Utah Geological Survey, a division of Utah Department of Natural Resources, in cooperation with U.S Geological Survey

Open-File Report 439
Progress Report Geologic Map of the Provo 30' x 60' Quadrangle, Utah

EXPLANATION

Line Type

- reservoir water lines
- contact, well located
- contact, approximately located
- contact, concealed
- moraine crest
- landslide scarp
- normal fault, well located
- normal fault, approximately located
- normal fault, concealed
- lineament
- thrust fault, well located
- thrust fault, approximately located
- thrust fault, concealed
- low-angle normal fault, well located
- low-angle normal fault, approximately located
- low-angle normal fault, concealed
- detachement fault, well located
- fold axis, well located
- fold axis, approximately located
- fold axis, concealed
- leader lines
- 7.5' quadrangle boundaries

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

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, and 03HQAG0096. 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.

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

(year 4 of a multiyear project) by Kurt N. Constenius and James C. Coogan

2004

PROVO, UTAH
0111-A1-TM-100
1986

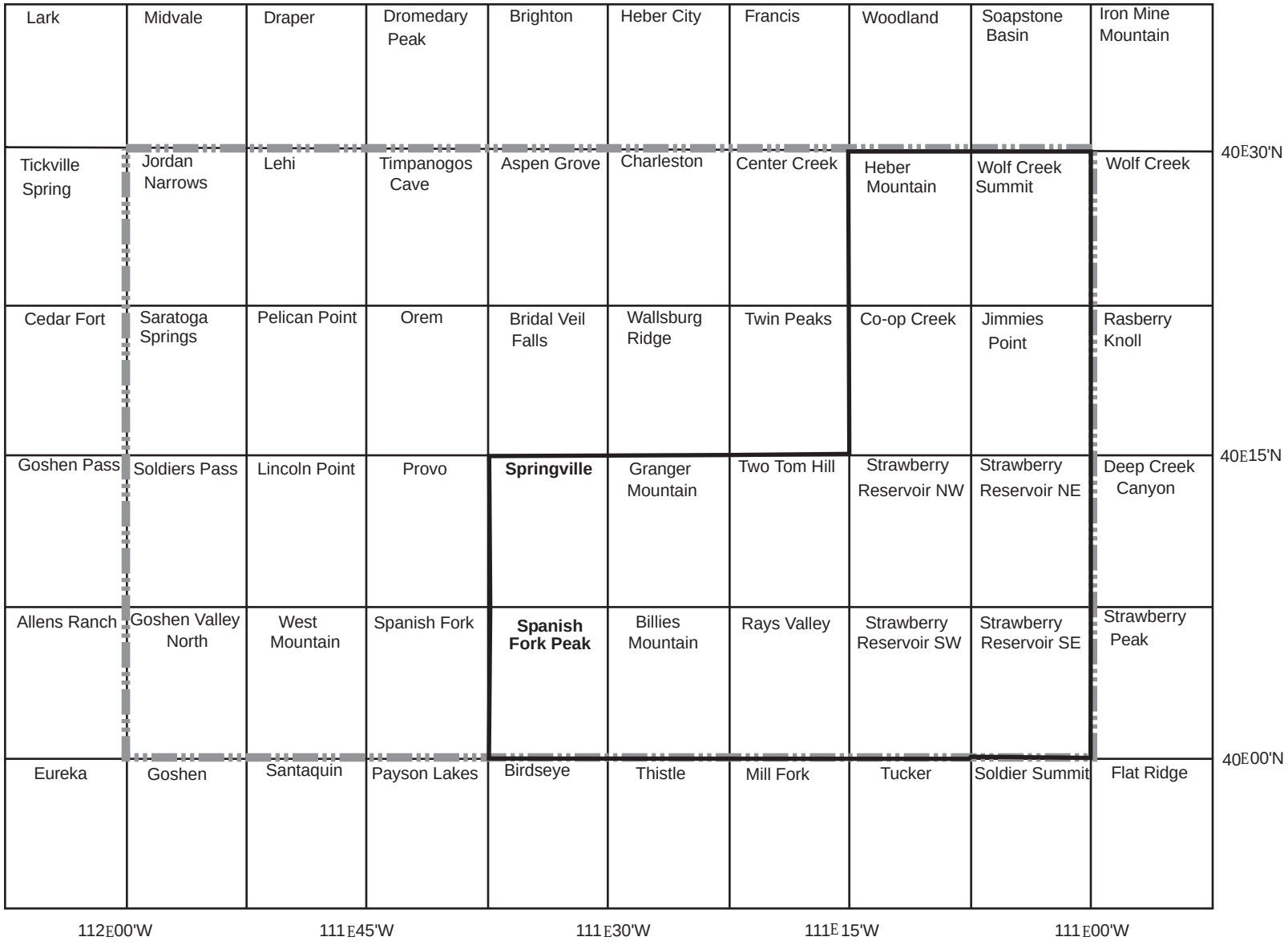
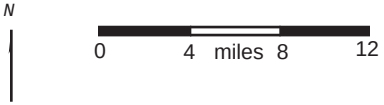
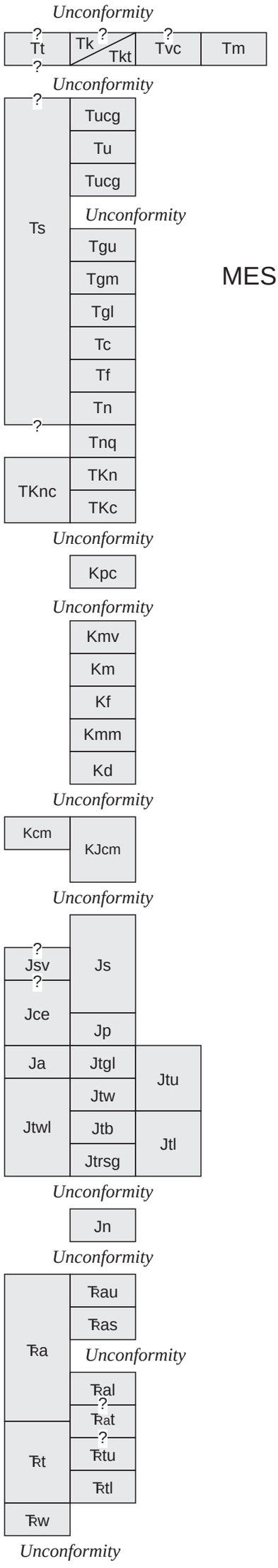


Figure 1. Provo 30' x 60' quadrangle, Utah index to geologic mapping. Solid box for year 4. **Bold** lettering on quadrangles mapped in 2003-2004.

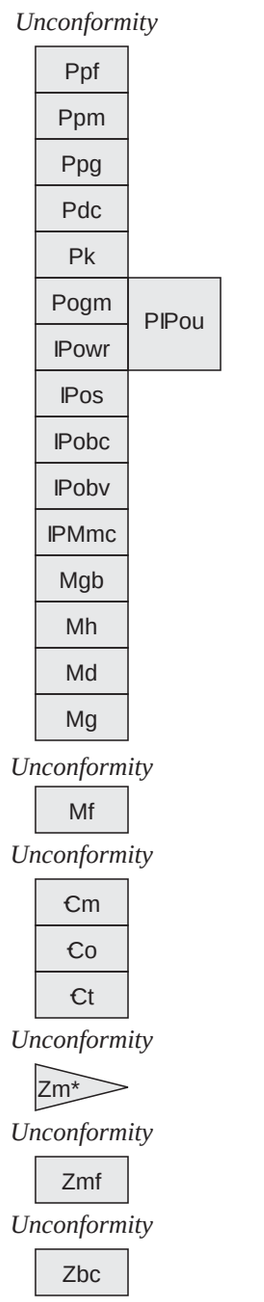


PROVO 30' X 60'

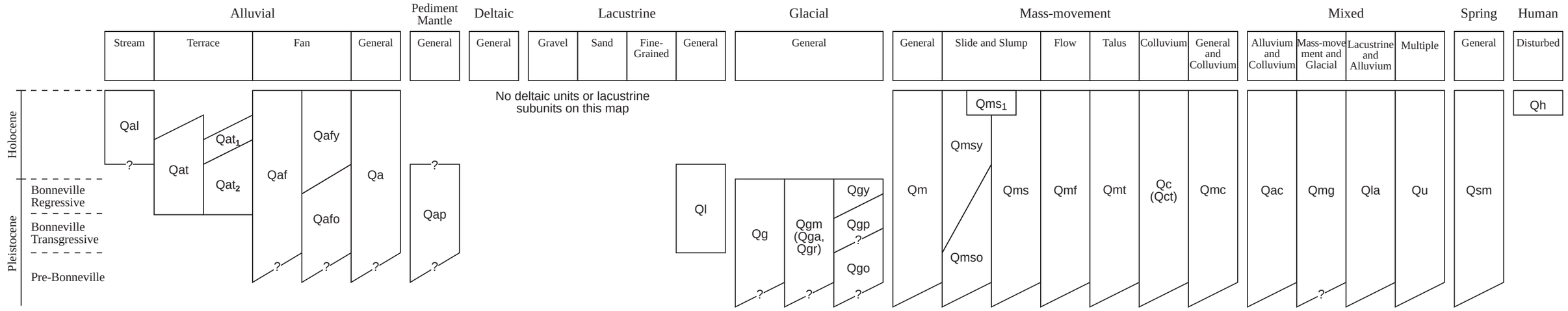
TERTIARY AND MESOZOIC CORRELATION CHART



PALEOZOIC CORRELATION CHART

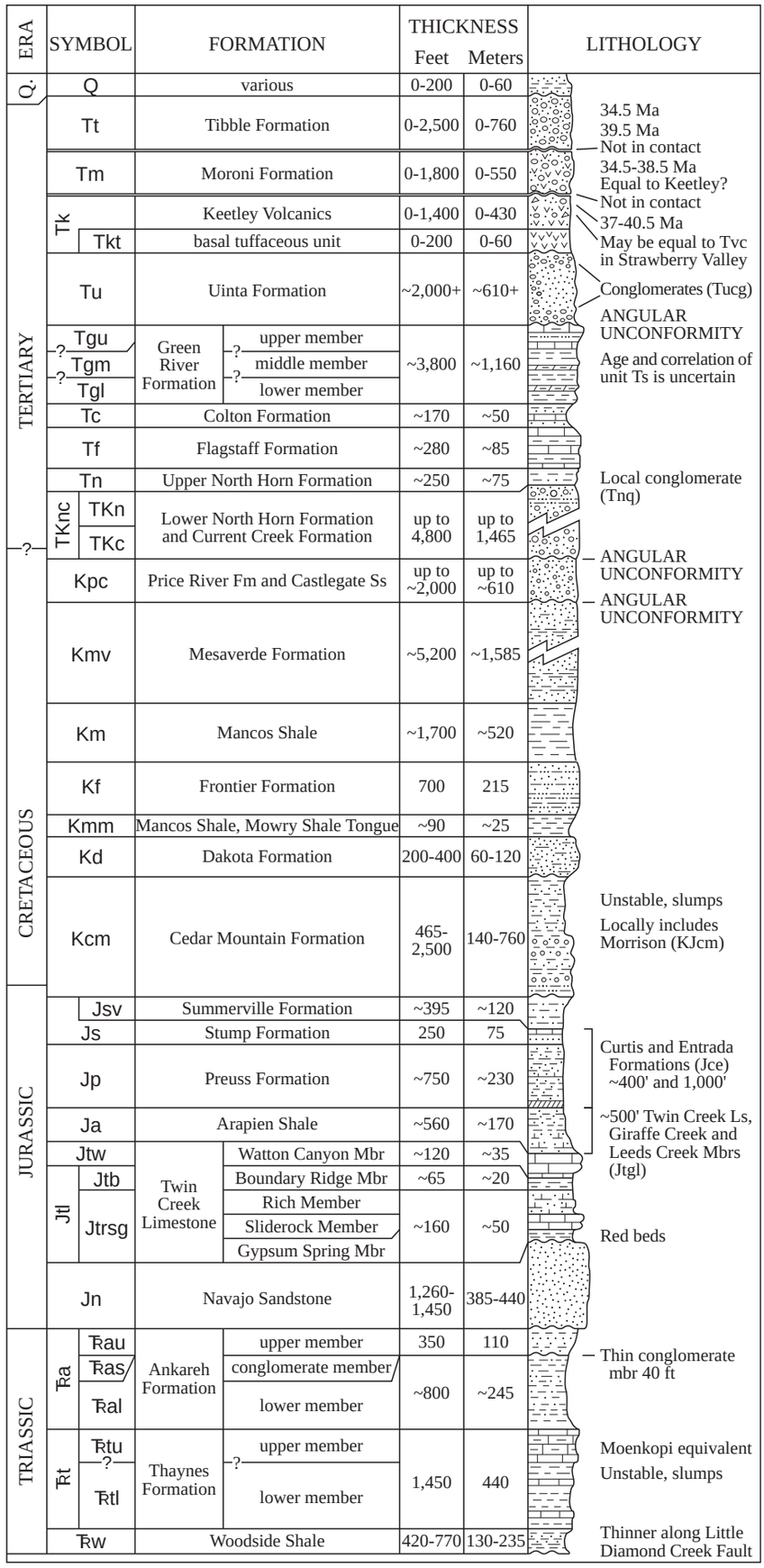


* Not in present map area



PROVO 30x60' QUATERNARY

PROVO 30' X 60'


ERA
SYMBOL
FORMATION
THICKNESS
Feet
Meters
LITHOLOGY
Q.
TERTIARY
CRETACEOUS
JURASSIC
TRIASSIC
Q
various
0-200
0-60
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
Tkt
basal tuffaceous unit
0-200
0-60
May be equal to Tvc in Strawberry Valley
Tu
Uinta Formation
~2,000+
~610+
Conglomerates (Tucg)
ANGULAR UNCONFORMITY
Tgu
Tgm
Tgl
Green River Formation
upper member
middle member
lower member
~3,800
~1,160
Age and correlation of unit Ts is uncertain
Tc
Colton Formation
~170
~50
Tf
Flagstaff Formation
~280
~85
Tn
Upper North Horn Formation
~250
~75
Local conglomerate (Tnq)
TKnc
TKn
TKc
Lower North Horn Formation and Current Creek Formation
up to 4,800
up to 1,465
ANGULAR UNCONFORMITY
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)
Jsv
Summerville Formation
~395
~120
Js
Stump Formation
250
75
Jp
Preuss Formation
~750
~230
Curtis and Entrada Formations (Jce) ~400' and 1,000'
Ja
Arapien Shale
~560
~170
~500' Twin Creek Ls, Giraffe Creek and Leeds Creek Mbrs (Jtgl)
Jtw
Watton Canyon Mbr
~120
~35
Jtl
Jtb
Jtrsg
Twin Creek Limestone
Boundary Ridge Mbr
Rich Member
Sliderock Member
Gypsum Spring Mbr
~65
~20
~160
~50
Red beds
Jn
Navajo Sandstone
1,260-1,450
385-440
Trau
Tra
Tras
Tral
Ankareh Formation
upper member
conglomerate member
lower member
350
110
~800
~245
Thin conglomerate mbr 40 ft
Trtu
Trt
Trtl
Thaynes Formation
upper member
lower member
1,450
440
Moenkopi equivalent
Unstable, slumps
Trw
Woodside Shale
420-770
130-235
Thinner along Little Diamond Creek Fault

PROVO 30' X 60' PALEOZOIC UNITS

ERA	SYMBOL	FORMATION		THICKNESS Feet	THICKNESS Meters	LITHOLOGY
PERMIAN	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	
PENNSYLVANIAN	PIPou 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
	IPMmc	Manning Canning 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	
	Mh	Humbug Formation		520	160	*Apatognathus* *Fenestella*
	Md	Deseret Limestone		575	175	
	Mg	Gardison Limestone		~900	~275	*Syringopora*
	Mf	Fitchville Dolomite		100-265	30-80	Regional unconformity
CAMB.	Cm	Maxfield Limestone		350-595	105-180	White dolo in Rock Cyn
	Co	Ophir Formation		100-250	30-75	*Glossopleura*
	Ct	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.

PROGRESS REPORT GEOLOGIC MAP OF THE EAST PART OF THE PROVO 30' x 60' QUADRANGLE, UTAH

(year 4 of a multi-year project)

by

Kurt N. Constenius and James C. Coogan

2004

Utah Geological Survey
Open-File Report 439

Utah Geological Survey
a division
Utah Department of Natural Resources

This open-file release is a progress report that provides the public with the results of the fourth year of mapping on a multi-year project. The map is incomplete and inconsistencies, errors, and omissions have not been resolved. This map does not conform to UGS policy and editorial standards. It may be premature for an individual or group to take action based on the contents.

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Map Unit Descriptions

Qh Human disturbance (Historic) – Fill material used at Strawberry and Currant Creek dams and along U.S. Highway 6 in Spanish Fork Canyon.

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-upper Pleistocene Lake Bonneville; 0 to 20 feet (0-6 m) thick.

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.

Qat1,2 Stream-terrace alluvium (Holocene and 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 1; in the Spanish Fork Peak quadrangle Qat2 terraces are graded to the Provo level of upper Pleistocene Lake Bonneville; 0 to 45 feet (0-14 m) thick.

Qaf, Qafy, Qafo
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; Qafy are Holocene and deflect stream channels; Qafo are deeply incised by younger drainages; generally less than 40 feet (12 m) thick.

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 Qat2; 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.

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; composed of Pennsylvanian quartzite in the upper Strawberry River drainage; locally includes protalus ramparts in southwest part of map area; 0 to 30 feet (0-9 m) thick.

Qmf Flow deposits (Holocene and Upper(?) Pleistocene) – Large-scale earthflows deposited on gently inclined terraces between Right Fork and Left Fork of Currant Creek, younger deposits on steeper slopes northeast and southeast of Current Creek Reservoir, and scattered deposits elsewhere in map area; all exhibit hummocky internal morphology and distinct hummocky margins; 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 Current Creek Formation (youngest deposits); as much as 200 feet (60 m) thick.

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, head 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 historic 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), Current Creek Formation (TKc), and clay-rich Mesozoic rocks (Kmv, TRa); thicknesses highly variable.

Qmg Mass-movement and glacial deposits, undivided (Holocene and Upper Pleistocene) -- Glacial deposits (see unit Qg description) in displaced slide masses in north part of map area, and in 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 southwest 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 southwest part of map area and mostly Pinedale in age.

Qga Glacial outwash (Pleistocene) – Stratified, variably sorted, alluvially reworked debris of uncertain age; unit used in southwest part of map area.

Qgr Rock glaciers (Pleistocene) -- Angular, mostly cobble- to boulder-sized debris with little matrix in unvegetated mounds with lobate crests; includes protalus ramparts; inactive (no ice matrix); unit used in southwest 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 deposited in the upper reaches of non-vegetated cirque basins in northeast part of map area; 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 derived from headwall bedrock sources; in northeast part of map area, present in broad, generally north-facing valleys and some steep-walled, south-facing, high-elevation cirques; includes outwash deposits; moraines, where present, show moderate to sharp morphology; till has weak soil development; about 15,000 to 30,000 years old; 0-150 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; 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 comprised by 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.

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.

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; Ar/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 2,500 feet (0 to 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 1,800 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 Ar/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 was Ar/Ar dated at 40.45±0.18 Ma (table 1); 0 to more than 1,400 feet (0-430+ m) thick.

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 was Ar/Ar dated at 37.25±0.14 Ma (table 1); another sample (KNC6901-1), from near Peoa, Utah was Ar/Ar dated at 38.20±0.11 Ma (Constenius and others, 2003); 0 to about 200 feet (0-60 m) thick.

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 Ar/Ar dated at 37.73±0.28 Ma (table 1); at least 1,500 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: light-gray, tan, and red, medium- to thick-bedded, lenticular-bedded, pebbly sandstone; brick-red, reddish-brown, variegated, very thick- to thin-bedded mudstone, commonly with floating sand grains; red-brown, tan, and gray conglomerate with sandstone to mudstone matrix; and 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; at least 2,000 feet (610 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 1,500 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 2,200 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 1,200 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 in 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 1,800 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 4,800 feet (1,460 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 2,000 feet (0 to 610 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 5,200 feet (1,585 m) thick.

Km Mancos Shale (Upper Cretaceous) -- Dark-gray, bentonitic shale with minor gray limestone and gray, fine-grained sandstone; very poorly exposed; about 1,700 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.

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 2,500 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 1,000 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.

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, 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 unit; about 500 feet (150 m) thick.

Jtwl Twin Creek Limestone, Watton Canyon, Boundary Ridge, Rich, Sliderock, and Gypsum Spring Members (Middle Jurassic) – Only mapped in Billies Mountain quadrangle where upper two members are indistinct and are mapped 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.

Jtl Twin Creek Formation, lower members (Middle Jurassic) -- Mapped 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 Formation, 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.

Jtrsg Twin Creek Formation, Rich, Sliderock and Gypsum Spring Members (Middle Jurassic) – Light-gray, soft, shaley 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.

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 1,260 to 1,450 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 1,485 to 1,530 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.

TRas Ankareh Formation, conglomerate 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.

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; 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 quadrangle, subdivided elsewhere; top not exposed. Neighbor (1959) reported a dip-corrected thickness of 1,450 feet (440 m), based on four wells on the Diamond Fork anticline.

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; structurally thickened in Heber Mountain 7.5' quadrangle; about 1,000 feet (300 m) thick.

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. Structurally thinned along Little Diamond Creek fault system.

Ppf Park City Formation, Franson Member (Permian) – 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 (Permian) – 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 (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; 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 a 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; 1,265 feet (386 m) were drilled in the Amoco Cottonwood Canyon well, Ray's Valley quadrangle. Baker (1947) reported a 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, Heber Mountain, and Co-op Creek quadrangles.

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; 8,200 to 10,255 feet (2,500 to 3,126 m) thick.

IPowr Oquirrh Formation, Wallsburg Ridge Member (Pennsylvanian, Missourian-Virgilian) – Light-gray to yellowish-brown, thick-bedded, fine- to medium-grained quartzite and sandstone; feldspathic (orthoquartzite) to siliceous; quartzites have common conchoidal fracture; locally thinly laminated to cross-bedded; includes rare, silty and sandy, gray limestone interbeds; about 3,700 feet (1,130 m) thick in Center Creek quadrangle on north margin of map area and about 7,000 feet (2,135 m) thick to southwest in Bridal Veil Falls quadrangle.

IPos Oquirrh Formation, Shingle Mill Limestone Member (Pennsylvanian, Des Moinesian) – Dark-gray to black, thin-bedded limestone containing abundant black chert and locally abundant fossils; 200 to 450 feet (60-140 m) thick.

IPobc Oquirrh Formation, Bear Canyon Member (Pennsylvanian, Des Moinesian to Atokan) – Gray to tan, limy to quartzitic sandstone with interbedded gray to black, thin- to thick-bedded, cherty to locally sandy limestone; about 3,250 feet (990 m) thick in present map area and thickening northward.

IPobv Oquirrh Formation, Bridal Veil Limestone Member (Pennsylvanian, Atokan and older) – 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; 1,245 feet (380 m) thick.

IPMmc 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 1,650 feet (500 m).

Mgb Great Blue Limestone (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 2,800 feet (855 m) in Rock Canyon, Bridal Veil Falls quadrangle.

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 coral 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.

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 250 feet (30-75 m) thick.

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 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 1,170 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, coarse-grained to conglomeratic quartzite with interbedded gray, green and purple micaceous quartzite and phyllite, and purple, red and maroon slate; exposed thickness about 1,350 feet (410 m).

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Map Symbols

reservoir high-water shoreline (blue)

contact, dashed where approximately located, dotted where concealed

normal fault, dashed where approximately located, dotted where concealed, ball and bar on hanging wall

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

detachment fault, 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

mass-movement scarp

strike and dip of bedding

upright, top certain in middle, from previous work on right (these works are marked by * in references)

vertical

overturned

horizontal

sample location with number (see table 1 for Ar-Ar dates)

springs
H- hot to warm
C-cold
S-sulphur, hydrogen sulfide?
M-methane bubbles

sinkhole (in Spanish Fork Peak quadrangle)

boreholes, with name

landslide with nearly intact block of unit in parentheses; in Billies Mountain quadrangle

TABLE 1. Summary of Ar-Ar 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#	Tvc, stock?	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.