Progress Report Geologic Map of the East Part of the Provo 30' x 60' Quadrangle, Utah and Wasatch Counties, Utah

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This geologic map was funded by the Utah Geological Survey and U.S. Geological Survey, National Cooperative Geologic Mapping Program through U.S. Geological Survey STATEMAP Agreement Numbers 99HQAG0138, 01HQAG100, 02HQAG055, 03HQAG0096, 04HQAG0040, and 05HQAG0084. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

Open-File Report 490
Utah Geological Survey
a division of
Utah Department of Natural Resources
2006

Map Unit Descriptions

Qh Human disturbance (Historical) -- Fill material used at Deer Creek, Strawberry, and Currant Creek dams, along U.S. Highway 189 in Provo Canyon and U.S. Highway 6 in Spanish Fork Canyon, and at sewage lagoon west of Heber City.

Qa Alluvium, undivided (Quaternary) -- Sand, silt, clay, and gravel in stream and alluvial-fan deposits; composition depends on source area; in Spanish Fork Canyon mapped alluvium is pre-latest Pleistocene Lake Bonneville, lip of upper surface at least 120 feet (40 m) above active stream, and 0 to 20 feet (0-6 m) thick; in Bridal Veil Falls quadrangle the alluvium is about 160 feet (50 m) above active stream, about 160 feet (50 m) thick, and is mostly latest Pleistocene (Pinedale) age glacial outwash.

Qay Younger alluvium (Holocene and Upper Pleistocene) -- Moderately sorted sand, silt, and gravel forming a broad planar surface in Heber Valley; age constrained by local veneers of loess or alluvium, and stage II (Birkeland and others, 1991) soil carbonate development; likely deposited as glacial outwash in braided streams and therefore mostly late Pleistocene in age; borehole data indicate up to about 450 feet (140 m) thickness of fill in map area (Qay+Qao), and thicknesses about 100 feet (30 m) less than estimate from gravity data for same locations (see Peterson, 1970).

Qam Middle alluvium (Upper Pleistocene) -- Variably sorted, unconsolidated silt, sand, and gravel deposited by streams and in alluvial fans; mapped on sloping benches 120 to 240 feet (35-70 m) above active drainages in Wallsburg Ridge, Two Tom Hill, and Granger Mountain quadrangles, thinner and 160 to 300 feet (50-90 m) above active drainages in Aspen Grove quadrangle; estimated thickness 20 to 80 feet (5-25 m).

Qao Older alluvium (Middle and Lower Pleistocene) -- Moderately sorted, unconsolidated, sand and silt with lenses of pebbles and cobbles; clasts are subrounded to rounded Oquirrh Formation and minor intermediate volcanic rock, likely Keetley Volcanics; mapped about 300 feet (90 m) above Provo River (now obscured by Deer Creek Reservoir) in what is likely a paleo-meander (QTa of Biek and others, 2003); 0 to about 30 feet (0-9 m) thick; Sullivan and others (1988) suggested these deposits are older than 730 ka; similar small exposure in Daniels Canyon, Center Creek quadrangle, is 300 to 400 feet (90-120 m) above drainage.

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. Locally underlain by and interbedded with spring tufa in western Heber Valley.

Qat, Qat2, Qat3

Stream-terrace alluvium (Holocene and Upper Pleistocene) -- Sand, silt, clay, and gravel in terraces above floodplains; number suffixes apply to local drainages with multiple terrace levels with lowest (youngest) terraces labeled 2; Qat2 surfaces typically 10 to 35 feet (3-11 m) above adjacent drainage while Qat3 surfaces typically 35 to 60 or more feet (11-18+ m) above adjacent drainage; 0 to 45 feet (0-14 m) thick. In the Spanish Fork Peak quadrangle, Qat3 is graded to the Provo level of latest Pleistocene Lake Bonneville and is more than 40 feet (12 m) above drainages; partly glacial outwash in Center Creek quadrangle.

Qaf Alluvial-fan deposits, undivided (Holocene and Upper(?)Pleistocene) -- Mostly sand, silt, and gravel that is poorly stratified and poorly sorted; deposited mainly by debris flows at drainage mouths; used where age(s) of fans uncertain; generally less than 40 feet (12 m) thick.

Qafy, Qafm

Younger alluvial-fan deposits (Holocene and Upper Pleistocene) -- Mostly sand, silt, and gravel that is poorly stratified and poorly sorted; deposited mainly by debris flows at drainage mouths; Qafy fans are mostly Holocene and deflect stream channels; Qafm fans are mostly Upper Pleistocene, incised by active drainages, and are characterized by carbonate-bearing soil horizons (stage II to III of Birkeland and others, 1991); generally less than 40 feet (12 m) thick.

Qaf3 Intermediate-level alluvial-fan deposits (Pleistocene) -- Deposits similar to Qafm, but development of soil carbonate horizon (stage III of Birkeland and others, 1991) and amount of drainage incision intermediate between Qafm (stage II to III) and Qafo (stage III+ to IV); 0 to about 50 feet (0-15 m) thick.

Qafo Older alluvial-fan deposits (Pleistocene) -- Mostly sand, silt, and gravel that is poorly stratified and poorly sorted; deposited mainly by debris flows at drainage mouths; Qafo fans are deeply incised by younger drainages and are likely Middle Pleistocene in age; some may be as old as unit QTa (Pleistocene-Pliocene); generally less than 40 feet (12 m) thick. Qafo in Springville quadrangle is above Qat3; Qafo in Center Creek quadrangle is 200 feet (60 m) above active drainages; Qafo in Charleston quadrangle is not an incised remnant but has stage III+ to IV soil carbonate development.

Qap Pediment-mantle deposits (Quaternary) -- Alluvial sand and gravel deposited on broad surfaces on top of Cretaceous bedrock above the mouths of tributaries to Currant Creek, north and northwest of Currant Creek Reservoir; possibly correlative downstream with Qat3; 0 to 50 feet (0-15 m) thick.

Qac Alluvium and colluvium (Quaternary) -- Includes stream and fan alluvium, colluvium, and, locally, mass-movement deposits; 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.

Qct Colluvium and talus, undivided (Quaternary) -- Angular debris at the base of and on steep, variably vegetated slopes in cirques in the southwest part of map area; typically extending downslope to cover glacial deposits. Also mapped in steep washes in Charleston and Aspen Grove quadrangles.

Qm Mass-movement deposits, undivided (Quaternary) -- Includes slides, slumps, and flows, as well as colluvium and talus; mapped on steep slopes where several mass-movement processes may contribute to deposit; composition depends on local sources; 0 to 40 feet (12 m) thick.

Qmc Mass movement and colluvial deposits, undivided (Quaternary) -- Includes landslide, slump, slopewash, and soil creep; mapped in areas of subdued morphology where separate mapping of mass movement and colluvial deposits is not possible; composition depends on local sources; 0 to 40 feet (12 m) thick.

Qmt Talus deposits (Holocene and Pleistocene) -- Angular debris on and at the base of steep, mostly unvegetated slopes; often composed of Oquirrh Formation quartzite; locally includes protalus ramparts in southwest part of map area; 0 to 30 feet (0-9 m) thick.

Qmf Flow deposits (Holocene and Pleistocene) -- Large-scale earthflows formed on Manning Canyon Shale near Provo Canyon and on younger units near Currant Creek, and scattered deposits elsewhere in map area; all exhibit hummocky internal morphology and distinct hummocky margins; near Provo Canyon deposits grade into mega-breccia (QTmb) of nearly intact bedrock; near Currant Creek largest flows formed where conglomerates of the Uinta Formation lie above Upper Cretaceous clay-rich bedrock (older deposits), in clay-rich Mesozoic bedrock (younger deposits), and in the Currant Creek Formation (youngest deposits); as much as 200 feet (60 m) thick near Currant Creek and at least that thick near Provo Canyon.

Qms, Qmsy, Qmso, Qms1

Slides and slumps (Quaternary) -- Poorly sorted clay- to boulder-sized material derived from steep local source terrain; generally characterized by hummocky topography, main and internal scarps, and chaotic bedding in displaced bedrock; locally includes flow deposits; morphology becomes subdued with age; divided into younger (Holocene) and older deposits where possible (suffixes y and o, respectively); Qms1 are historical slides, slumps, and flows; bedrock units most susceptible to mass movements include the Tertiary Moroni Formation (Tm), Keetley Volcanics (Tk, Tkt), volcaniclastic rocks of Strawberry Valley (Tv), Uinta Formation (Tu and Tucg), Currant Creek Formation (TKc), clay-rich Mesozoic rocks (Kmv, TRa), and the Manning Canyon Shale (Mmc); thicknesses highly variable. Large blocks of bedrock in slides, slumps, and flows are mapped separately with the bedrock unit in parentheses in the label - Qms(rx unit).

Qmg Mass-movement and glacial deposits, undivided (Holocene and Upper Pleistocene) --

Glacial deposits (see unit Qg description) in displaced slide masses in northeast part of map area, and in Aspen Grove, Spanish Fork Peak, and Billies Mountain quadrangles; includes displaced bedrock in the lobate mass on the north side of Lake Creek drainage, Heber Mountain quadrangle; up to 300 feet (90 m) thick.

Qg Glacial deposits, undivided (Pleistocene) -- Includes till (moraine deposits) and outwash of various ages; unit used in west and northeast part of map area.

Qgm Moraines (Pleistocene) -- Non-stratified, poorly sorted clay, silt, sand, cobbles, and boulders deposited in moraines of uncertain age; unit used in west part of map area and mostly Pinedale in age.

Qga Glacial outwash (Pleistocene) -- Stratified, variably sorted, alluvialy reworked debris of uncertain age; unit used in west part of map area.

Qgr Rock glacier deposits (Pleistocene) -- Angular, mostly cobble- to boulder-sized debris with little matrix in unvegetated mounds with lobate crests; locally includes protalus ramparts; inactive (no ice matrix); unit used in west part of map area; may be same age as younger glacial deposits (Qgy); likely 0 to 30 feet (0-9 m) thick.

Qgy Younger glacial deposits (Upper Pleistocene) -- Non-stratified, poorly sorted clay, silt, sand, cobbles, and boulders in upper reaches of non-vegetated cirque basins in northeast part of map area and Bridal Veil Falls quadrangle; deposits derived from headwall bedrock sources; generally characterized by sharp, non-vegetated moraines and very poor soil development; 0 to 50 feet (0-15 m) thick.

Qgp Glacial deposits, Pinedale age (Upper Pleistocene) -- Non-stratified, poorly sorted clay, silt, sand, gravel, cobbles, and boulders; includes outwash deposits; moraines, where present, show moderate to sharp morphology; till has weak soil development; about 15,000 to 30,000 years old; locally include small wet depressions in which younger sediment has accumulated; in northeast part of map area, present in broad, generally north-facing valleys and some steep-walled, south-facing, high-elevation cirques; 0 to 150 feet (0-46 m) thick.

Qgo Older glacial deposits (Pleistocene) -- Non-stratified, poorly sorted clay, silt, sand, gravel, cobbles, and boulders; has well-developed soil and subdued moraine morphology; locally includes small slides and slumps; possibly Bull Lake age; 0 to at least 50 feet (0-15+ m) thick.

Ql Lacustrine deposits (Upper Pleistocene) -- Undivided Lake Bonneville deposits; used in southwest part of map area; at least 20 feet (6 m) thick.

Qla Lacustrine and alluvial deposits, undivided (mostly Upper Pleistocene) -- Benches composed of lacustrine and alluvial deposits below and slightly above the Bonneville shoreline in Spanish Fork Canyon; likely stream and fan alluvium, deposited during transgression of Lake Bonneville, overlain by thin lacustrine deposits with post-Bonneville fan alluvium on the upper part of the benches.

Qst Spring tufa deposits (Holocene and Pleistocene) -- Largely concealed by and interfingering with Heber Valley fill, so mapped as Qa/Qst with Qst only at major springs; tufa is highly porous, pale yellowish gray, tan weathering calcium carbonate; present as beds in valley fill to depths greater than 150 feet (45 m).

Qrc Residuum and Colluvium (Quaternary) -- Poorly sorted clay- to boulder- sized, locally derived material; typically mapped on north-facing, vegetated slopes where bedrock and contacts are concealed; 0 to about 15 feet (0-5 m) thick. Only mapped in Center Creek and Twin Peaks quadrangles.

Qu Quaternary deposits, undivided -- Used in Utah Valley where U.S. Geological Survey strip map (Machette, 1992) provides a more accurate portrayal of the geology.

QTa High-level alluvium (Lower Pleistocene and/or Pliocene?) -- Clay- to boulder-size, locally derived material on gently sloping surfaces 300 to 600 feet (90-180 m) above adjacent drainages in Wallsburg Ridge quadrangle; similar poorly sorted deposits have upper surfaces about 350 feet (105 m) above Center Creek, Center Creek quadrangle; may be younger than QTaf; estimate 0 to 50 feet (0-15 m) thick.

QTaf High-level alluvial fans (Lower Pleistocene and Pliocene?) -- Poorly sorted, clay- to boulder-size, locally derived material in gently sloping fan remnants as low as 450 feet (140 m) above and up to 800 to 1500 feet (245-460 m) above Daniels Canyon, Center Creek quadrangle; 0 to 50 feet (0-15 m) thick. Near Cummings Flat, mixed-clast (Oquirrh & volcanic rocks) deposits reflect nearby Keetley Volcanic rocks (Tk).

QTmb Mega-breccia (Pleistocene and Pliocene?) -- Formed by displacement on underlying Manning Canyon Shale near Provo Canyon; ranges from nearly intact bedrock to mega-blocks to blocks to rubble “floating” in younger Quaternary landslide, slump, and flow deposits (Qms, Qmf); shown as complex thrust faulting in previous mapping (see Baker, 1964, 1972a).

Taf Tertiary alluvial-fan deposits (Pliocene?) -- Poorly to moderately sorted, clay- to boulder-sized material that is poorly exposed on northwest end of Round Valley, Charleston quadrangle; clasts weathering out of material are subangular sandstone and limestone of adjacent Oquirrh Formation; unit may be alluvial-fan deposits (Qaf3), colluvium, and regolith that mantle the Bear Canyon Member of the Oquirrh Formation; estimate 0 to 650 feet (0-200 m) thick.

Ti Intrusive rocks (Miocene-Oligocene) -- Biotite-bearing, dark-gray, medium- to fine-grained quartz diorite (Baker, 1976) that intrudes Granger Mountain Member of Oquirrh Formation and probably the Uinta Formation (middle Eocene); $^{40}Ar/^{39}Ar$ biotite age of 34.7±0.16 Ma (sample KNC9299-1, table 1) puts the intrusion in the age range of volcanic rocks in the area (table 1) and the older potassic mafic rocks (lamproites) to north (34-35 Ma) (Mitchell and Bergman, 1991); exposure is in Second Set Canyon south wall (section 12, T. 6 S., R. 5 E., Twin Peaks quadrangle) and is several hundred feet wide and about 1500 feet (460 m) long, elongate to the northwest.

Tt Tibble Formation (lower Miocene - upper middle Eocene) - Brick-red, red-brown, and gray, cobble to boulder conglomerate; lithic clasts predominantly Pennsylvanian-Permian sandstone and quartzite; largest boulders about 6 feet (2 m) across; intercalated with variegated brick-red and gray mudstone, bentonitic mudstone, and poorly sorted sandstone; minor white to light-gray tuffaceous sandstone and medium-gray microcrystalline limestone; rare thin beds of light-gray tuff; the Tibble is an extensional basin-fill deposit that overlies with angular unconformity, and is in fault contact with, pre-Tertiary hanging-wall rocks of the Charleston-Nebo thrust sheet; mapped in graben in Granger Mountain, Spanish Fork Peak, Timpanogos Cave, and Aspen Grove quadrangles; fossiliferous, "soft" weathering, gray shale in Pole Canyon, Spanish Fork Peak quadrangle, yielded an early Miocene-Oligocene gastropod fauna; $^{40}Ar/^{39}Ar$ biotite ages of 34.4±1.4 and 39.51±0.36 Ma are from upper and lower beds, respectively, in the Timpanogos Cave quadrangle (KNC72393-1T and KNC61093-2T, Constenius and others, 2003); thickness ranges from 0 to 2500 feet (0-762 m).

Tm Moroni Formation (Oligocene- upper Eocene) - Very light-gray, gray, and white, tuffaceous and pumiceous sandstone and tuff interbedded with lesser conglomerate, pumice, welded tuff, and limestone; conglomerate clasts vary from pebbles and cobbles to small boulders (~20 inches [0.5 m]); sedimentary clasts from Pennsylvanian-Permian Oquirrh Formation, Permian Diamond Creek Sandstone and Park City Formation, and Cambrian Tintic Quartzite; igneous rocks predominantly gray to very dark-gray, reddish brown-weathering andesite-dacite porphyry; tuffs and tuffaceous sandstones poorly exposed, conglomerate bed in lower part of unit is ledge forming and about 65 feet (20 m) thick; formation rests unconformably on Tu; top removed by erosion, 0 to an estimated 1800 feet (~550 m) thick; mapped as Tibble Formation by Young (1976), but not like Tibble; samples KNC71194-5, KNC101701-1, and KNC101701-4 from Billies Mountain quadrangle were $^{40}Ar/^{39}Ar$ dated at 34.68±0.09, 34.86±0.09, and 37.18±0.38 Ma, respectively (table 1).

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 Co-op Creek quadrangle yielded an $^{40}Ar/^{39}Ar$ age of 40.45±0.18 Ma (table 1); 0 to more than 1400 feet (0-430+ m) thick. Includes mixed (Oquirrh & volcanic rock) clast unit Ta of Biek and others (2003).

Tkq Keetley Volcanics, quartzite clast unit (Oligocene(?) - upper Eocene) -- Gray tuffaceous volcanic sandstone matrix with granules to boulders of Oquirrh Formation quartzite and some limestone; locally contains Mesozoic rock clasts from sand to gravel size that form sedimentary sandstone and sandstone matrix; only mapped separately in the Center Creek quadrangle where it is distinct because it lacks volcanic clasts; 0 to about 450 feet (0-140 m) thick, but thickness may include interbedded volcanic strata.

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 Co-op Creek quadrangle yielded an $^{40}Ar/^{39}Ar$ age of 37.25±0.14 Ma (table 1); 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 in northeast part of map area; may be as much as 800 feet (240 m) thick in Center Creek quadrangle if bedding dip in area is minimal.

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. Possibly correlative northward to Keetley Volcanics and southward to Moroni Formation; sample KNC92899-2 from Co-op Creek quadrangle was $^{40}Ar/^{39}Ar$ dated at 37.73±0.28 Ma (table 1); at least 1500 feet (460 m) thick, with top not exposed.

Ts Sandstone and conglomerate (Eocene-Paleocene?) -- Brick-red and red-brown sandstone and pebble conglomerate; lithic clasts of Oquirrh Formation sandstone/quartzite and limestone predominate; exposed at the mouth of Spanish Fork Canyon; may be equivalent to upper North Horn or Uinta Formation; exposed thickness about 160 feet (50 m).

Tu Uinta Formation, main body (middle Eocene) -- Includes: (1) light-gray, tan, and red, medium- to thick-bedded, lenticular-bedded, pebbly sandstone; (2) brick-red, reddish-brown, variegated, very thick- to thin-bedded mudstone, commonly with floating sand grains; (3) red-brown, tan, and gray conglomerate with sandstone to mudstone matrix; and (4) dark-gray to yellowish- and purplish-gray marlstone of probable pedogenic origin; interfingers northward with underlying Tucg, and westward with overlying Tucg, but conglomerates are not otherwise distinguishable; only conglomerate is present in Center Creek quadrangle; at least 2000 feet (600 m) exposed.

Tucg Uinta Formation, conglomerate (middle Eocene) -- Gray, red, and red-brown, thick- to very thick-bedded conglomerate, commonly stained red by weathering of interbedded, thin, red-brown mudstone; clasts vary in size from pebbles and cobbles to large boulders 3 to 10 feet (1-3 m) in diameter; quartzite clasts derived from Pennsylvanian-Permian Oquirrh Formation predominate, with clasts derived from Precambrian Uinta Mountain Group, Cambrian Tintic Quartzite, Pennsylvanian Weber Formation, Permian Park City Formation, Triassic Thaynes Formation, and Jurassic Twin Creek Limestone locally present; 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 eastward and southward over short distances; up to 1500 feet (460 m) thick.

Tgu Green River Formation, upper member (middle Eocene) -- Sandstone, siltstone, mudstone, marlstone and minor oil shale. Sandstone is light gray, light-brown-weathering, calcareous, and medium to thick bedded; some beds are trough cross-stratified and fine to medium grained, grading to siltstone; occasionally coarse-grained to conglomeratic. Marlstone is dark gray, weathering to light tan, light gray, or gray, thin to thick bedded, and microcrystalline. Mudstone is predominantly greenish gray to dark gray and poorly exposed. Oil shale is rare, grayish brown to dark brown, and fissile. Sandstone and marlstone form steep slopes and cliffs, with thin benches along oil shale and mudstone horizons. More than 400 feet (120 m) thick at Island Mountain where the base of the unit is not exposed. Unit progressively truncated and is completely removed by erosion to the west in the Billies Mountain and Two Tom Hill quadrangles along the basal Uinta Formation unconformity.

Tgm Green River Formation, middle member (middle Eocene) -- Lower part is dominantly dark brown, light-bluish-gray-weathering, fissile to platy, thinly laminated oil shale and marlstone; upper part is mostly greenish-gray and gray mudstone, gray siltstone, and tan, fine- to medium-grained sandstone; distinctive small steel-blue to dark-bluish-gray concretions throughout; at least 2200 feet (670 m) thick in complete sections. Unit progressively truncated and is completely removed by erosion to the west in the Billies Mountain and Two Tom Hill quadrangles along the basal Uinta Formation unconformity.

Tgl Green River Formation, lower member (middle Eocene) -- Greenish-gray, fissile to blocky shale and mudstone as very thick beds separated by thinly laminated, gray marlstone; also contains gray-green, waxy-textured claystone and thin-bedded, brown-weathering sandstone that is locally micaceous; sandstone contains rare vertebrate fossils as lags (gar scales, turtle and crocodile plates); oil shale is common near base; at least 1200 feet (365 m) thick in complete sections. Unit progressively truncated and is completely removed by erosion to the west, in the Billies Mountain and Two Tom Hill quadrangles along the basal Uinta Formation unconformity.

Tc Colton Formation (lower Eocene) -- Medium- to coarse-grained, light-gray, light-brown-weathering, calcareous sandstone in thin to thick beds; interbedded with medium-gray, microcrystalline limestone, and red-brown, gray and gray-green mudstone; top of formation in Rays Valley 7.5' quadrangle is at the top of an extremely fossiliferous sandstone bed containing *Unionidae* bivalves, gastropods, and vertebrate fossils (gar scales, crocodile teeth, crocodile and turtle plates and bones); about 170 feet (50) m thick.

Tf Flagstaff Limestone (lower Eocene) -- Medium-gray, very thick-bedded, microcrystalline limestone; weathers white and light gray; hard and brittle; forms cliffs; interbedded with less-resistant, variegated brick-red, purplish-gray, maroon, red-brown, yellow and gray marlstone and calcareous mudstone; light-gray, thin- to medium-bedded, medium- to coarse-grained sandstone increases in abundance up section; about 280 feet (85 m) thick.

Tn North Horn Formation, upper member (Paleocene) -- Brick-red, thick- to very thick-bedded mudstone, siltstone, and sandstone; interbedded with very thick-bedded, medium-gray-weathering, dense, microcrystalline limestone interbeds containing fossil gastropods; conglomerate locally present as thick, lenticular, channel-fill deposits containing pebbles to rare boulders of Pennsylvanian-Permian Oquirrh Formation; about 200 feet (60 m) thick.

Tnq North Horn Formation, quartzite conglomerate member (Paleocene) -- Light-gray, thick- to very thick-bedded, cobble to boulder (up to about 3 feet [1 m] across) conglomerate with dominantly well-rounded, gray and tan quartzite clasts from the Oquirrh Formation; intercalated with light-gray, yellow-tan-weathering, and minor brick-red, medium- to coarse-grained sandstone; limonitic staining common; upper contact conformable with Tn; lower contact is profound angular unconformity with Permian rocks; present in Granger Mountain area; 0 to 250 feet (0-75 m) thick.

TKn North Horn Formation, lower member (Upper Cretaceous; Maastrichtian-Paleocene) -- Light- to medium-gray or brick-red or red-brown conglomerate, commonly discolored by red-colored slopewash from thin, interbedded, red mudstone; medium- to very thick-bedded; cobble- to boulder-sized clasts of Pennsylvanian-Permian Oquirrh Formation sandstone, quartzite, and limestone predominate; at least 1800 feet (550 m) thick.

TKnc North Horn and Currant Creek Formations, undivided (Upper Cretaceous; Maastrichtian-Paleocene) -- Conglomerate, sandstone, siltstone, and minor shale of TKn and TKc; mapped together in area of poor exposure on east side of upper Co-op Creek drainage.

TKc Currant Creek Formation (Upper Cretaceous; Maastrichtian and Paleocene) -- 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; about 4800 feet (1460 m) thick.

Kpc Price River Formation and Castlegate Sandstone (Upper Cretaceous; Campanian-Maastrichtian) - Light-gray, thick- to very thick-bedded, cobble to boulder conglomerate, dominated by well-rounded, gray and tan, quartzite clasts; largest boulders exceed 10 feet (3 m) across; minor intercalated sandstone; conglomerate contains light silvery-gray sandstone matrix; matrix also characterized by white, smooth- to earthy-textured, clay blebs; lithic clasts >99% Pennsylvanian-Permian Oquirrh Formation quartzite, quartzite clasts derived from Proterozoic Mutual Formation and Cambrian Tintic Quartzite present in trace amounts; overlain with angular unconformity by TKn; underlain by Kcm with angular unconformity; thickness ranges from 0 to 2000 feet (0 to 600 m).

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; up to 5200 feet (1585 m) thick.

Km Mancos Shale (Upper Cretaceous) -- Dark-gray, bentonitic shale with minor gray limestone and gray, fine-grained sandstone; very poorly exposed; about 1700 feet (520 m) thick.

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; contains an oyster coquina marker bed in the lower 50 feet (15 m); extensively burrowed in the middle; about 700 feet (215 m) thick. Very poorly exposed in Center Creek quadrangle.

Kmm Mancos Shale, Mowry Shale Tongue (Lower Cretaceous) -- Dark-gray, platy to blocky, fissile, siliceous shale in lower part, with abundant teleost fish scales. Upper part contains massive-weathering, greenish-gray claystone; about 90 feet (25 m) thick.

Kd Dakota Formation (Lower Cretaceous) -- Sandstone, white to tan, very thick-bedded, cross-bedded, with extensive quartz veins; interbedded with gray and variegated siltstone; thickens northward from about 200 to 400 feet (60-120 m).

Kcm Cedar Mountain Formation (Lower Cretaceous) -- Mapped separately in Billies Mountain quadrangle. 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; 465 feet (142 m) thick.

KJcm Cedar Mountain (Lower Cretaceous) and Morrison (Upper Jurassic) Formations, undivided -- Pinkish-gray, quartz- and chert-pebble conglomerate and pebbly sandstone in thick, fining-upward, trough-cross-stratified beds; interbedded with greenish-gray and light-red siltstone and medium-grained, pinkish-gray sandstone; base not exposed; up to 2500 feet (760 m) thick in southeastern Heber Mountain 7.5' quadrangle.

Jsv Summerville Formation (Middle Jurassic) - Red-orange mudstone, siltstone, and sandstone; only mapped in Billies Mountain quadrangle and conformably overlies Curtis Formation; see Imlay (1980) for correlation; 395 feet (120 m) thick.

Js Stump Formation (Middle Jurassic) -- Light-gray, medium-bedded, calcareous sandstone in lower part; gray to green-gray, thick-bedded, ridge-forming, bioclastic limestone and sandy limestone in upper part; about 250 feet (75 m) thick.

Jce Curtis and Entrada Formations, undivided (Middle Jurassic) -- Only mapped in Billies Mountain quadrangle; lateral equivalent of lower (Curtis Member of) Stump and Preuss Formations; see Imlay (1980) for more information. Curtis - Greenish-gray, sandy shale, mudstone, and sandstone, with minor dark-red-brown sandstone; about 400 feet (120 m) thick. Entrada - Dark-red, red-brown, and purplish red-brown, with minor light-gray and light-brown, thin- to medium-bedded sandstone and siltstone; about 1000 feet (300 m) thick.

Jp Preuss Formation (Middle Jurassic) -- Red, brownish-red, purplish red, and minor light-gray, thin- to medium-bedded sandstone and siltstone; poorly exposed; about 750 feet (230 m) thick.

Ja Arapien Shale (Middle Jurassic) - Light-gray-green and light-gray shale interbedded with light-gray, tan-weathering, ripple cross-laminated, calcareous siltstone and sandstone; minor interbeds of red shale, light-yellow-gray sandstone, and gray-green to brown, micritic limestone; thickness about 560 feet (170 m); only mapped in Billies Mountain quadrangle, equivalent to unit Jtgl.

Jtc Twin Creek Limestone, undivided (Middle Jurassic) -- Used in Center Creek quadrangle; Arapien-Twin Creek interval thins to southwest to only 1200 feet (370 m) thick south of map area in Spanish Fork Canyon (Baker, 1947; Imlay, 1967).

Jtu Twin Creek Limestone, upper members (Middle Jurassic) -- Mapped in Co-op Creek and Heber Mountain 7.5' quadrangles where upper Twin Creek is structurally attenuated; divided into units Jtgl and Jtw elsewhere; top not exposed; estimated undeformed thickness is about 650 feet (200 m) from regional relationships.

Jtgl Twin Creek Limestone, Giraffe Creek and Leeds Creek Members (Middle Jurassic) -- Thinly interbedded, light-gray to light-greenish-gray, soft, shaly 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 unit; about 500 feet (150 m) thick in northeast and northwest parts of map area.

Jtwl Twin Creek Limestone, Watton Canyon, Boundary Ridge, Rich, Sliderock, and Gypsum Spring Members (Middle Jurassic) -- Unit only used in Billies Mountain quadrangle where Giraffe Creek and Leeds Creek members are indistinct and are shown by some workers as the Arapien Shale; about 600 feet (180 m) thick (Imlay, 1980).

Jtw Twin Creek Limestone, Watton Canyon Member (Middle Jurassic) -- 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 in northeast part of map area and about 250 feet (75 m) thick in Charleston quadrangle.

Jtl Twin Creek Limestone, lower members (Middle Jurassic) -- Unit used in Co-op Creek and Heber Mountain 7.5' quadrangles where lower Twin Creek is structurally attenuated; divided into units Jtb and Jtrsg elsewhere; estimated undeformed thickness is about 230 feet (70 m) from regional relationships.

Jtb Twin Creek Limestone, Boundary Ridge Member (Middle Jurassic) -- Red to purplish-red shale and siltstone, and minor gray siltstone; recessive and poorly exposed; about 65 feet (20 m) thick in northeast part of map area and about 120 feet (35 m) thick in Charleston quadrangle.

Jtrsg Twin Creek Limestone, Rich, Sliderock and Gypsum Spring Members (Middle Jurassic) -- Light-gray, soft, shaly limestone in upper part; dark-gray, thick-bedded, bioclastic limestone in middle, and thin (5-foot [1.5-m] thick) purple shale at base; about 160 feet (50 m) thick in northeast part of map area and about 420 feet (125 m) thick in Charleston quadrangle.

Jn Navajo 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; Nugget of some previous workers; about 1260 to 1450 feet (385-440 m) thick.

TRa Ankareh Formation (Upper and Lower(?) Triassic) -- Dull-red, reddish-brown and purple, thin-bedded mudstone, siltstone, and medium- to thin-bedded, fine-grained sandstone; siltstone is locally micaceous; green reduction spots common; in Co-op Creek 7.5' quadrangle, the brecciated, light-red sandstone near the base of unit is probably the conglomerate member, and the lower Ankareh member is included in unit TRat (see below); at least 300 feet (90 m) feet thick. Baker (1947) cited a total thickness of 1485 to 1530 feet (453 to 466 m).

TRau Ankareh Formation, upper member (Upper Triassic) -- Red, purplish-red, and reddish-gray, thin-bedded mudstone, siltstone, and fine-grained sandstone; about 350 (110 m) feet thick in northeast part of map area and 450 feet (135 m) thick in Aspen Grove quadrangle (Baker, 1964).

TRam Ankareh Formation, middle member (Upper Triassic) -- Gray to white, very thick-bedded, cross-bedded, coarse-grained sandstone and pebble conglomerate; about 40 feet (12 m) thick; possibly equivalent to the Gartra member.

TRal Ankareh Formation, lower member (Lower Triassic) -- Red and purple siltstone and shale, and purplish-gray, calcareous siltstone; thin bedded throughout; poorly exposed; about 800 feet (245 m) thick in northeast part of map area and 1000 feet (300 m) thick in Aspen Grove quadrangle (Baker, 1964).

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; north of the map area Kummel (1954, figure 21) portrays the formations as intertonguing; about 350 feet (110 m) thick.

TRt Thaynes Formation, undivided (Lower Triassic) -- Greenish-gray to brownish-gray, thin-bedded, silty limestone and fine-grained, calcareous sandstone; only used in northeast corner of map area and Billies Mountain and Charleston quadrangles, subdivided elsewhere; top not exposed. Neighbor (1959) reported a dip-corrected thickness of 1450 feet (440 m), based on four wells on the Diamond Fork anticline; total Thaynes only 950 feet (290 m) thick in Aspen Grove quadrangle (Baker, 1964), where it is subdivided by Smith (1969) into three members. Smith's members are not equivalent to those used elsewhere in map area.

TRtu Thaynes Formation, upper member of Smith (1969) (Lower Triassic) -- Gray siltstone with some grayish-green shale and gray limestone; 446 feet (136 m) thick in Aspen Grove quadrangle (Smith, 1969).

TRad Ankareh Formation, Decker tongue of Smith (1969) (Lower Triassic) -- Poorly exposed dark-red to brownish-red siltstone and silty shale with minor fine-grained sandstone at type area in Aspen Grove quadrangle; 222.5 feet (68 m) thick but may be faulted (Smith, 1969).

TRtl Thaynes Formation, lower member of Smith (1969) (Lower Triassic) -- Gray siltstone and limestone; 457 feet (140 m) thick in Aspen Grove quadrangle (Smith, 1969).

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 (90 m) thick.

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, and structurally thickened in Heber Mountain 7.5' quadrangle.

TRw Woodside Shale (Lower Triassic) -- Dark-red to red-brown shale and siltstone; poorly exposed; forms strike valleys; 420 to 600 feet (130 to 180 m) thick; about 770 feet (235 m) were drilled in the Amoco Cottonwood Canyon well, Ray's Valley quadrangle; queried in Wallsburg Ridge quadrangle because, as mapped, unit is less than 200 feet (<60 m) thick. Structurally thinned along Little Diamond Creek fault system, and appears far thinner than regional minimum in Wallsburg Ridge quadrangle; also only 315 feet (95 m) thick in Aspen Grove quadrangle (Baker, 1964).

Thin Upper Paleozoic Strata in Footwall of Charleston-Nebo thrust system

Pp Park City and Phosphoria Formations, undivided (Permian) - Consists of upper [Franson], middle [Meade Peak] and lower [Grandeur] units that are 352, 60, and 458 feet (107, 18, & 140 m) thick, respectively, just north of the Aspen Grove quadrangle (Baker, 1964); though about ½ thickness, units are lithologically like their counterparts elsewhere in Provo 30' x 60' quadrangle.

IPw Weber Quartzite (Lower(?) Pennsylvanian) - Mainly gray to buff, quartz-cemented sandstone with some interbedded gray cherty limestone (Baker, 1964); excessively thick in the Aspen Grove quadrangle compared to areas to north (8000 feet [2440 m] versus 1000 to 3500 feet [300-1070 m]) (after Baker, 1964), suggesting a transition northward out of the Oquirrh Basin onto continental shelf or structural thickening in the Aspen Grove area.

IPrv Round Valley Limestone (Lower Pennsylvanian) - Light- to medium-gray limestone with black, white, and orange-red chert and some thin beds of buff to gray sandstone; 225 to 400 feet (70-120 m) thick just north of Aspen Grove quadrangle (Baker, 1964).

Mdo Doughnut Formation (Upper Mississippian, Chesterian?) - Gray to dark-gray, thin-bedded limestone overlying black shale with some interbedded thin, fine-grained, gray, quartzose sandstone beds (after Baker, 1964); thickness uncertain; 1300 feet (400 m) thick just north of Aspen Grove quadrangle, but only 400 feet (120 m) thick farther north away from Charleston-Nebo thrust (Crittenden, 1959; Baker, 1964); again, this suggests a transition northward out of the Oquirrh Basin onto continental shelf or structural thickening, here with upper carbonate part likely structurally thickened while lower shale part is structurally attenuated.

Thick Upper Paleozoic Strata

Pp Park City and Phosphoria Formations, undivided (Permian)

Ppf Park City Formation, Franson Member -- Dolomite; light tannish gray; weathers very light tannish-gray to white; very thick bedded; silty to sandy; with small, quartz-filled vugs and light-gray, white, and tan chert as nodules and stringers; commonly highly fractured to brecciated; about 650 feet (200 m) thick in Willow Creek area of Co-op Creek 7.5' quadrangle; 660 feet (200 m) were drilled in the Amoco Cottonwood Canyon well, Ray's Valley quadrangle. Faulted out in the Spanish Fork Peak and Billies Mountain quadrangles by the Little Diamond Creek fault system.

Ppm Phosphoria Formation, Meade Peak Phosphatic Member -- Dark-gray to black, fissile, siliceous, occasionally oolitic shale and 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 225 feet (70 m) thick in Willow Creek area of Co-op Creek 7.5' quadrangle; 267 feet (81 m) were drilled in the Amoco Cottonwood Canyon well, Ray's Valley quadrangle. Faulted out in the Spanish Fork Peak and Billies Mountain quadrangles by the Little Diamond Creek fault system.

Ppg Park City Formation, Grandeur Member -- Dominantly dolomite 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; 685 feet (210 m) thick in the Willow Creek area of Co-op Creek 7.5' quadrangle; 835 feet (255 m) were drilled in the Amoco Cottonwood Canyon well, Ray's Valley quadrangle. Baker (1947) reported an 883-foot (269 m) thickness. Faulted out in the Spanish Fork Peak and Billies Mountain quadrangles by the Little Diamond Creek fault system.

Pdc Diamond Creek Sandstone/Formation (Permian) -- Very light-gray, yellowish-brown and salmon-red-brown, very thick-bedded and trough cross-bedded, fine-grained, friable sandstone, with thin-bedded, light-gray, calcareous sandstone interbeds; poorly exposed, forms swale between Grandeur and Kirkman carbonate ribs; in Little Diamond Creek area, it is ledge-forming, buff- and salmon-colored, cross-bedded, medium- to coarse-grained sandstone with lesser thin-bedded, sandy limestone and dolomite; 165 feet (50 m) thick in the Willow Creek area of Co-op Creek 7.5' quadrangle; 1265 feet (386 m) were drilled in the Amoco Cottonwood Canyon well, Ray's Valley quadrangle. Baker (1947) reported an 835-foot (255 m) thickness.

Pk Kirkman Limestone (Permian, 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 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; thickness varies from 97 to 375 feet (30-115 m) on the west side of the Strawberry River valley; 334 feet (102 m) were drilled in the Amoco Cottonwood Canyon well, Ray's Valley quadrangle.

PIPou Oquirrh Formation, Granger Mountain and Wallsburg Ridge Members, undivided -- Used in Springville quadrangle.

Pogm Oquirrh Formation, Granger Mountain Member (Permian, Wolfcampian) -- Gray, tan-weathering, limy, silty sandstone; minor beds with abundant track and trail markings; interbedded with minor gray, red, and buff quartzite, light-gray sandstone, and thick beds of gray limestone in lower part of unit; 8200 to 10,255 feet (2500 to 3126 m) thick.

Pogml Oquirrh Formation, Granger Mountain Member, limestone unit (Permian?, Wolfcampian?; Pennsylvanian, Virgilian) -- Unit locally present at bottom of Granger Mountain Member; not present in Wallsburg Ridge 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; 0 to about 500 feet (0-150 m) thick (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 (orthoquartzite) to siliceous; quartzites commonly have conchoidal fracture; locally thinly laminated to cross-bedded; includes rare, silty and sandy, gray limestone interbeds; about 3700 feet (1130 m) thick in Center Creek quadrangle on north margin of map area and about 7000 feet (2135 m) thick to southwest in Bridal Veil Falls quadrangle.

IPos Oquirrh Formation, Shingle Mill Limestone Member (Pennsylvanian, Missourian-Desmoinesian) -- Dark-gray to black, thin-bedded limestone containing abundant black chert and locally abundant fossils; 200 to 450 feet (60-140 m) thick; Biek and Lowe (2005) reported that conodont fauna in their Shingle Mill map unit in Charleston quadrangle indicate a Missourian age rather than the Desmoinesian age reported by Baker (1976).

IPobc Oquirrh Formation, Bear Canyon Member (Pennsylvanian, Desmoinesian and Atokan) -- Gray to tan, limy to quartzitic sandstone with interbedded gray to black, thin- to thick-bedded, cherty to locally sandy limestone; about 3250 feet (990 m) thick in present map area and thickening northward; latest Morrowan conodonts reported in lowest part of roughly equivalent strata in Bridal Veil Falls quadrangle (Shoore, 2005).

IPobv Oquirrh Formation, Bridal Veil Limestone Member (Pennsylvanian, Atokan[?] and Morrowan) -- Medium-gray to black, thin- to thick-bedded limestone with local beds of quartzite; limestone contains much brown to black chert and some abundantly fossiliferous beds; 1245 feet (380 m) thick; latest Chesterian (Late Mississippian) conodonts reported in lowest part of Member in Bridal Veil Falls quadrangle (Shoore, 2005); but Baker (1964a) reported a Pennsylvanian fossil assemblage in the underlying Manning Canyon Shale.

Mmc Manning Canyon Shale (Pennsylvanian? and Mississippian) -- Black to brown shale with numerous thin beds of light-brown-weathering, gray, fine-grained, shaly sandstone, some lenses or beds of rusty-weathering grit, and one or more thick beds of gray to black, cherty limestone; shale is carbonaceous with occasional nodules of marcasite; measured thickness in Bridal Veil Falls quadrangle 1650 feet (500 m) (Baker, 1972a).

Mgb Great Blue Limestone (Upper Mississippian) -- Dark-gray to nearly black, light- to medium-gray weathering, thin- and regularly bedded limestone and shaly limestone with interbedded black and brown shale beds up to 50 feet (15 m) thick, and, near base, scattered thin beds of olive-brown-weathering, dark-gray, fine-grained quartzite; attenuated by faulting south of Slide Canyon; measured thickness 2800 feet (850 m) in Rock Canyon, Bridal Veil Falls quadrangle. Black shale is prominent basal part in southwest Bridal Veil Falls quadrangle and in area; described as basal unit 100 feet (30 m) thick and shown as 300 feet (90 m) thick by Crittenden (1959); Baker (1947) showed a 750-foot (230-m) thick covered interval above the base at Rock Canyon.

Mh Humbug Formation (Mississippian) -- Light- to dark-gray, cherty limestone and some dolomite interbedded with light-gray to buff, brown-weathering, limy to quartzitic sandstone, which causes characteristic brown and gray bands in outcrops; measured thickness 520 feet (160 m) in Rock Canyon, Bridal Veil Falls quadrangle.

Md Deseret Limestone (Upper(?) Mississippian) -- Interbedded, thick-bedded limestone and dolomite with distinctive light- and dark-gray banded outcrops; fossil crinoids and corals common; black chert occurs as thin layers, blebs and irregular masses in most beds and is locally very abundant; 575 feet (175 m) thick.

Mg Gardison Limestone (Lower(?) Mississippian) -- Dark-gray, "stair-step"-forming, mostly thin-bedded limestone with scattered abundant light-brown to black chert; about 900 feet (275 m) thick in Rock Canyon, but may include Deseret strata.

Mf Fitchville Dolomite (Lower(?) Mississippian) -- Medium- to light-gray, cliff-forming dolomite with numerous small vugs; lacks chert, which is atypical for Mississippian units; interbedded limestone in upper part; buff to gray, locally conglomeratic, coarse-grained sandstone or grit comprise basal bed 1 to 20 feet (0.3-6 m) thick; 100 to 265 feet (30-80 m) thick.

Cm Maxfield Limestone (Middle(?) Cambrian) -- Mainly light- to dark-gray, thin-bedded limestone with yellow-brown to grayish-yellow mottling, and with interbedded gray to white dolomite and oolitic or pisolitic limestone; unconformably overlain by Fitchville; so 350 to less than 850 feet (105 to <260 m) thick; 595 feet (180 m) thick in Bridal Veil Falls quadrangle.

Co Ophir Formation (Middle(?) Cambrian) -- Olive-green, slope-forming, micaceous shale with thin beds of greenish sandstone and a zone of thin beds of yellow to brown-mottled shaly limestone in upper part; contact with Maxfield is gradational and may not have been picked consistently; about 100 to 290 feet (30-90 m) thick in Springville and Bridal Veil Falls quadrangles. However, 510 feet (155 m) thick in American Fork Canyon with characteristic three units: upper shale/micaceous sandstone [phyllite] (170 feet [50 m] thick), middle limestone (100 feet [30 m] thick), and lower shale and sandstone (250 feet [75 m] thick) (Baker, 1964)

Ct Tintic Quartzite (Cambrian) -- Light-brown weathering, cliff- and ledge-forming, off-white to tan quartzite with quartz-pebble conglomeratic beds in lower 200 feet (60 m) and boulders of quartz a foot (0.3 m) or more in diameter near basal unconformity; interbedded greenish quartzite and phyllite in top 90 feet (30 m) forming gradational contact with overlying Ophir; measured thickness 1170 feet (355 m) in Slate Canyon, Springville quadrangle.

Zmf Mineral Fork Tillite (Upper Proterozoic) -- Gray to brown, dark-brown- to black-weathering, unstratified and poorly sorted, micaceous siltstone with scattered boulders of dolomite, quartzite, sandstone, and altered (green) igneous rock up to 1 foot (0.3 m) in diameter; unconformity at base; at least 200 feet (60 m) thick in Bridal Veil Falls quadrangle, thinning southward to nothing near Slate Canyon.

Zbc Big Cottonwood Formation (Upper and Middle Proterozoic) -- Purple to maroon, brown, and pinkish-gray, fine-grained to conglomeratic quartzite with interbedded gray, green, brown, and purple micaceous quartzite and phyllite, and purple, red, and maroon slate; exposed thickness about 400 feet (120 m) near Deer Creek Reservoir and 1350 feet (410 m) east of Provo; age from Link (1993).

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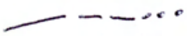
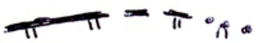
Map Symbols


reservoir high-water shoreline (blue); note that Strawberry Reservoir is now higher than shown on base map


contact, dashed where approximately located, dotted where concealed


normal fault, dashed where approximately located, dotted where concealed, ball and bar on hanging wall, arrow with number indicates fault dip direction and angle


low-angle normal fault, dashed where approximately located, dotted where concealed, paired hachures on hanging wall


detachment fault, dashed where approximately located, dotted where concealed, open teeth on hanging wall


thrust fault, dashed where approximately located, dotted where concealed, solid teeth on hanging wall

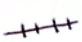

lineament

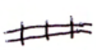

fold axes (red), dashed where approximately located, dotted where concealed, arrow indicates plunge, upright on left, overturned on right

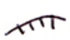

anticline

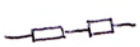

syncline


monocline, antiformal hinge on left, synformal hinge on right

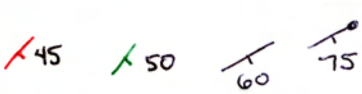

moraine crest


double ridge crest, possible sackungen


mass-movement scarp


mega-breccia block

strike and dip of bedding



upright, top certain in middle, from previous work on right (red=Baker, green=Welsh, brown=other; marked by * in references)

25	upright, photogrammetric
35	upright, approximate
	vertical
65 85	overturned
	horizontal
JC99-20	sample location with number (see table 1 for $^{40}Ar/^{39}Ar$ ages)
	springs H- hot to warm C-cold S-sulphur, hydrogen sulfide? M-methane bubbles
	sinkhole (in Spanish Fork Peak quadrangle)
Mountain Fuel Thistle Dome	boreholes, with name
Qms (Mmc)	landslide with nearly intact block of unit in parentheses

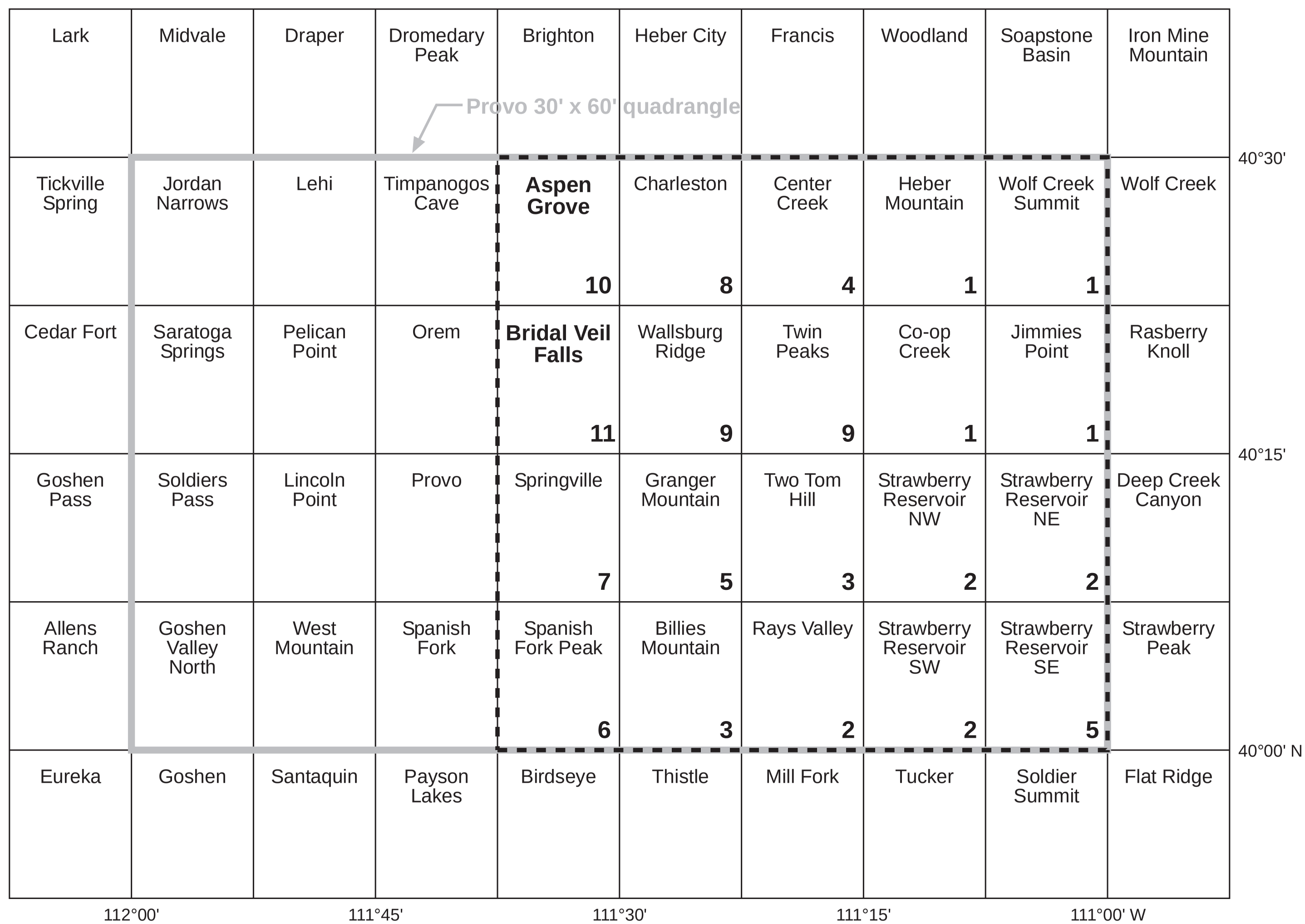


Figure 1. Provo 30' x 60' quadrangle, Utah, index to geologic mapping. Dashed box for year 6. **Bold** lettering on quadrangles mapped in 2005-2006. Numbers refer to list.

Index to geologic mapping, listed in order of completion or revision for this project (oldest first), numbers are those used on figure 1.

1 Coogan, J.C., 2000, Geologic maps of the Heber Mountain, Wolf Creek Summit, Co-op Creek, and Jimmies Point quadrangles, Wasatch County, Utah: unpublished mapping for this project, Utah Geological Survey files, scale 1:24,000.

2 Constenius, K.N., 2000, Geologic maps of the Rays Valley, Strawberry Reservoir NW, Strawberry Reservoir NE, and Strawberry Reservoir SW quadrangles, Utah and Wasatch Counties, Utah: unpublished mapping for this project, Utah Geological Survey files, scale 1:24,000.

3 Constenius, K.N., 2002, Geologic maps of the Two Tom Hill and Billies Mountain, quadrangles, Utah and Wasatch Counties, Utah: unpublished mapping for this project, Utah Geological Survey files, scale 1:24,000.

4 Biek, R.F., Hylland, M.D., Welsh, J.E., and Lowe, Mike, 2003, Geologic map of the Center Creek quadrangle, Wasatch County, Utah: Utah Geological Survey Map 192, 25 p., scale 1:24,000.

5 Constenius, K.N., 2003, Geologic maps of the Granger Mountain quadrangle, Utah County and Strawberry Reservoir SE quadrangle, Wasatch County, Utah: unpublished mapping for this project, Utah Geological Survey files, scale 1:24,000.

6 Baker, A.A., 1972, Geologic map of NE part of Spanish Fork Peak quadrangle, Utah: U.S. Geological Survey Open-File Report 72-9, scale 1:24,000; modified and mapping of quadrangle completed by K.N. Constenius, 2004, for this project, Utah Geological Survey files, scale 1:24,000.

7 Baker, A.A., 1973, Geologic map of the Springville quadrangle, Utah County, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-1103, 5 p., scale 1:24,000; modified by K.N. Constenius, 2004, for this project, Utah Geological Survey files, scale 1:24,000.

8 Biek, R.F., and Lowe, Mike, 2005, Interim geologic map of the Charleston quadrangle, Wasatch County, Utah: Utah Geological Survey Open-File Report 452, 32 p., scale 1:24,000.

9 Constenius, K.N., 2005, Geologic maps of the Wallsburg Ridge and Twin Peaks quadrangles, Utah and Wasatch Counties, Utah: unpublished mapping for this project, Utah Geological Survey files, scale 1:24,000.

10 Baker, A.A., 1964, Geologic map of the Aspen Grove quadrangle, [Utah and Wasatch Counties,] Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-239, scale 1:24,000; highly modified by K.N. Constenius, 2006, for this project, Utah Geological Survey files, scale 1:24,000.

11 Baker, A.A., 1972, Geologic map of the Bridal Veil Falls quadrangle, [Utah and Wasatch Counties,] Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-998, scale 1:24,000; modified by K.N. Constenius, 2006, for this project, Utah Geological Survey files, scale 1:24,000.

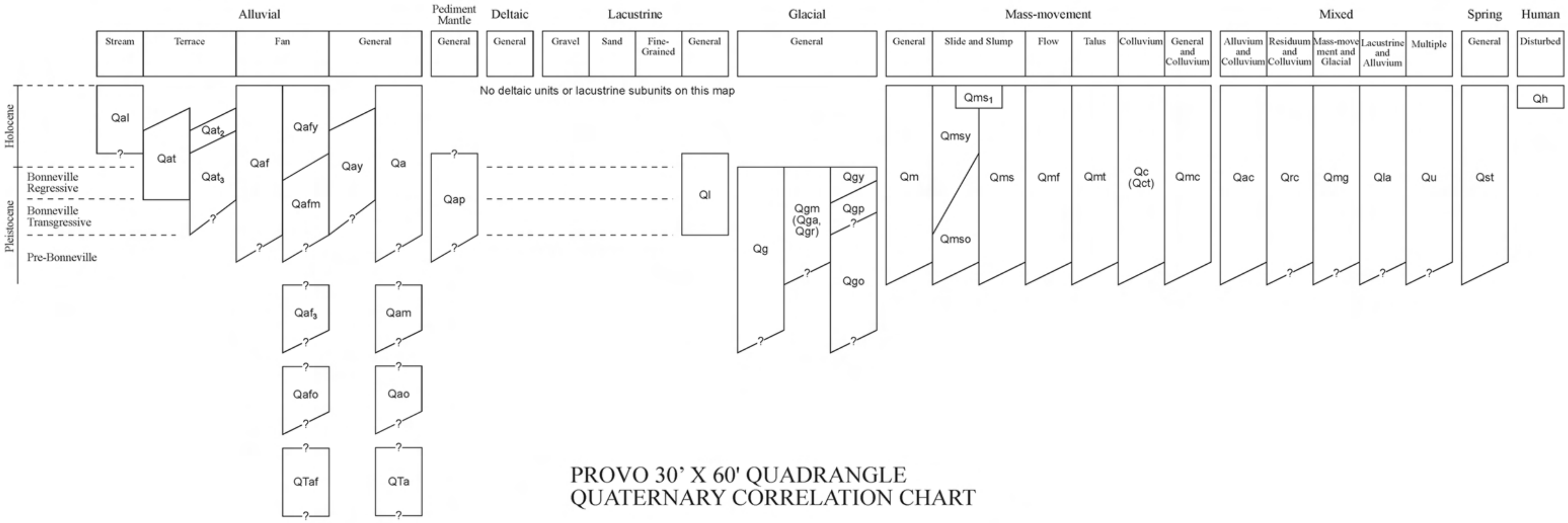
TABLE 1. Summary of $^{40}Ar/^{39}Ar$-age analyses from the area of the Provo 30' x 60' quadrangle (modified from Constenius and others, 2003; in particular, latitude and longitude for samples on map in this open-file report and ages for analyses funded by STATEMAP).

Sample number	Unit	Latitude	Longitude	Age+2sd (Ma)	Mineral	Type of analysis
KNC72393-1T#	Tibble, volc.	40° 28.831'	111° 38.710'	34.4±1.4	biotite	single crystal Argon-ion step-heating
KNC7894-44*	Moroni	39° 56.864'	111° 31.028'	34.43±0.10	sanidine	single crystal CO_2 fusion
KNC101701-7*	Moroni	39° 51.374'	111° 25.852'	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$
KNC9299-1	intrusion	40° 19.119'	111° 19.639'	34.70±0.16	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$
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° 44.480'	111° 20.902'	38.20±0.11	sanidine	single crystal CO_2 fusion
KNC61093-2T#	Tibble, lower	40° 28.979'	111° 38.468'	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 locations that are not on map are: *sample not from Provo 30' x 60' map area and #sample not from this open-file report map area.

Tvc=Volcaniclastic rocks of Strawberry Valley

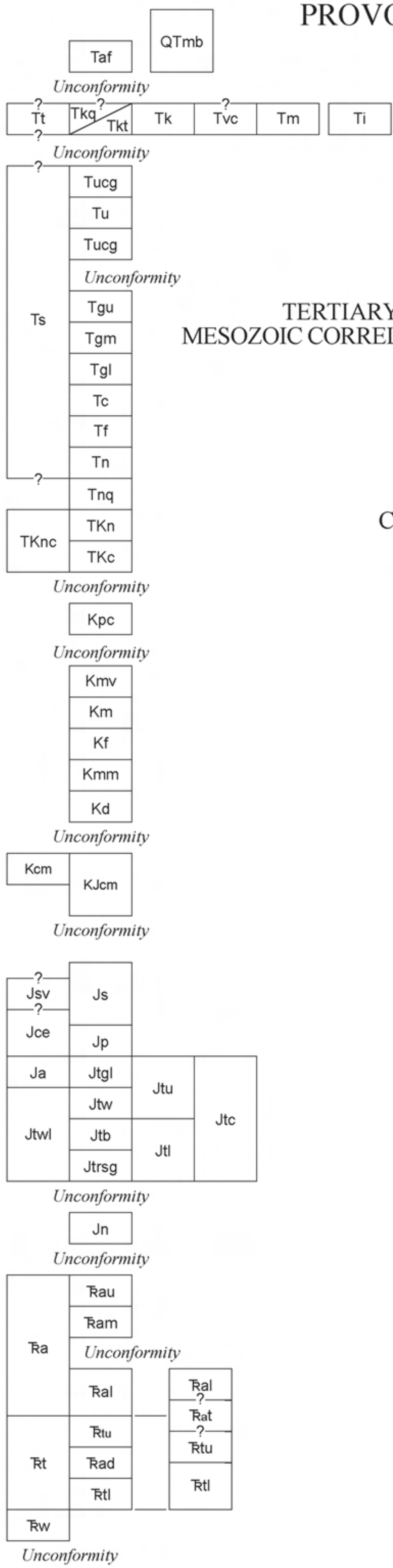
All analyses performed at the New Mexico Geochronology Research Laboratory, Socorro, New Mexico, except Argon-ion step heating analyses which were done at the University of Alaska, Fairbanks.
$ Indicates analysis paid for by STATEMAP funding.



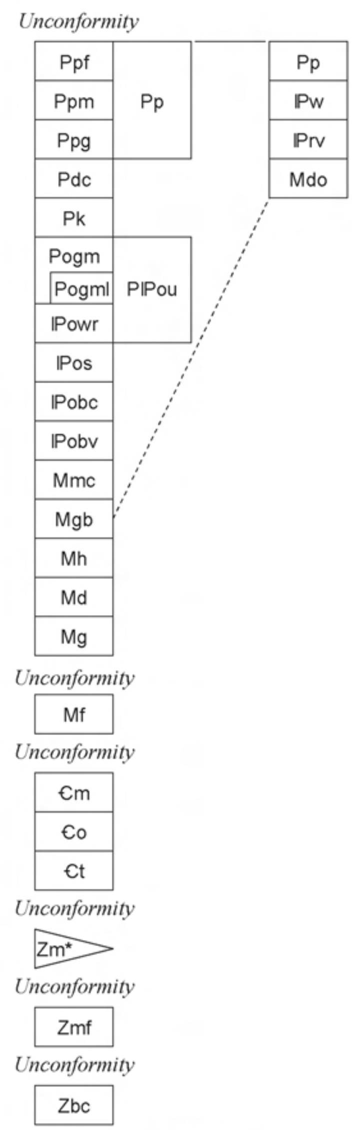
PROVO 30' X 60' QUADRANGLE
QUATERNARY CORRELATION CHART

PROVO 30' X 60' QUADRANGLE

TERTIARY AND MESOZOIC CORRELATION CHART

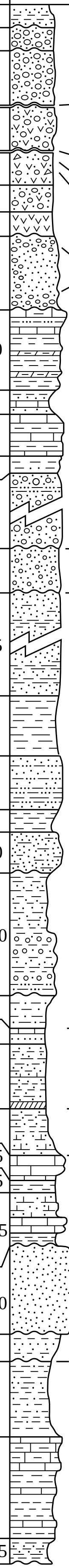


PALEOZOIC CORRELATION CHART



* Not in present map area

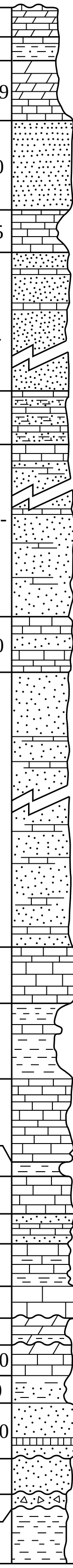
PROVO 30' X 60' QUADRANGLE CENOZOIC-MESOZOIC LITHOLOGIC COLUMN



ERA	SYMBOL	FORMATION	THICKNESS Feet	THICKNESS Meters	LITHOLOGY
Q.	Q	various	0-200	0-60	
TERTIARY	Taf	alluvial fan	0-750	0-230	Age uncertain
	Tt	Tibble Formation	0-2,500	0-760	34.5 Ma 39.5 Ma Not in contact
	Tm	Moroni Formation	0-1,800	0-550	34.5-38.5 Ma Equal to Keetley? Not in contact
	Tk	Keetley Volcanics	0-1,400	0-430	37-40.5 Ma
	Tkq	quartzite clast unit	0-450	0-140	May be equal to Tvc
	Tkt	basal tuffaceous unit	0-200	0-60	in Strawberry Valley
	Tu	Uinta Formation	~2,000+	~610+	Conglomerates (Tucg) ANGULAR UNCONFORMITY
	?Tgu	Green River Formation – upper member ?	~3,800	~1,160	Age and correlation of unit Ts is uncertain
	?Tgm	Green River Formation – middle member ?			
	Tgl	Green River Formation – lower member			
	Tc	Colton Formation	~170	~50	
	Tf	Flagstaff Formation	~280	~85	
	Tn	Upper North Horn Formation	~200	~60	Local conglomerate (Tnq)
?	TKnc: TKn, TKc	Lower North Horn Formation and Current Creek Formation	up to 4,800	up to 1,465	ANGULAR UNCONFORMITY
CRETACEOUS	Kpc	Price River Fm and Castlegate Ss	up to ~2,000	up to ~610	ANGULAR UNCONFORMITY
	Kmv	Mesaverde Formation	~5,200	~1,585	
	Km	Mancos Shale	~1,700	~520	
	Kf	Frontier Formation	700	215	
	Kmm	Mancos Shale, Mowry Shale Tongue	~90	~25	
	Kd	Dakota Formation	200-400	60-120	
	Kcm	Cedar Mountain Formation	465-2,500	140-760	Unstable, slumps Locally includes Morrison (KJcm)
JURASSIC	Jsv	Summerville Formation	~395	~120	
	Js	Stump Formation	250	75	Curtis and Entrada Formations (Jce) ~400' and 1,000'
	Jp	Preuss Formation	~750	~230	
	Ja	Arapien Shale	~560	~170	~500' Twin Creek Ls, Giraffe Creek and Leeds Creek Mbrs (Jtgl)
	Jtw	Twin Creek Limestone (Jtc) – Watton Canyon Mbr	~120-250	~35-75	
	Jtl: Jtb	Twin Creek Limestone (Jtc) – Boundary Ridge Mbr	~65-120	~20-35	Jtc members thin to east
	Jtl: Jtrsg	Twin Creek Limestone (Jtc) – Rich Member, Sliderock Member, Gypsum Spring Mbr	~160-420	~50-125	Red beds
	Jn	Navajo Sandstone	1,260-1,450	385-440	
TRIASSIC	Ꞧa: Ꞧau	Ankareh Formation – upper member	350	110	
	Ꞧa: Ꞧam	Ankareh Formation – middle member	~800	~245	Thin conglomerate middle mbr 40 ft (12 m)
	Ꞧa: Ꞧal	Ankareh Formation – lower member			
	Ꞧt: Ꞧtu	Thaynes Formation – upper member	1,450	440	Moenkopi equivalent
	Ꞧt: ? Ꞧtl	Thaynes Formation – ? lower member			Ꞧad locally Unstable, slumps
	Ꞧw	Woodside Shale	420-770	130-235	Thinner along Little Diamond Creek Fault

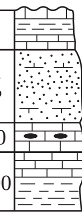
PROVO 30' X 60' QUADRANGLE PALEOZOIC LITHOLOGIC COLUMN

ERA	SYMBOL		FORMATION		THICKNESS Feet	THICKNESS Meters	LITHOLOGY
PERMIAN	Pp	Ppf	Park City and Phosphoria Formations	Franson Member	~660	~200	Cut out by Little Diamond Creek Fault
		Ppm		Meade Peak Member	225-270	70-80	
		Ppg		Grandeur Member	685-883	210-269	
	Pdc		Diamond Creek Sandstone		165-1,270	50-390	
	Pk		Kirkman Limestone		97-375	30-115	
	PIPou	Pogm	Oquirrh Formation	Granger Mountain Member (Wolfcampian)	8,200-10,255	2,500-3,125	
		Pogml		limestone member	0-500	0-150	
? PENNSYLVANIAN		IPowr		Wallsburg Ridge Mbr (Missourian-Virgilian)	~3,700-7,000	~1,130-2,135	*Triticites* Thickens westward
	IPos			Shingle Mill Ls Mbr (Lower Missourian)	200-450	60-140	*Eowaeringella*
	IPobc			Bear Canyon Member	3,250	990	*Fusulina* *Profusulina*
	IPobv			Bridal Veil Limestone Member	1,245	380	Morrowan fossils are abundant-- brachiopods
?	Mmc		Manning Canyon Shale		1,650	500	*Dictyoclostus* *Cravenoceras* *Lepidodendron*
MISSISSIPPIAN	Mgb		Great Blue Limestone	Upper limestone mbr	1,800	550	
				Long Trail Shale Mbr	300	90	Forms strike valley
				Topliff Limestone Mbr	700	215	*Apatognathus*
	Mh		Humbug Formation		520	160	*Fenestella*
	Md		Deseret Limestone		575	175	
	Mg		Gardison Limestone		~900	~275	*Syringopora*
	Mf		Fitchville Dolomite		100-265	30-80	Regional unconformity
CAMB.	Ꞓm		Maxfield Limestone		350-595	105-180	White dolo in Rock Cyn
	Ꞓo		Ophir Formation		100-500	30-150	*Glossopleura*
	Ꞓt		Tintic Quartzite		1,170-1,300	355-400	25' diabase 160' above base
PROT.	Zm*		Mutual Formation		0-1,300	400	Only in Am Fk Cyn
	Zmf		Mineral Fork Tillite		0-200	60	Olive-drab
	Zbc		Big Cottonwood Formation		1,350+	410+	Purple and green argillite in Slate Cyn



*Not in present map area.

PROVO 30’ X 60’ QUADRANGLE
THIN PALEOZOIC STRATA LITHOLOGIC COLUMN

ERA	SYMBOL	FORMATION	THICKNESS Feet	THICKNESS Meters	LITHOLOGY
P	Pp	Park City and Phosphoria Fms	870	265	 Phosphorite
PENN	ℙw	Weber Quartzite	3500-8000?	1070-2440?	
	ℙrv	Round Valley Limestone	225-400	70-120	
MISS	Mdo	Doughnut Formation	400-1300	120-400	

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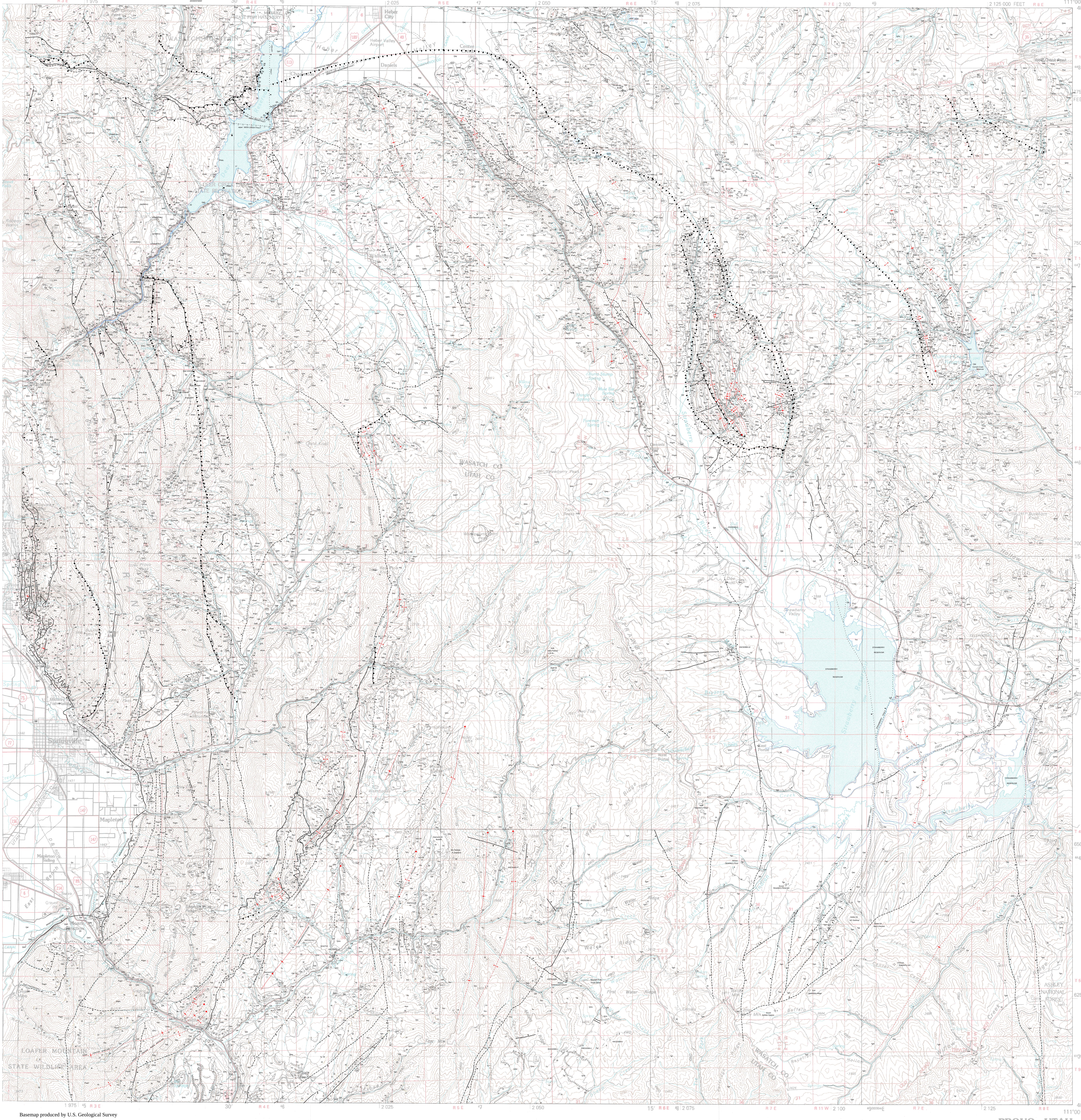

Basemap produced by U.S. Geological Survey

SCALE 1:62,500

1 CENTIMETER ON THE MAP REPRESENTS 1 KILOMETER ON THE GROUND
CONTOUR INTERVAL 50 METERS
SUPPLEMENTARY CONTOUR INTERVAL 25 METERS

PROVO, UTAH
0111-A1-TM-100
1986

This geologic map was funded by the Utah Geological Survey and the U.S. Geological Survey, National Cooperative Geologic Mapping Program through U.S. Geological Survey STATEMAP award numbers 99HQAG0138, 01HQAG100, 02HQAG0055, 03HQAG0096, 04HQAG0040, and 05HQAG0084. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Goverment.

Progress Report Geologic Map of the East Part of the Provo 30' x 60' Quadrangle, Utah

by Kurt N. Constenius, James C. Coogan, and Robert F. Biek

2006