UTAH GEOLOGICAL SURVEY
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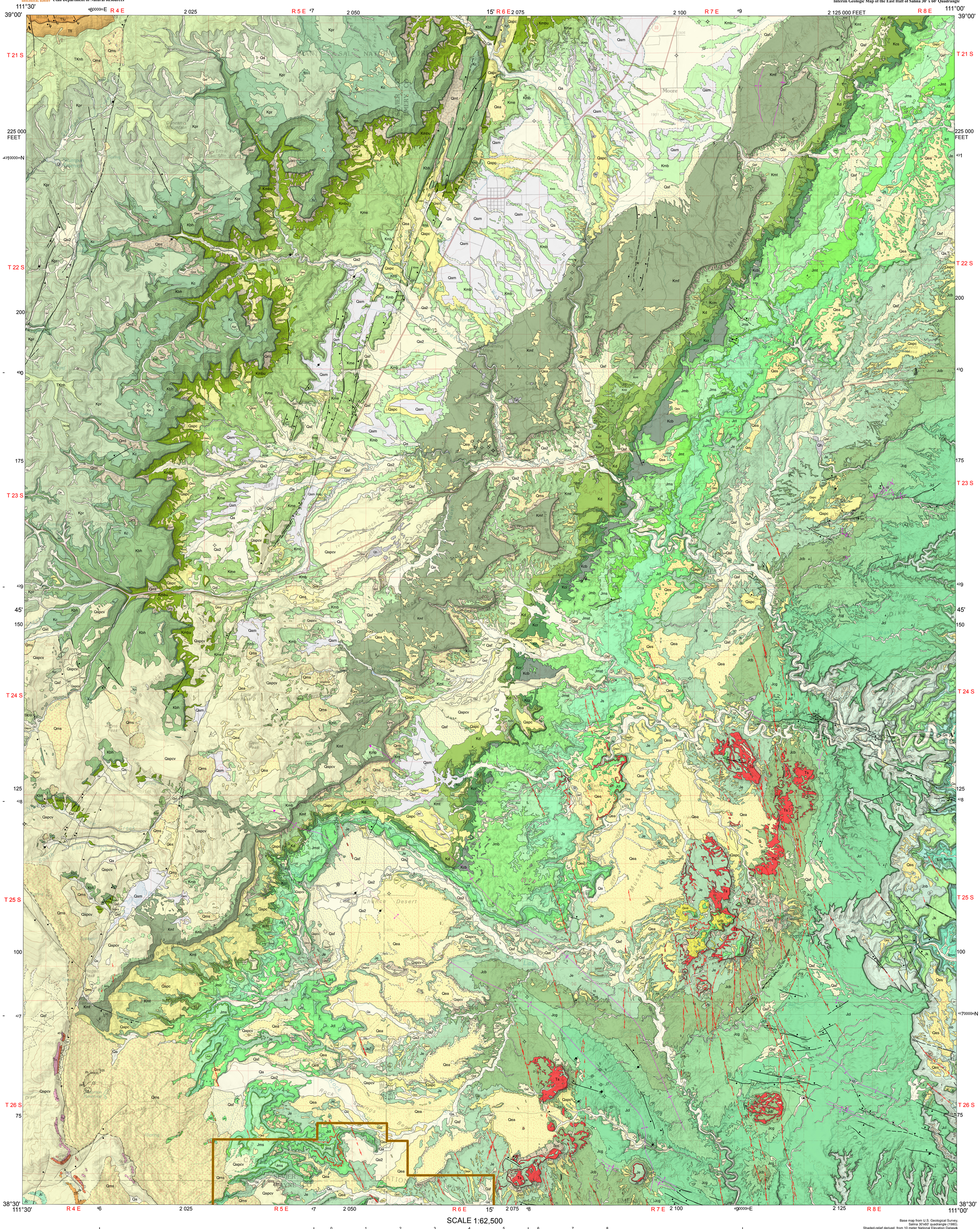
Utah Department of Natural Resources

Plate 1
Utah Geological Survey Open-File Report 642DM
Interim Geologic Map of the East Half of Salina 30' x 60' Quadrangle



SCALE 1:62,500

TOPOGRAPHIC CONTOUR INTERVAL 50 METERS

QUADRANGLE LOCATION

INTERIM GEOLOGIC MAP OF THE EAST HALF OF THE SALINA 30' X 60' QUADRANGLE, EMERY, SEVIER AND WAYNE COUNTIES, UTAH

by
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2016

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APPROXIMATE MEAN DECLINATION, 2016

Base map from U.S. Geological Survey, Salina 30'x60' quadrangle (1980).
Shaded-relief derived from 10 meter National Elevation Dataset
Projection: UTM Zone 12
Datum: NAD 1927
Spheroid: Clarke 1866

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DESCRIPTION OF MAP UNITS

QUATERNARY

Qh **Human emplaced fill and disturbed areas (Historical)** – Gypsum, crushed stone, and road fill quarries; most road fill deposits and other disturbed areas not mapped.

Qa **Alluvial river, stream, and wash deposits, undifferentiated (Holocene to late Pleistocene)** – Sand, silt, clay, granules, pebbles, and sparse cobbles in and adjacent to rivers, streams, and washes; commonly well sorted along rivers and larger streams and poorly to moderately sorted along smaller streams and washes; commonly includes variable amounts of locally derived colluvium and slope wash, and windblown sand and silt; consists primarily of locally derived material along washes; includes deposits in active channels and on incised low-level benches and terraces generally up to about 10 meters (33 ft) above active channels (locally higher); deposits on larger benches are differentiated as Qa2, but smaller bench deposits are included in Qa where too thin to differentiate at this scale; locally includes other types of deposits too small to map separately; generally 0 to 10 meters (0–33 ft) thick.

Qa_2 **Level two alluvium (Holocene to late Pleistocene)** – Sand, silt, clay, granules, pebbles, and sparse cobbles forming large, incised, low-level alluvial terraces or broad benches; similar to older parts of Qa; mapped where deposits form large benches in protected areas near the margins of larger alluvial drainages; consists primarily of locally derived materials; typically more than 10 meters (33 ft) above active channels; locally includes lower level terrace deposits similar to Qat and other types of deposits that are not mapped separately; generally 0 to 10 meters (0–33 ft) thick.

Qam **Alluvial mud (Holocene to late Pleistocene)** – Mostly unconsolidated clay, silt, and sand deposited as fans and mudflows; eroded from Mancos Shale outcrops; form valley fill and mud-dominated, broad, gently sloping alluvial fans; locally deeply incised by erosion; weakly stratified and nearly structureless; as much as 15 meters (50 ft) thick.

Qaf **Alluvial-fan deposits (Holocene to late Pleistocene)** – Mostly unconsolidated, poorly sorted silt, sand, gravel, and cobbles in a crudely bedded to nonstratified granule to clay matrix; angular to subrounded; carried from surrounding slopes by debris flows from torrential rainfall and deposited where washes decrease in gradient, forming fan-shaped deposits; cut-and-fill channel features locally present; deposited near the base of steep slopes, cliffs, and ledges, and at the mouths of streams and washes; commonly include minor alluvium and eolian deposits; as much as 15 meters (50 ft) thick.

Qat **Terrace alluvium (early Holocene to middle Pleistocene)** – Moderately well sorted, pebble to cobble gravel with some silt and sand in terraces along major rivers and streams; clasts are mostly rounded to subrounded, but a few locally derived clasts are angular; contains mixed sedimentary and igneous clasts up to 0.6 meter (2 ft) in diameter, but mostly pebbles to cobbles up to 5 centimeters (2 in) in diameter; basal parts are generally coarser; commonly partly to fully consolidated in basal parts with cementing calcic soil (caliche), especially in the older (higher) deposits; caliche is locally as thick as 3.5 meters (12 ft); form benches at irregular levels up to 180 meters (600 ft) above modern drainages; thickness varies widely, but commonly less than 10 meters (30 ft) thick.

Qapc **Alluvial pediment-mantle and colluvial deposits (early Holocene to middle Pleistocene)** – Primarily locally derived, poorly to moderately sorted, rounded to angular boulders, cobbles, pebbles, granules, sand, silt, and clay deposited primarily by debris flows and ephemeral streams; crudely stratified, mostly matrix supported; commonly mantled by eolian deposits; preserved on older, bench-like, beveled bedrock surfaces between modern drainages at various levels up to 120 meters (400 ft) above local base level; grade upslope into colluvial, talus, and landslides deposits (smaller not mapped separately); map unit commonly includes associated colluvial deposits formed as the pediment flanks erode; commonly less than 15 meters (50 ft) thick.

Qapcv **Alluvial pediment-mantle and colluvial deposits with volcanic clasts (early Holocene to middle Pleistocene)** – Primarily locally derived, poorly to moderately sorted, rounded to angular boulders, cobbles, pebbles, granules, sand, silt, and clay deposited primarily by debris flows and ephemeral streams; similar to Qapc deposits, but contain significant quantities of rounded, commonly vesicular, volcanic boulders; crudely stratified, mostly matrix supported; commonly mantled by eolian deposits; preserved on older, bench-like, beveled bedrock surfaces between modern drainages at various levels up to 120 meters (400 ft) above local base level; grade upslope into colluvial, talus, and landslides deposits (smaller not mapped separately); contain significant landslides near Geyser Peak; map unit commonly includes associated colluvial deposits formed as the pediment flanks erode; commonly less than 15 meters (50 ft) thick.

Qmt **Talus (Holocene to late Pleistocene)** – Unconsolidated, very poorly sorted, angular, rock-fall blocks, boulders, and small fragments in steep fan-shaped deposits derived from erosion of overlying cliffs and ridges; common on slopes beneath the Ferron Sandstone Member and Castlegate Sandstone; commonly grade downslope into colluvial deposits on wider benches; widespread but only larger deposits mapped; 3 to 6 meters (10–20 ft) thick.

Qms, Qms (Kmb), Qms(Js), Qms(Jsmt), Qms(Jmb)
Landslides and slumps (Holocene to middle Pleistocene) – Large, coherent blocks to fragmented masses of bedrock and poorly sorted angular rock fragments, mud, and sand transported downslope by mass movement; common on steep slopes of Mancos Shale; most debris varies in size from 0.2 to 3 meters (0.5 to 10 ft) in diameter; thicknesses vary; locally, large, mostly coherent slump blocks are labeled with their formation symbol (Kmb, etc.).

Qmb **Mass-movement boulder deposits (Holocene to middle Pleistocene)** – Large, angular to subrounded boulders and cobbles in a matrix of gravel, silt, and clay particles primarily derived from Tertiary sill and dike complexes in the southeast part of the quadrangle; deposited primarily by colluvial, landslide, talus, and residual weathering processes; thickness generally 6 meters (20 ft) or less.

Qea **Mixed eolian sand and alluvium (Holocene to middle Pleistocene)** – Unconsolidated wind-blown sand and silt interspersed with silt, sand, and gravel of alluvial origin; generally dominated by eolian deposits; commonly display a well-developed calcic soil (caliche) horizon in the upper part; commonly deposited by sheetwash and wind; locally include other types of deposits too small to map separately; 15 meters (50 ft) or less thick.

Qes **Eolian sand (Holocene to middle Pleistocene)** – Unconsolidated, fine- to medium-grained, wind-blown sand deposited in sheets and low mounds; generally pale orange brown but locally nearly white to pale brown; commonly covers older alluvial surfaces and bedrock units; locally interlayered with alluvial deposits; gradational with Qea deposits; contains small areas of dune deposits, especially longitudinal dunes trending northeast in response to prevailing winds; 0 to 5 meters (0–15 ft) thick; locally thicker.

Ql **Lacustrine deposits (Holocene)** – Thin, planar, well-bedded, well-sorted silt and sand deposits in closed basins; includes minor alluvial and eolian sand and gravel remnants; most are in lakes and reservoirs in northwest part of map area; less than 3 meters (10 ft) thick.

TERTIARY

Ts, Td
Tephrite, phonotephrite, and trachybasalt sills and dikes (early Pliocene) – Light-gray to dark-green-gray sills (Ts) and dikes (Td) in southeast part of map area; have chilled zone at contacts with sedimentary rocks into which they are intruded; Williams and Hackman (1971) described these as diabase, but Gartner (1986) classified them as zoned tephrite, phonotephrite, and trachybasalt (higher Na_2O+K_2O than typical basaltic rocks); Gartner (1986) stated that labradorite is the main feldspar present, with secondary augite, analcite, biotite, thomsonite, anorthoclase, olivine, and natrolite; locally porphyritic; resistant and commonly found intruded into several sedimentary horizons from a feather edge to nearly 30 meters (100 ft) in thickness; sills locally split and divide; dikes are nearly vertical and appear to cut and act as feeders to sills; mostly intruded into Middle Jurassic rocks; present in eastern part of map area and extend south into Cathedral Valley; two samples from sills yielded ^{40}Ar/^{39}Ar ages of 4.35±0.04 Ma and 4.49±0.08 Ma, from Mussentuchit Wash (NE sec. 36, T.24S., R.6E.) and Hebes Mountain (SE sec. 27, T.24S., R.7E.), respectively; Delaney and Gartner (1997) reported that this "San Rafael dike swarm" is 3 to 7 Ma; Nelson (1989) reported three K/Ar ages ranging from 3.8 to 5.4 Ma; 0 to 3 meters (0–10 ft) thick.

Tbgp **Trachybasalt of Geyser Peak (early Pliocene to late Miocene)** – Small local trachybasalt lava flows containing less than 15% phenocrysts (14% olivine and 0.5% clinopyroxene) in a groundmass of plagioclase, clinopyroxene, and iron-titanium oxides with little or no olivine (Nelson, 1989); may be related to intrusions (Ts and Td) to the east; present on top and just south of Geyser Peak; have K/Ar ages ranging from about 3.5 to 7.0 Ma (Nelson, 1989); 0 to 30 meters (0–100 ft) thick.

Tv **Interbedded trachyte ash-flow tuff and volcanic-clast conglomerate (late Oligocene)** – Red-brown to gray, highly jointed, weakly porphyritic trachytic ash-flow tuffs interbedded with volcanic pebbles and cobbles; crystal-poor flow rock contains about 2% plagioclase phenocrysts (up to 5 mm in diameter) and minor clinopyroxene, orthopyroxene, and cubic iron-titanium oxide in a dull to glassy groundmass of iron-titanium oxides interspersed among alkali feldspar laths (Nelson, 1989); mapped by Nelson (1989; his units Td, Tds, and Tda) near Geyser Peak; an ongoing study by the Utah Geological Survey may establish regional correlation with named units (see discussion of map units Tlj and Tlc in Biek and others, 2015); probably about 25 Ma in age; 45 to 120 meters (150–400 ft) thick.

Tr **Shoshonitic volcanic rocks of Riley Spring (late Oligocene)** – Poorly exposed, red-brown to gray, crystal-rich, porphyritic shoshonite (high potassium trachyandesite) consisting of about 35 percent phenocrysts of plagioclase, augite, olivine, iron-titanium oxide, and trace amounts of orthopyroxene in a dark to very dark gray-black matrix of olivine, iron titanium oxides, plagioclase, and glass or sanidine (Nelson, 1989); whether unit is an ash-flow tuff or lava flow is still under debate (Biek and others, 2015); mapped by Nelson (1989; his unit Tr) near Riley Spring and Geyser Peak; an ongoing study by the Utah Geological Survey may establish regional correlation with named units (see discussion of map units Tlj and Tjv in Biek and others, 2015); probably about 26 Ma in age; 60 to 90 meters (200–300 ft) thick.

Tf, Tfl, Tfu
Flagstaff Formation (late Paleocene) – Limestone, white, light gray, yellow gray, pink gray, and light brown; thin to thick bedded and locally massive; dense and mostly microcrystalline; some beds are cherty; has some algal nodules, local oncolites, gastropods, ostracodes, and bivalves; contains subordinate gray shale; largely a lacustrine deposit; forms resistant ledges and cliffs; divided into Tfu (upper member) which has blocky outcrops and distinct bedding, and Tfl (lower member) which has less blocky outcrops and less-prominent bedding; exposed in the northwest and southwest corners of the east half of the Salina 30' x 60' quadrangle map; late Paleocene in age (Franczyk and others, 1992); 60 to 335 meters (200–1100 ft) thick.

TERTIARY-CRETACEOUS

TKnh **North Horn Formation (early Paleocene to Late Cretaceous, Maastrichtian)** – Variegated mudstone, lenticular sandstone, and limestone; mudstone is light red brown or purple, gray green, or light gray; sandstone is fine grained and brown, gray, or yellow gray; and limestone is very light gray or yellow gray; also contains local conglomerate beds with pebbles of chert and quartzite; thin to thick bedded; forms gentle to steep slopes with local ledges; forms a series of wide rolling slopes overlying more resistant cliff- or ledge-forming units; locally prone to landsliding; Cretaceous-Tertiary boundary not recognized in this quadrangle (Difley, 2007); present in the northwest corner of the east half of the Salina 30' x 60' quadrangle; Late Cretaceous (Maastrichtian) to Paleocene in age (Franczyk and others, 1992; Difley, 2007); 150 to 180 meters (500–600 ft) thick.

CRETACEOUS

Kpr **Price River Formation (Late Cretaceous, late Campanian)** – Sandstone, tan-gray to brown, medium- to coarse-grained in lower part and fining upward, subangular to subrounded; quartzose, but dark minerals and lithics make up 5 percent of the rock; locally contains conglomerate or conglomeratic sandstone in lower part; resistant and blocky with gray, muddy, fine-grained sandstone and siltstone partings and slope intervals, especially in the upper portion of the formation; bedding is mostly planar with some low-angle cross-beds; forms a steep sequence of cliffs broken by short slopes; Campanian in age (about 72–74 Ma; Fouche and others, 1983); about 140–170 meters (460 to 550 ft) thick.

Kc **Castlegate Sandstone (Late Cretaceous, Campanian)** – Sandstone, gray to very light-gray, weathers gray orange, medium to coarse grained, locally conglomeratic, thick bedded to massive, resistant; forms cliffs and benches above the less resistant Blackhawk Formation; Campanian in age (about 74–75 Ma; Fouch and others, 1983); 30 to 60 meters (100–200 ft) thick.

Kbh **Blackhawk Formation (Late Cretaceous, Campanian)** – Interbedded sandstone and shale containing dark-gray carbonaceous shale, coaly shale, and mineable coal beds near base; sandstone is tan to yellow gray, mostly fine grained; forms calcareous thin- to thick-bedded cliffs and ledges; shale mostly gray, forming steep slopes; overall the outcrop forms a brownish-gray steep slope with irregularly spaced sandstone ledges and cliffs; Campanian in age (about 77–75 Ma; Fouch and others, 1983); about 180 to 260 meters (600–850 ft) thick.

Ksp **Star Point Sandstone (Late Cretaceous, early Campanian)** – Sandstone, yellow-gray, light-brown, and white; fine- to medium-grained; platy with some shale partings; lower part intertongued with gray shale of the Mancos Shale below; forms resistant cliff above the upper Blue Gate Member of the Mancos Shale; Campanian in age (about 82–84 Ma; Cobban and others, 2006; Aschoff and Steel, 2011); 30 to 120 meters (100–400 ft) thick.

Kmbu **Upper Blue Gate Shale Member of Mancos Shale (Late Cretaceous, early Campanian)** – Medium to dark blue-gray marine shale, yellow- to blue-gray sandy shale, and yellow-gray, fine-grained sandstone; interbedded sandstone increases toward top; forms steep slope beneath the Star Point Sandstone cliff; early Campanian and time equivalent to the Masuk Shale Member of the Mancos Shale (Cobban and others, 2006); 90 to 245 meters (300–800 ft) thick.

Kme **Emery Sandstone Member of Mancos Shale (Late Cretaceous, Santonian)** – Yellow-gray, friable sandstone, fine to medium grained; forms cliffy ledges with minor slopes of sandy gray shale; early Santonian (Fouch and others, 1983); 120 to 245 meters (400–800 ft) thick, thickening southward.

Kmel **Lower ledge of Emery Sandstone Member (Late Cretaceous, Santonian)** – Tongue of Emery Sandstone in area north of town of Emery; forms prominent ledge in the Blue Gate Member about 30 meters (100 ft) below the main member; 12 to 25 meters (40–80 ft) thick.

Kmb **Blue Gate Shale Member of Mancos Shale (main part) (Late Cretaceous, Campanian to Santonian)** – Pale blue-gray, marine shale, nodular and irregularly bedded mudstone, and siltstone with several yellow-gray sandy beds; weathers into low rolling hills and badlands; Campanian to Santonian in age (Molenaar and Cobban, 1991); 300 to 490 meters (1000–1600 ft) thick.

Kmf **Ferron Sandstone Member of Mancos Shale (Late Cretaceous, Turonian)** – Alternating yellow-gray, light-brown, and white sandstone, sandy gray shale, gray carbonaceous shale, and coal; sandstone is mostly fine to medium grained; calcareous; lenticular, thin to very thick beds; forms resistant cliff above Tununk Member; contains several mineable coal beds; Turonian in age (Molenaar and Cobban, 1991); 120 to 215 meters (400-700 ft) thick, thickening to the southwest.

Kmt **Tununk Shale Member of Mancos Shale (Late Cretaceous, Turonian to Cenomanian)** – Medium- to dark-gray marine shale; forms steep slope under Ferron Sandstone Member cliff; becomes increasingly sandy towards top; has 5- to 10-foot (1.5–3 m) sandstone bed that makes a ledge (not mapped) 100 feet (30 m) below the top in the northwest part of the eastern half of the Salina 30' x 60' quadrangle; lower contact with Dakota is generally abrupt but conformable, and is a disconformity where the Dakota is thin or missing; lower contact is marked by a change from gray-green shale (Cedar Mountain Formation) to gray shale and by a local basal gravel (Eaton and others, 2001); a zone of fossil bivalves (Pycnodonte newberryi) is found a few feet above the contact; Turonian to Cenomanian in age (Molenaar and Cobban, 1991); 150 to 245 meters (500–800 ft) thick.

Kdcm **Dakota (Naturita)** and Cedar Mountain Formations, undivided – on cross section only.

Kd **Dakota (Naturita) Formation (Late Cretaceous, Cenomanian)** – Variable assemblage of yellow-gray sandstone, conglomerate, conglomeratic sandstone, light-brown shale, and coal; sandstone is generally fine to coarse grained, cross-bedded, thick bedded, and lenticular; conglomerate contains gray quartzite and black chert pebbles up to 8 cm (3 in) in diameter; coal beds, where present, are generally less than 60 cm (2 ft) thick; forms ledges and slopes; some workers have proposed "correcting" the name of this unit to the Naturita Formation (see Carpenter, 2014)—a consensus has not been reached; Cenomanian in age (Gustason, 1989; Eaton and others, 2001); 6 to 35 meters (20–120 ft) thick.

unconformity

Kcm **Mussentuchit Member of Cedar Mountain Formation (Late to Early Cretaceous, Cenomanian-Albian)** – Sandy, silty, and smectitic mudstone; gray, white, and light-green-gray; contains a few thin, green-gray, lenticular sandstone beds and some lignitic zones near the top; forms smooth rounded slopes with local ledges; Albian to Cenomanian in age based on youngest fauna straddling the Albian-Cenomanian boundary and a radiometric age of 98.39 Ma obtained by Cifelli and others (1997); 12 to 33 meters (37–110 ft) thick.

Kcs **Short Canyon Member of Cedar Mountain Formation (Late to Early Cretaceous, Cenomanian-Albian)** – Conglomerate, conglomeratic sandstone, and sandstone ledges separated by slope-forming sandstone, local gray to black carbonaceous (and possibly coaly) shale, and rare thin gypsiferous sandstone lenses; ledges are cross-stratified, gray, gray brown, and brown, and contain poorly sorted subrounded to subangular grit to cobbles as much as 12 cm (4 in) across; clasts are quartzite, siliceous limestone, and sandstone; slope-forming sandstone is mostly light gray or green gray, fine to medium grained, poorly cemented and friable; only present in the Short Canyon area; Cenomanian to Albian in age (Hunt and others, 2011); 0 to 32 meters (0–104 ft) thick and discontinuous, thickening northward in quadrangle.

Kcr **Ruby Ranch Member of Cedar Mountain Formation (Early Cretaceous, Albian-Aptian)** – Silty mudstone that contains nodular brown limestone beds with a basal muddy sandstone bed; mostly green-gray, light gray, and purple; locally contains a few lenticular ledges of fine-grained, locally pebbly sandstone, especially at base; brown limestone ledges commonly break up and litter the smooth slopes; Early Cretaceous (Aptian-Albian) in age according to fossil evidence and radiometric and stratigraphic relations (Kirkland and others, 1999; Kirkland and Madsen, 2007); 23 to 40 meters (76–131 feet) thick.

Kcb **Buckhorn Conglomerate Member of Cedar Mountain Formation (Early Cretaceous, Barremian-Aptian?)** – Gray-brown conglomerate, conglomeratic sandstone, and sandstone; contains pebble- and cobble-sized clasts of quartzite, chert, and black siliceous limestone in a matrix of poorly sorted, fine- to coarse-grained sandstone interbedded with gray-green silty and sandy shale; sandstone is trough cross-bedded, lenticular, and discontinuous; forms ledges and benches that are channeled into underlying purple part of Brushy Basin Member of Morrison Formation; mapped only where outcrops form benches; is included with Ruby Ranch Member (Kcr) where thin or less well developed; Greenhalgh and Britt (2007) and Kirkland and Madsen (2007) place the Buckhorn in the late Early Cretaceous, and Hunt and others (2011) date it from Barremian to Aptian; 0 to 12 meters (0–40 feet) thick.

K-0 *unconformity*

JURASSIC

Jm **Morrison Formation, undivided** – on cross section only.

Jmb **Brushy Basin Member of Morrison Formation (Late Jurassic, Tithonian)** – Color-banded, variegated (gray-purple, gray-green, yellow, moderate-red-brown, white) siltstone, claystone, mudstone, and shale interbedded with minor brown and gray nodular limestone beds and white, gray, and light-brown-gray, cross-bedded sandstone lenses; contains a few conglomeratic sandstone beds at base that form ledges; commonly smectitic; generally forms steep slopes devoid of vegetation; lower contact is placed at base of mudstone sequence; forms rounded slopes and hills or steep slope beneath Cedar Mountain Formation; Tithonian in age (Demko and others, 2004; Kowallis and others, 2007); 45 to 130 meters (150–425 ft) thick.

Jms **Salt Wash Member of Morrison Formation (Late Jurassic, Tithonian to Kimmeridgian)** – Gray, brown, and white sandstone, conglomeratic sandstone, and conglomerate interbedded with subordinate red-brown siltstone; mudstone and siltstone form slopes and recesses between channel sandstone lenses; sandstone lenses thicken and coarsen upward in the unit; upper lenses are commonly coarse grained, trough cross-bedded, and locally contain vanadium and uranium minerals; also contains thin sandy limestone beds, especially in the lower parts of the member; lower contact is placed at base of lowest dominant sandstone lens; Tithonian to Kimmeridgian in age (Demko and others, 2004; Bradshaw and Kowallis, 2009); 45 to 90 meters (150–300 ft) thick.

Jmst **Salt Wash and Tidwell Members of Morrison Formation, undivided** – Mapped where the Salt Wash Member is thin or discontinuous and cannot be mapped separately from the Tidwell Member in the central part of the map area.

Jmt **Tidwell Member of Morrison Formation (Late Jurassic, Kimmeridgian)** – Gray-red-purple, dark-red-brown, and light-gray, thin-bedded, calcareous siltstone and marl interbedded with very fine grained, thin-bedded sandstone, and gray, thin-bedded or nodular-weathering limestone; mostly slope forming; locally contains a thick gypsum bed as much as 5 meters (15 ft) thick at base; lower contact marked by change from red-brown to light-brown beds of the Summerville Formation; Kimmeridgian in age (Demko and others, 2004; Bradshaw and Kowallis, 2009); lower contact is a disconformity; generally 6 to 15 meters (20–50 ft) thick, but locally may be thicker.

J-5 *unconformity*

Jsr **San Rafael Group: Summerville, Curtis, Entrada, Carmel, and Temple Cap Formations, undivided** – on cross section only.

Js **Summerville Formation (Late Jurassic, Oxfordian)** – Thin, even-bedded, red-brown siltstone, sandstone, and gypsum, interbedded with minor limestone and shale; forms interbedded, locally steep convex slopes, vertical cliffs, and earthy slopes; sandstone is generally fine grained and weathers platy; limestone is gray, crystalline, and nodular; gypsum is present in veinlets, thin beds, and nodule zones; jasper nodules are present near the top; lower contact is gradational with the Curtis Formation; considered Oxfordian in age (Imlay, 1980; Wilcox and Currie, 2006; Wilcox, 2007); 60 to 120 meters (200–400 ft) thick.

Jct **Curtis Formation (Late Jurassic, Oxfordian)** – Green-gray to light brown, fine- to coarse-grained sandstone and green-gray siltstone and mudstone; glauconitic; lower part forms cliffs or steep slopes, upper part forms slopes and grades upward into Summerville Formation; most beds are planar, a few exhibit cross-stratification; forms light band between the brownish Summerville above and red-brown Entrada Formation below; Oxfordian in age (Imlay, 1980; Wilcox and Currie, 2006; Wilcox, 2007); 30 to 75 meters (100–240 ft) thick.

J-3 *unconformity*

Je, Jem
Entrada Sandstone, undivided (Middle Jurassic, Callovian) – Orange-brown to light- brown siltstone to fine-grained sandstone; contains scattered medium- to coarse-grained lenses; thin to thick bedded; abundant gypsum in thin beds and satin-spar veinlets mostly in lower units; weathers to rounded (sloping), horizontally grooved cliffs with some thin-bedded earthy slopes; contains a prominent white, fine-grained sandstone marker bed locally mapped separately (Jem); Callovian in age (Anderson and Lucas, 1994; Hunt and Lockley, 1995; Perkes and Morris, 2011); 180 to 275 meters (600–900 ft) thick.

Jc **Carmel Formation, undivided (Middle Jurassic, Callovian to Bajocian)** – Only mapped in southwest corner of east half of Salina 30' x 60' quadrangle near Geyser Peak.

Jcb **Banded unit of Winsor Member of Carmel Formation (Middle Jurassic, Callovian to Bathonian)** – Interbedded mudstone, siltstone, sandstone, and thin gypsum beds; mostly light-gray or light-brown-gray with subordinate red or red-brown bands; irregular cyclical deposits; many mudstone and siltstone beds are criss-crossed with satin-spar gypsum veinlets; forms slopes and gypsum ledges; Callovian to Bathonian in age (Imlay, 1980; Blakey and others, 1983; Sprinkel and others, 2011; Doelling and others, 2013); about 85 meters (275 ft) thick.

Jcg **Gypsiferous unit of Winsor Member of Carmel Formation (Middle Jurassic, Bathonian)** – Interbedded red-brown, fine-grained sandstone, red-brown siltstone, and impure silty alabaster gypsum; sandstone and siltstone form earthy weathering slopes and gypsum forms resistant ledges up to 6 meters (20 ft) thick; Bathonian in age (Imlay, 1980; Blakey and others, 1983; Sprinkel and others, 2011; Doelling and others, 2013); 30 to 38 meters (100¬–125 ft) thick.

Jcl **Lower members of Carmel Formation (Middle Jurassic, Bathonian to Bajocian)** – Combined Paria River, Crystal Creek, and Co-op Creek Limestone Members. Paria River Member dominated by limestone and calcarenite in thin to medium beds that are platy weathering and forms ledges and slopes, and contains a thick gypsum bed near base; Crystal Creek Member is gray-pink sandstone that weathers red-brown, forms steep slopes, and contains criss-crossing satin-spar gypsum veinlets; Co-op Creek Limestone Member is mostly ledgy limestone and calcarenite with thin interbeds or partings of siltstone, mudstone, and fine-grained calcareous sandstone; Bathonian to Bajocian in age (Imlay, 1980; Blakey and others, 1983; Sprinkel and others, 2011; Doelling and others, 2013); Paria River Member is 49 to 53 meters (160–175 ft) thick; Crystal Creek Member is 8 to 9 meters (25–30 feet) thick; Co-op Creek Limestone Member is 9 to 12 meters (30–40 ft) thick; complete lower member as mapped is 66 to 74 meters (215–245 ft) thick.

Jt **Temple Cap Formation (formerly Page Sandstone) (Middle Jurassic, Bajocian)** – Sandstone, light-gray-pink, light-brown, or light-red-brown; fine- to coarse-grained; partly cross-bedded; friable and porous; medium- to thick-bedded; commonly resistant; Temple Cap Formation is used instead of Page Sandstone in this area following Sprinkel and others (2011) and Doelling and others (2013); Bajocian in age (Imlay, 1980; Blakey and others, 1983; Sprinkel and others, 2011; Doelling and others, 2013); 0 to 14 meters (0–45 ft) thick.

J-1 *unconformity*

JꞦgc **Glen Canyon Group** – on cross section only. Consists of Navajo, Kayenta, and Wingate Formations.

Jn, Jnb
Navajo Sandstone (Early Jurassic, Toarcian to Pleinsbachian) – Mostly light-gray-pink to gray (in San Rafael Swell commonly bleached or altered to pale yellow gray by hydrocarbons), fine- to medium-grained, cross-bedded quartz sandstone in large trough sets; contains few scattered dark mineral grains; grains are mostly subangular; well sorted and friable; mostly massive; lower third commonly weathers to cliffs, the remainder into domes and rounded knolls; mostly calcareous; Jnb resembles the main body but forms prominent 40- to 60-meter (130–200 ft) cliff at base of formation; Toarcian to Pleinsbachian in age (Dickinson and Gehrels, 2003); 40 to 60 meters (130–200 ft) thick.

Jk **Kayenta Formation (Early Jurassic, Pleinsbachian to Sinemurian)** – Gray-purple, red-brown, and pale-red (in San Rafael Swell commonly bleached or altered to pale yellow gray by hydrocarbons), medium- to thick-bedded to locally massive, irregularly bedded and cross-bedded (mostly low-angle), fine- to coarse-grained sandstone; thin red-brown shaly siltstone forms local partings; contains local white to very light-gray and dark-brown beds of intraformational conglomerate and lenses of gritstone, pebble conglomerate, and limestone; many sandstone beds are micaceous; lower contact with Wingate Sandstone is conformable and sharp; forms a series of thick step-like ledges, cliffs, and benches; mostly fluvial, but contains a few eolian beds in upper part; Pleinsbachian to Sinemurian in age (Peterson, 1994; Curtis and Padian, 1999); about 45 to 90 meters (150–300 ft) thick.

JURASSIC-TRIASSIC

JꞦw **Wingate Sandstone (Early Jurassic to Late Triassic, Hettangian to Rhaetian)** – Moderate red-orange (in San Rafael Swell commonly bleached or altered to pale yellow gray by hydrocarbons), dark-brown-weathering, fine-grained, massive, cross-bedded, eolian, quartzose sandstone; forms vertical cliffs along canyon walls; commonly stained with manganese oxide (desert varnish); local partings of sandy siltstone are common near the base; generally well cemented with calcium carbonate, but is locally siliceous; contact with unit below is generally abrupt and placed at the base of the Wingate cliff; Hettangian to Rhaetian in age (Dubiel, 1987; Jensen and Kowallis, 2005); 73 to 130 meters (240–420 ft) thick.

Ꞧ-5 *unconformity*

Ꞧcu **Upper members of Chinle Formation (Church Rock, Owl Rock, and Petrified Forest Members) (Late Triassic, Norian)** – Consists of three members mapped together. Church Rock Member is medium- to dark-red-brown, pink-gray, light-brown (upper third is commonly bleached yellow-gray to tan-gray by hydrocarbons), very fine to fine-grained, blocky and resistant sandstone beds 1 to 2 meters (3–5 ft) thick with few partings of gritstone and fine- to coarse-grained, cross-bedded sandstone and siltstone; forms step-like cliff; Owl Rock Member consists of upper slope-forming, mottled, pale-purple to yellow-gray to medium-red-brown siltstone with thin to indistinct bedding and lower ledge-forming, lenticular and cross-bedded sandstone, conglomeratic sandstone, and conglomerate with petrified wood; Petrified Forest Member consists of upper mottled paleosol slope that is mostly gray-purple, gray, green-gray, and red-brown sandy mudstone and lower sandstone bench that is fine to medium grained, mostly moderate red to light brown and 1.5 to 8 meters (5–25 ft) thick; deposited in fluvial-lacustrine environment with overbank floodplain deposits and abundant soil development (Dubiel, 1987); Norian in age (Lucas, 1993; Irmis and others, 2011); total thickness of the three members is 73 to 113 meters (240–370 ft) in the San Rafael Swell, thickening southward.

Ꞧcl **Lower members of Chinle Formation (Moss Back, Monitor Butte, and Temple Mountain Members) (Late Triassic, Norian to Carnian)** – Consists of three members mapped together. Overall, lower members are gray or gray-brown interfingering sequence of cliff- and bench-forming quartzose pebble conglomerate, fine- to medium-grained massive sandstone, limestone-pebble conglomerate, fine-grained platy-weathering sandstone, and minor gray mudstone; these beds interfinger and intergrade, and one or more may be locally absent; contains scattered fragments and logs of petrified wood, especially near the top and bottom; contains clay galls, pellets, and carbonized wood near the base; locally contains uranium and copper ore; has calcareous cementation; sandstone beds are cross-bedded (low angle), lenticular, and weather platy toward the top; fluvial deposit; member thickens where it is channeled into units below; Moss Back Member unconformably overlies Monitor Butte, Temple Mountain, or locally the Moody Canyon Member of the Moenkopi Formation; Temple Mountain and Monitor Butte Members are discontinuous and locally intergrade and intertongue; Temple Mountain (basal member) consists mostly of mottled (mostly grayish-purple, white, and moderate-yellow), indistinct to massive siltstone and sandstone (paleosols), whereas Monitor Butte contains less massive siltstone beds and lenses of medium- to coarse-grained quartzose sandstone; Moss Back Member is ledgy, gray, medium to thick-bedded lenticular sandstone, conglomeratic sandstone, and conglomerate; combined lower members are 4 to 52 meters (12–170 ft) thick; Carnian to Norian in age (Lucas, 1993; Irmis and others, 2011); Moss Back is 0 to 45 meters (0–150 ft) thick; combined Temple Mountain and Monitor Butte Members are 0 to 20 meters (0–66 ft) thick.

Ꞧ-3 *unconformity*

Ꞧmm **Moody Canyon Member of Moenkopi Formation (Early Triassic, Olenekian)** – Red-brown and moderate-brown, fine-grained sandstone and siltstone in even, thin beds with local medium beds; forms steep slope with subtle resistant ribs and a few ledges near top; gradational and intertongues with underlying Torrey Member (lower contact and Torrey Member not exposed in quadrangle), but forms slope that is not generally as steep; locally contains thin veinlets of cross-cutting satin-spar gypsum; Olenekian in age (Dubiel, 1994; Lucas and others, 2007) 43 to 75 meters (140–250 ft) thick.

SUBSURFACE GEOLOGY

The eastern part of the quadrangle climbs onto the western flank of the San Rafael Swell (cross section A–A'), a major Laramide uplift to the east (Doelling and others, 2015, see descriptions of Permian and older units). Of particular note, a major unconformity developed across the Emery paleohigh during the Pennsylvanian to Early Permian, removing or preventing deposition of Pennsylvanian strata (Hintze and Kowallis, 2009, p. 43; Morgan and Waanders, 2013; Doelling and others, 2015).

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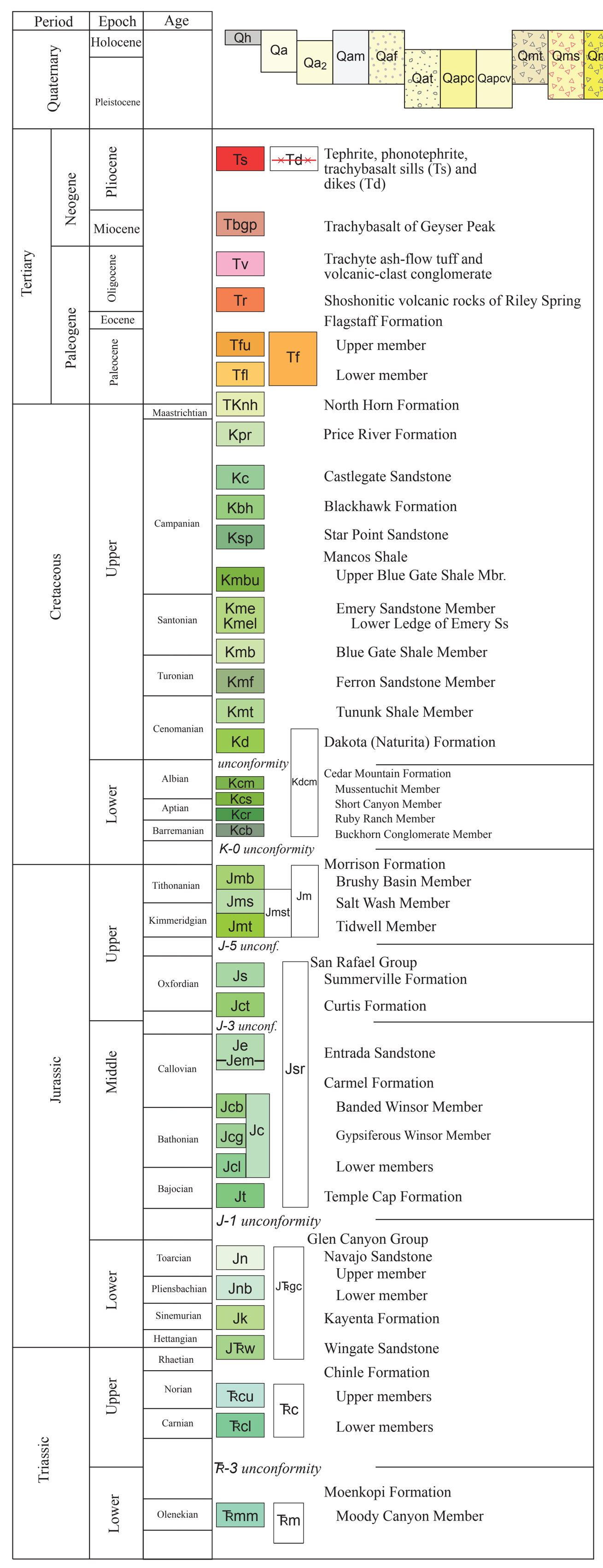
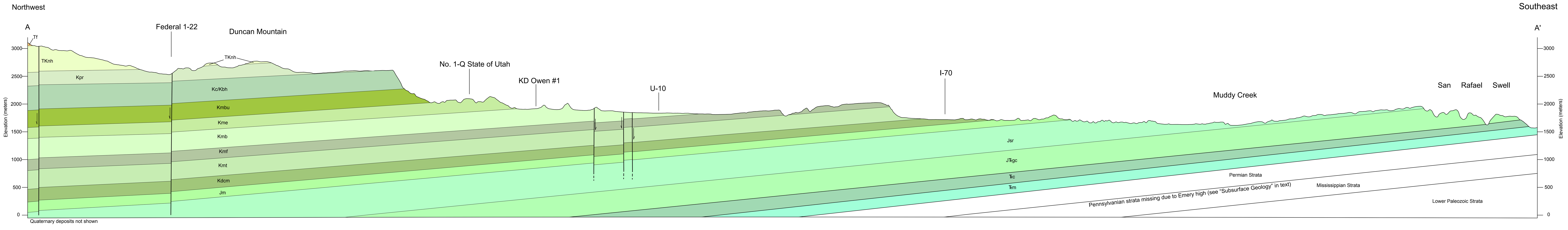
MAP SYMBOLS

- Contact - Dashed where approximately located
- Marker bed (Jem) within Entrada Formation (Je)
- Igneous dike or sill - Dashed where approximately located
- Normal fault - Bar and ball on downthrown side; dashed where approximately located; dotted where concealed
- Joint
- Landslide scarp - dashed where approximately located
- National Park Boundary
- Anticlinal axis - showing plunge; dotted where concealed
- Monoclinal axis - showing plunge; dotted where concealed
- Synclinal axis - showing plunge; dashed where approximately located; dotted where concealed; queried(?) where existence uncertain
- Strike and dip of bedding
- Vertical joint
- Drill hole - abandoned
- Drill hole - dry hole
- Drill hole - gas well, abandoned
- Drill hole - gas well, shut-in
- Drill hole - oil well, abandoned
- Drill hole - abandoned - converted to water well
- Mine or quarry
- Mine or quarry - abandoned
- Spring

CORRELATION OF MAP UNITS