'	34.43±0.10	sanidine	single crystal CO_2 fusion
KNC101701-7*	Moroni	39° 51.377'	111° 25.807'	34.63±0.09	sanidine	single crystal CO_2 fusion
KNC71194-5	Moroni(?)	40° 07' 16.5"	111° 25' 37.4"	34.68±0.09	sanidine	single crystal CO_2 fusion$
KNC90299-1	intrusion	40° 19.056'	111° 19.657'	34.70±0.16	biotite	furnace step-heating$
SP-603A	Tsp, CRP tuff	40° 12' 12.2"	111° 58' 40.0"	34.70±0.07	sanidine	single crystal CO_2 fusion$
SP-1603B	Tsp, CRP tuff	40° 09' 18.7"	111° 58' 46.5"	34.70±0.07	sanidine	single crystal CO_2 fusion$
SP-1903	Tsp, basal tuff	40° 09' 22.7"	111° 58' 33.1"	34.79±0.10	biotite	furnace step-heating$
KNC101701-1	Moroni(?)	40° 04' 23.3"	111° 27' 21.4"	34.86±0.09	sanidine	single crystal CO_2 fusion$
L33103-9	Tvte	40° 28.010'	111° 50.419'	35.25±0.13	biotite	furnace step-heating$
KNC101701-4	Moroni(?)	40° 04' 02.3"	111° 26' 22.7"	37.18±0.38	biotite	single crystal CO_2 fusion$
KNC92799-6	Keetley, "base"	40° 22' 17.8"	111° 10' 19.8"	**37.25±0.14**	hornblende	furnace step-heating$
KNC92899-2	Tvc	40° 15' 44.5"	111° 12' 23.2"	**37.73±0.28**	biotite	furnace step-heating$
KNC6901-1*	Keetley	40° 44.483'	111° 20.857'	38.20±0.11	sanidine	single crystal CO_2 fusion
KNC61093-2T	Tibble, lower	40° 28.982'	111° 38.422'	39.51±0.36	biotite	single crystal Argon-ion step-heating
KNC92799-5	Keetley	40° 22' 21.9"	111° 10' 19.3"	**40.45±0.18**	hornblende	furnace step-heating$

*=sample not from Provo 30' x 60' quadrangle map.

Tvtw=Volcanic rocks of west Traverse Mountains
Tsp=Soldiers Pass Formation
Tvte=Volcanic rocks of east Traverse Mountains
CRP=Chimney Rock Pass Tuff Member
Tvc=Volcaniclastic rocks of Strawberry Valley

All analyses performed at the New Mexico Geochronology Research Laboratory, Socorro, New Mexico, except Argon-ion step heating analyses which were done at the University of Alaska, Fairbanks, and the University of California, Berkeley Geochronology Center for sample Tick 28.
$ Indicates analysis paid for by STATEMAP funding.

Appendix A
Utah Geological Survey Fusulinid Sample No. KNC 060106-14
LOCATION: Strawberry Quarry
Lat 40° 17.749' N Long 111° 13.574' W

FUSULINID TAXA

Triticites
Triticites cf. T. ventricosus

FUSULINID AGE

PERMIAN
Guadalupian

Leonardian

Wolfcampian lowermost

PENNSYLVANIAN
Virgilian

Missourian

Desmoinesian

Atokan (Derryan)

Morrowan

FUSULINID PRESERVATION & ABRASION

Good Fair **Poor**

CALCAREOUS ALGAE PRESENT
None

ROCK DESCRIPTION: Light gray-tan Sandstone. Fusulinid, bryozoan, very fine-fine grained calcareous Sandstone.

COMMENTS: Most of the fusulinids and bryozoans are a highly abraded detrital in the Sandstone. The fusulinids are fairly abundant. It should be pointed out that no Schwagerina were present in the large rock for positive proof of Wolfcampian age. The Triticites cf. T. ventricosus indicates lower Wolfcampian. The porosity is about 8 %.

Age determined with thin sections

A. J. Doc Wells Ph.D.
08/11/06

Appendix A
Utah Geological Survey Fusulinid Sample No. KNC 060108-4
LOCATION: Willow Creek, Co-op Creek 7.5' quadrangle
Wallsburg Ridge Member? of the Oquirrh Formation
Lat 40° 18.368' N Long 111° 12.959' W

FUSULINID TAXA

Triticites

FUSULINID AGE

PERMIAN
Guadalupian

Leonardian

Wolfcampian

PENNSYLVANIAN
Virgilian

Missourian middle

Desmoinesian

Atokan (Derryan)

Morrowan

FUSULINID PRESERVATION & ABRASION

Good Fair Poor

CALCAREOUS ALGAE PRESENT

Ivanovia: Green Codiacean Phylloid Algae.

ROCK DESCRIPTION: Light gray Biomicrite: Mudstone. Scattered very fine grained quartz sand in fusulinid, algal Mudstone.
COMMENTS: Look around for phylloid algal mounds.

Age determined with thin sections

A. J. Doc Wells Ph.D.
06/30/08

Appendix B Palynological Analysis

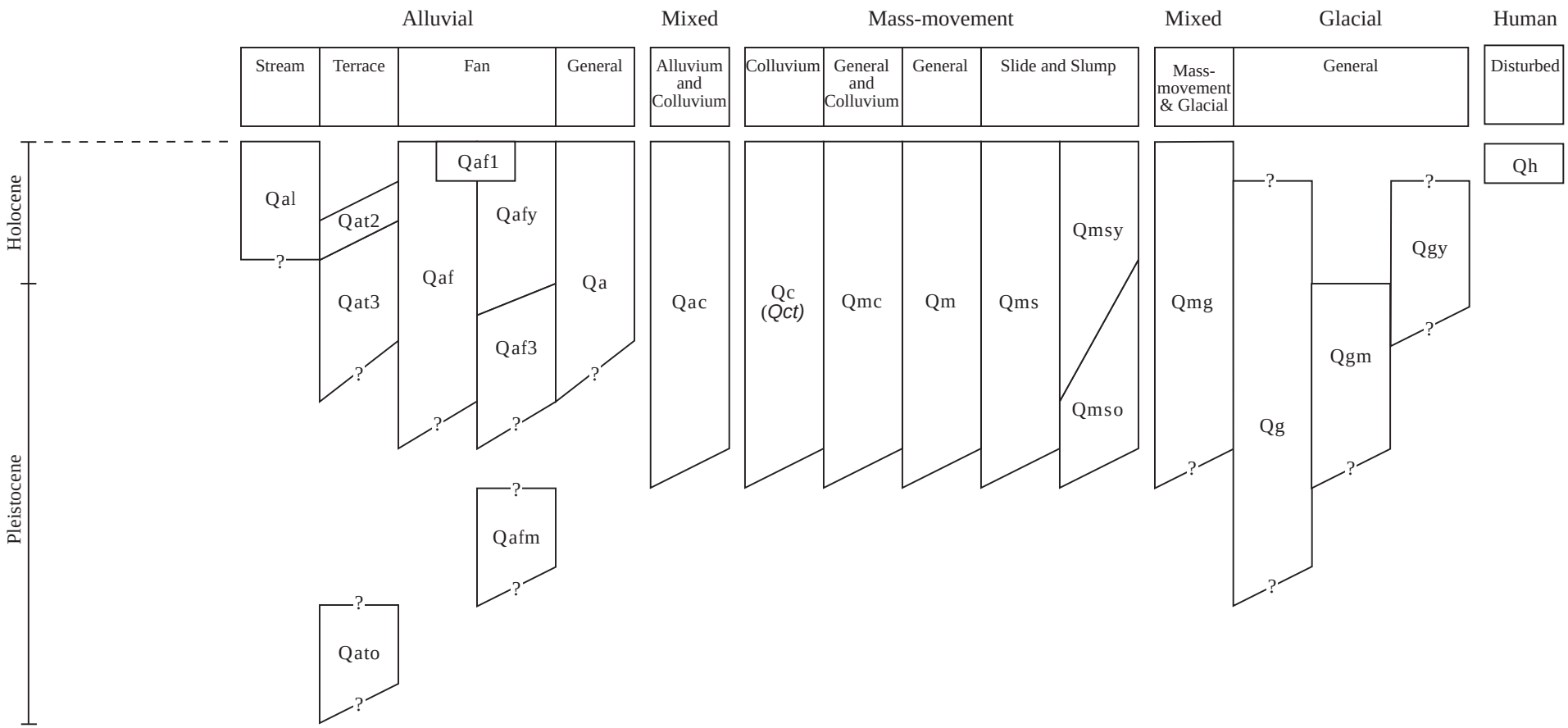
Report date: April 10, 2000
Sample number: Provo JC99-19.
Location: 1300' fnl/2225' fwl. Sec 28-1S-11W. Co-Op Creek quadrangle, unit Kf

Spores and Pollen:	Abundance
*Appendicisporites auritus**	(R)
Araucariacites australis	(R)
Camarozonosporites insignis	(R)
*Cicatricosisporites brevilaesuratus**	(R)
C. hallei	(R)
Classopollis classoides	(R)
Deltoidospora spp.	(F)
Gleicheniidites senonicus	(C)
Klukisporites pseudoreticulatus	(R)
Rugubivesiculites sp.	(R)
Taxodiaceae	(A)
Undifferentiated Bisaccates	(A)

Microplankton:	Abundance
Circulodinium distinction	(R)
Cleistosphaeridium spp.	(R)
Cometodinium whitei	(R)
Coronifera oceanica	(R)
*Cribropenidinium edwardsi**	(R)
*Dinopterygium cladoides**	(R)
*Florentinia cooksoniae**	(R)
F. stellatum	
Hysthchodinium pulchrum	(R)
Isabelidinium acuminatum	(R)
Odontochitina operculata	(F)
Oligosphaeridium complex	(R)
Palaeohystrichophora infusorioides	(R)
Palaeoperidinium cretaceum	(R)
Spiniferites ramosus	(C)
Veryhachium sp.	(R)

Organic Recovery: 50% Woody, 25% Cuticular, and 25% Amorphous
AGE: Late Cenomanian to Turonian (T6)
ENVIRONMENT: Nearshore Open Marine

Analysis by: Gerald Waanders

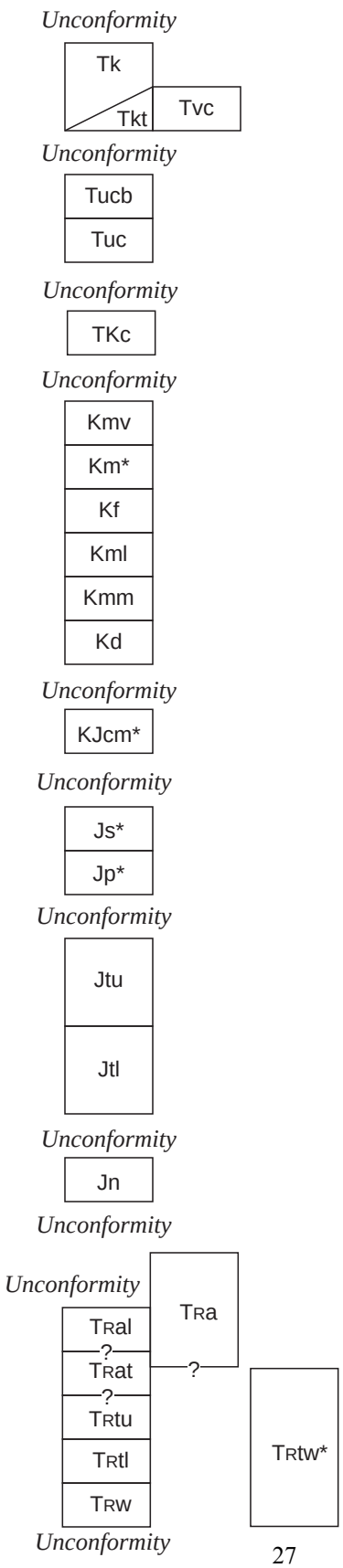


Co-op Creek quadrangle
QUATERNARY CORRELATION CHART

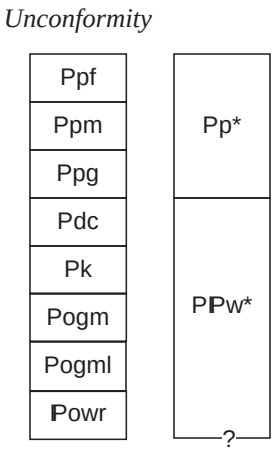
CO-OP CREEK QUADRANGLE BEDROCK CORRELATION CHART

*=not exposed, cross section figure only

TERTIARY AND MESOZOIC CORRELATION CHART



PALEOZOIC CORRELATION CHART



Lithologic Column, Co-op Creek - Currant Creek Area

ERA	SYMBOL	FORMATION		THICKNESS Feet	THICKNESS Meters	LITHOLOGY
Q	Q	surficial deposits		0-200	0-60	40.5 Ma Ar-Ar
TERTIARY	Tk	Keetley Volcanics		0-1400	0-425	May = Tvc in Strawberry Valley (37.7 Ma Ar-Ar)
	Tkt	basal tuffaceous unit		0-200	0-60	37.3 Ma Ar-Ar
	Tuc,Tucb	Uinta Formation		~2000+	~610+	Conglomerate (Tucb)
	?Tgu*, ?Tgm*, Tgl*	Green River Formation		~3800	~1158	Not exposed, and may or may not be present in subsurface.
	Tc*	Colton Formation		~170	~52	
	Tf*	Flagstaff Formation		~280	~85	
	TKc	Currant Creek Formation		<4800	<1460	UNCONFORMITY
?						ANGULAR UNCONFORMITY
CRETACEOUS	Kmv	Mesaverde Formation		~5200	~1585	Only small parts of Kmv exposed in Co-op Creek quadrangle
	Km*	Mancos Shale		~1700	~520	
	Kf	Frontier Formation		700	215	Upper part of Kf not exposed
	Kml	Mancos Shale, lower shale		~90	~27	
	Kmm	Mancos Shale, Mowry Shale Tongue		90	27	
	Kd	Dakota Formation		200-400	60-120	Lower part of Kd not exposed
	KJcm*	Cedar Mountain Formation and Morrison Formation		2650	810	
JURASSIC	Js*	Stump Formation		250	75	Curtis of some workers
	Jp*	Preuss Formation		~750	~230	Entrada of some workers
	Jtu	Twin Creek Limestone	Giraffe Creek and Leeds Creek Mbrs	~500	~150	Upper part of Jtu not exposed
			Watton Canyon Mbr	~120	~35	
	Jtl		Boundary Ridge Mbr	~65	~20	
			Rich Member	~160	~50	
			Sliderock Member			Red beds
			Gypsum Spring Mbr			upper and lower Jn contacts not exposed in this quadrangle
	Jn	Nugget Sandstone		1260	385	Navajo of some workers
TRIASSIC	TRa, ?TRal	Ankareh Formation	upper member	350	107	Middle conglomerate mbr, ~40 ft (12 m); may not be exposed
			lower member	~800	~245	
	?TRat		intertongued?	~350	~110	
	TRtw*, TRtu	Thaynes Formation	upper member	~300	~90	
	TRtl		lower member	~1000	~300	
	TRw	Woodside Shale		500	150	
PERMIAN	Pp*, Ppf	Park City and Phosphoria Formations	Franson Member	650	200	
	Ppm		Meade Peak Member	190-225	58-70	
	Ppg		Grandeur Member	685	210	
	Pdc	Diamond Creek Sandstone		450	140	
	Pk	Kirkman Limestone		97-375	30-115	Saline beds in subsurface
	Pogm	Oquirrh Formation	Granger Mountain Member	8200-10,255	2500-3125	Regional thickness Incompletely exposed and fault truncated here
	Pogml		Limestone unit	~500	~150	Regional thickness
?	IPowr		Wallsburg Ridge Mbr	~3700	~1128	Incompletely exposed

*=Not exposed in Co-op Creek quadrangle

Thicknesses are diagrammatic, no fixed scale.

GEOLOGIC SYMBOLS

contact, dashed where approximately located, dotted where concealed

normal fault, dashed where approximately located, dotted where concealed, ball and bar on hanging wall, dashed and queried where existence uncertain in northwest part of quadrangle

thrust fault, dashed where approximately located, dotted where concealed, solid teeth on hanging wall, bar and ball on thrust indicates reversal of movement due to later normal faulting

fault on figure 2, arrow indicates direction of movement, double headed arrow indicates reversal of movement due to later normal faulting

lineament, possible fault, but offset uncertain

terrace edge

fold hinge-zone trace (red), dashed where approximately located, dotted where concealed, arrow indicates plunge

anticline, upright on left, overturned on right

syncline, upright on left, overturned on right

synformal anticline

monocline

mass-movement scarp

cirque headwall?

50 35 strike and dip of bedding, from Welsh (1981) in red

45 50 upright, with bedding top indicators on right

vertical

75 overturned

horizontal

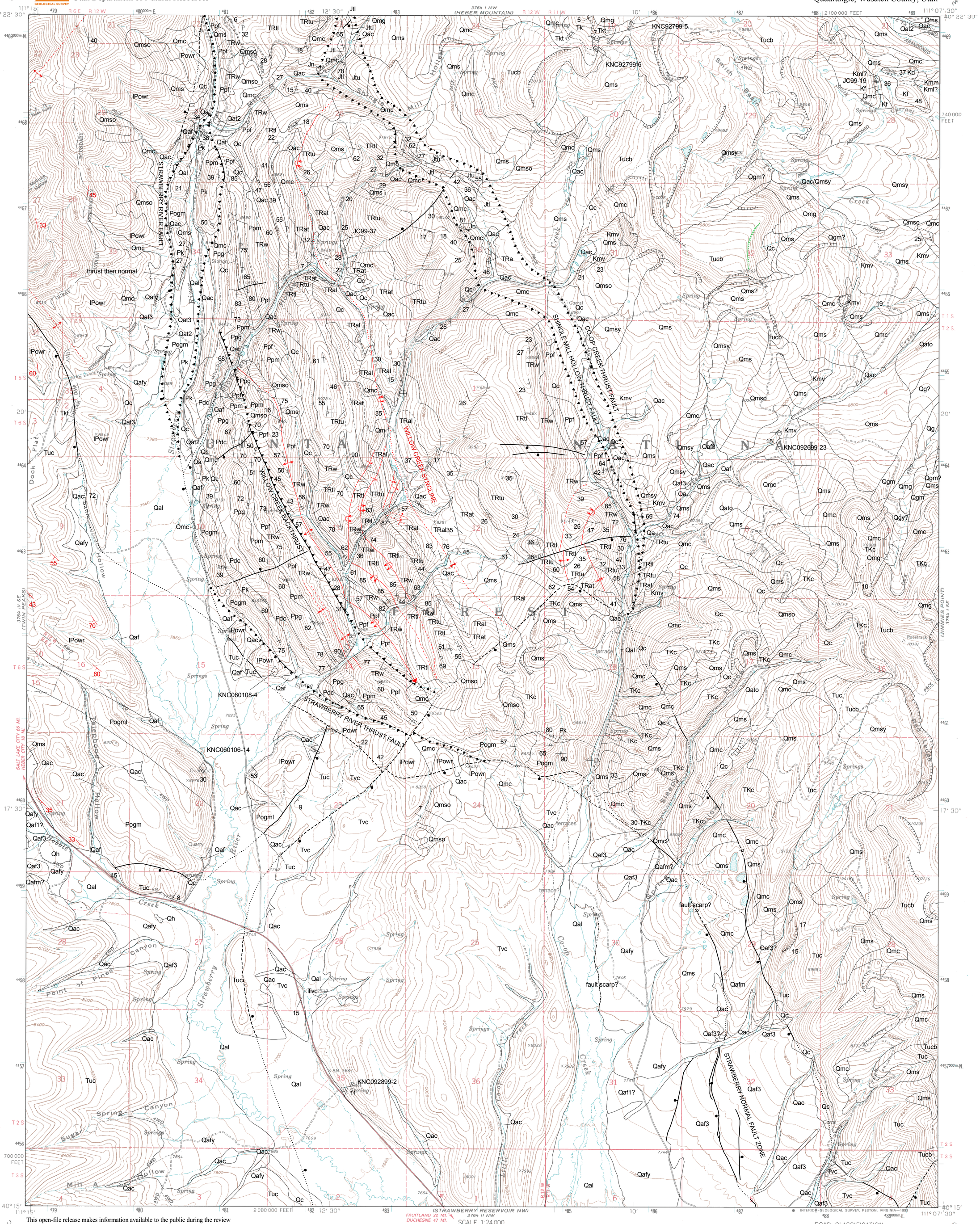
Sample location with number

$^{40}Ar/^{39}Ar$ (see table 1 for $^{40}Ar/^{39}Ar$ ages)

Fusulinid (see Appendix A)

Palynology (see Appendix B)

Utah Geological Survey, a division of
Utah Department of Natural Resources



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UTM GRID AND 1993 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
SUPPLEMENTARY CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

QUADRANGLE LOCATION

ROAD CLASSIFICATION

Primary highway, hard surface
Light-duty road, hard or improved surface
Secondary highway, hard surface
Unimproved road
Interstate Route
U. S. Route
State Route

INTERIM GEOLOGIC MAP OF THE CO-OP CREEK QUADRANGLE, WASATCH COUNTY, UTAH

by Kurt N. Constenius, James C. Coogan, and Jon K. King

2010

CO-OP CREEK, UTAH
40111-C2-TF-024
1993
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