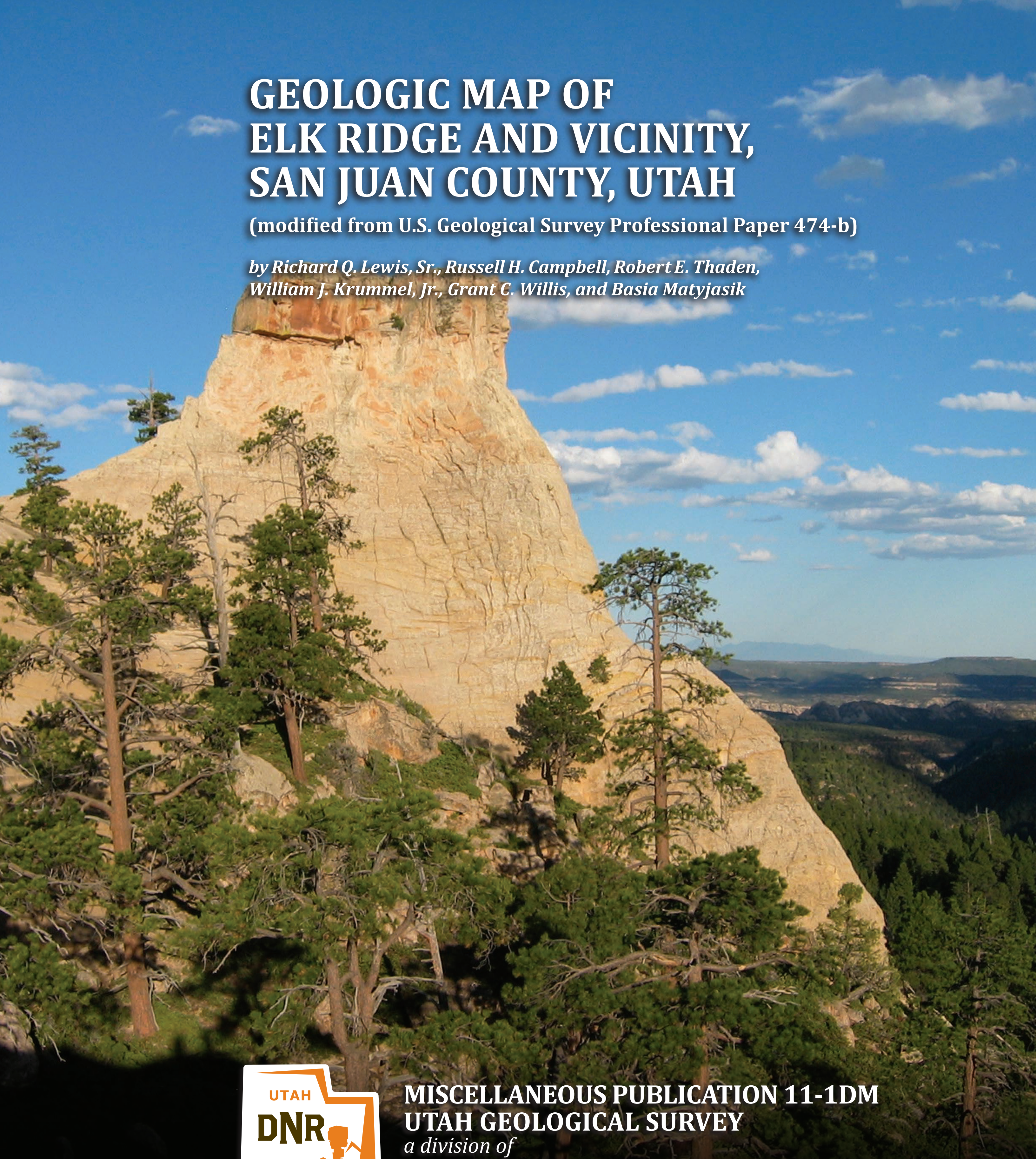
GEOLOGIC MAP OF ELK RIDGE AND VICINITY, SAN JUAN COUNTY, UTAH

(modified from U.S. Geological Survey Professional Paper 474-b)

by Richard Q. Lewis, Sr., Russell H. Campbell, Robert E. Thaden, William J. Krummel, Jr., Grant C. Willis, and Basia Matyjasik



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by Richard Q. Lewis, Sr.[1], Russell H. Campbell[1], Robert E. Thaden[1], William J. Krummel, Jr.[1], Grant C. Willis[2], and Basia Matyjasik[2]

[1]U.S. Geological Survey; mapping in 1953–57
[2]Utah Geological Survey; modifications in 2009–11

Cover photo: *Blocky sandstone bed deposited in an oasis-like setting between ancient sand dunes of the Jurassic Navajo Sandstone forms a resistant cap over a spire in the Chippean Rocks.*

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Gary R. Herbert, Governor

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Michael Styler, Executive Director

UTAH GEOLOGICAL SURVEY
Richard G. Allis, Director

PUBLICATIONS
contact
Natural Resources Map & Bookstore
1594 W. North Temple
Salt Lake City, UT 84116
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website: mapstore.utah.gov
email: geostore@utah.gov

UTAH GEOLOGICAL SURVEY
contact
1594 W. North Temple, Suite 3110
Salt Lake City, UT 84116
telephone: 801-537-3300
Web site: geology.utah.gov

This publication is a digital version of part of a map published by the U.S. Geological Survey (USGS) in 1965—"Geologic Map and Structure Sections of Elk Ridge and Vicinity, San Juan County, Utah," by R.Q. Lewis, Sr., R.H. Campbell, R.E., Thaden, and W.J. Krummel, Jr. The map was published as plate 2 of USGS Professional Paper 474-B, Geology and Uranium Deposits of Elk Ridge and Vicinity, San Juan County, Utah, by R.Q. Lewis, Sr., and R.H. Campbell.

The scale of the original source map from which this digital map was derived is 1:62,500. In 2009–11, Willis and Matyjasik made extensive modifications using photogrammetric methods to improve the fit of the geology to standard 1:24,000-scale USGS base maps. However, it was beyond the scope of this project to modify every contact, and correct location of many features could not be verified; therefore, spatial accuracy and detail of features on this map vary from 1:24,000 to 1:62,500.

The digital release of this geologic map was funded by the Utah Geological Survey and U.S. Forest Service. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the official policies, either expressed or implied, of the U.S. Government.

CONTENTS

TABLES

GEOLOGIC MAP OF ELK RIDGE AND VICINITY, SAN JUAN COUNTY, UTAH

(modified from U.S. Geological Survey Professional Paper 474-b)

by Richard Q. Lewis, Sr., Russell H. Campbell, Robert E. Thaden, William J. Krummel, Jr., Grant C. Willis, and Basia Matyjasik

SUMMARY

This digital dataset represents the geology of the Elk Ridge area in San Juan County, Utah. It is a digital version of most of a map published by the U.S. Geological Survey (USGS) in 1965 entitled *"Geologic map and structure sections of Elk Ridge and vicinity, San Juan County, Utah."* The source map, by R.Q. Lewis, Sr., R.H. Campbell, R.E., Thaden, and W.J. Krummel, Jr., was published as plate 2 of USGS Professional Paper 474-B, *Geology and Uranium Deposits of Elk Ridge and Vicinity, San Juan County, Utah,* by R.Q. Lewis, Sr., and R.H. Campbell. Spatial accuracy and detail of features in the digital dataset vary from 1:24,000 to 1:62,500 scale.

Elk Ridge is a high plateau that extends from the Abajo Mountains west to the Colorado River. The area consists of several high mesas dissected by deep canyons. Exposed strata range from the Pennsylvanian Paradox Formation exposed in the deepest canyons near the river, to the Upper Jurassic Salt Wash Member of the Morrison Formation exposed in the southeast corner of the map area. Overall, strata are gently folded by several broad anticlines and synclines, but are locally tilted up to about 30 degrees by several monoclinal folds. The largest of these folds, the Comb Ridge anticlinal bend, trends north-south through the southeastern part of the map area. Several high-angle normal faults with offsets ranging up to a few hundred feet cut across the area. In the northern part of the map area, east- to northeast-trending horsts, grabens, and rotated half-grabens form the southernmost part of the Needles District of Canyonlands National Park. In this area, deep incision by the Colorado River has destabilized strata, allowing it to slide toward the river canyon on the highly incompetent Paradox Formation.

The map area includes an important uranium district that was most active from the mid 1950s to 1960s. Several mines in this highly productive area yielded uranium and associated secondary copper and molybdenum minerals from the Shinarump, Monitor Butte, and Moss Back Members of the Chinle Formation. Many shafts, adits, pits, and prospects, most reclaimed, are scattered across the area.

DESCRIPTION OF MAP UNITS

QUATERNARY

Qae **Alluvial and eolian deposits** (Holocene)—Mostly moderately to poorly sorted, moderately rounded to angular, small boulder- to pebble-gravel, sand, silt, and clay deposited in small drainages and mixed with or covered by minor to large amounts of windblown sand and silt; locally includes minor colluvium and angular rubble from rock falls, landslides, and debris flows; clast composition reflects local lithologies; mapped in small washes where it typically includes deposits in active part of wash bottom to about 40 feet (12 m) above wash floor, but locally includes undifferentiated higher and older deposits; 0 to 20 feet (0–6 m) thick, but locally may exceed 60 feet (20 m) thick. Some deposits up to 30 or more feet (9+ m) above modern channels may be of historical age—Lewis and Campbell (1965) noted that a cabin built in the 1870s in the valley of North Cottonwood Creek was partially buried by stream alluvium, but in the early 1960s was perched about 30 feet (9 m) above the entrenched stream gulley.

Qafe **Mixed alluvial-fan, eolian, colluvial, and talus deposits** (Holocene to upper Pleistocene)—Poorly to moderately sorted small to large boulders with interstitial gravel, sand, and clay deposited on low- to moderate-relief slopes in areas where gullies, washes, and small stream channels reduce gradient as they cross from more-resistant to less-resistant bedrock units, and in poorly developed terraces along ephemeral streams; grades upward into and includes steep slopes mantled by talus rock-fall debris; sparsely to moderately mantled by eolian sand and silt in some areas; includes mixed alluvial-fan, debris-flow, slope-creep, slope-wash, rock-fall, eolian, and ephemeral-stream deposits; distal parts commonly have more eolian cover and are gradational with other surficial deposits; 0 to 30 feet (0–10 m) thick.

Qafeo **Older mixed alluvial-stream, alluvial-fan, colluvial, talus, and eolian deposits** (Holocene to middle Pleistocene)—Dissected remnants of poorly to moderately sorted small to large boulders, poorly sorted gravel, and interstitial sand to clay deposited in ephemeral streams and on low- to moderate-relief slopes in the upper part of Comb Wash; forms dissected alluvial-fan and terrace remnants; grades upward into and includes steep slopes mantled by talus; sparsely to moderately mantled by eolian sand and silt in some areas; includes mixed ephemeral-stream, alluvial-fan, debris-flow, slope-creep, slope-wash, rock-fall, and eolian deposits; as mapped includes younger deposits in active gulleys and streams that dissect deposits; 0 to 60 feet (0–20 m) thick.

Qeaf **Eolian, alluvial-stream, and alluvial-fan deposits** (Holocene to middle Pleistocene)—Moderately to very well sorted sand, silt, and clay deposited by wind, intermixed with poorly to moderately sorted boulder to pebble gravel and rubble deposited as slopewash and by alluvial fans, streams, and as sheetwash; deposited in shallow basins (some fault-bounded) in northern part of map area; in some areas deeply dissected while in other areas ephemeral streams and washes cross surface of deposits with no significant dissection; eolian component is generally dominant, but varies within deposits; in some areas, capped by thick calcic soil (caliche) that commonly forms a resistant bench; gradational with and locally includes deposits mapped in other areas as Qae; much of the unit is locally derived; up to 60 feet (20 m) exposed but may be thicker in some basins.

Qeat **Eolian sand over alluvial-terrace and other deposits** (Holocene to middle Pleistocene)—Very well sorted, well-rounded, mostly fine- to medium-grained, frosted quartz sand derived from the weathering of sandy bedrock; deposited by wind in sheets, mounds, and small dunes in protected areas on benches and slopes; commonly draped across and includes alluvial-terrace and alluvial-fan deposits, and across bedrock slopes; includes various amounts of alluvial, colluvial, and residual deposits; 0 to 45 feet (0–15 m) thick.

Qms **Mass-movement landslides and slumps** (Holocene to Pleistocene)—Chaotic, extremely poorly sorted, angular, massive blocks to clay-size material transported downslope; includes translational and rotational slides, slumps, and earthflows; transported materials vary from detached bedrock blocks up to several hundred feet across to surficial talus, colluvium, and alluvium; upper surfaces are typically hummocky with chaotic blocks; only largest landslide deposits are mapped, but smaller slumps and slides are common on many slopes and formations in the map area; mapped deposits generally form large coalescing landslide complexes in which individual blocks appear to have moved as much as about 0.5 mile (0.8 km); largest landslides are on Milk Ranch Point where the Moss Back Member is sliding on Monitor Butte Member beds that dip from 4 to 20 degrees; dominant where weathering of weak smectitic clay (especially in the Chinle members) is aided by precipitation infiltrating overlying highly fractured sandstone beds; highly variable in thickness; parts, generally near incised drainages, show evidence of historical movement but all landslides may be active, especially during wet periods.

JURASSIC

Morrison Formation

Jms **Salt Wash Member** (Upper Jurassic, Kimmeridgian)—Buff, gray, and yellowish-gray sandstone and pebbly sandstone lenses interbedded with gray, bluish-gray, and brownish-red mudstone; sandstone is chiefly medium- to course-grained quartz with a few pebbles of quartzite, chert, and mudstone; fluvial cross-bedding common; lenses of sandstone commonly fill scour depressions and irregularities in the upper surface of the underlying Bluff Sandstone; fluvial-lacustrine; only lower about 100 feet (30 m) preserved in map area, but about 280 feet (85 m) thick immediately east of map area.

Jmbl **Bluff Sandstone Member** (Upper Jurassic, Kimmeridgian)—Light-gray to yellowish-gray, massive to thick-bedded, medium- to coarse-grained quartz sandstone; basal part is thin bedded; commonly forms a cliff or series of resistant ledges above the less resistant Wanakah Formation; unconformably overlies the Wanakah Formation along a sharp contact with only minor relief; eolian with minor fluvial influence. At the time the source map was published (1965), the Bluff Sandstone was considered a formation in the San Rafael Group. O'Sullivan (1980) recognized that it is separated from the Wanakah by an unconformity and that it interfingers with the Salt Wash Member and therefore made it a member of the Morrison Formation (also see Peterson, 1988; Condon, 1989). It thins from a maximum of about 140 feet (43 m) in the southeast corner of the map area to a pinchout near Whiskers Draw.

J-5 unconformity

Jw **Wanakah Formation** (Upper Jurassic, Oxfordian)—Interbedded, thin-bedded, reddish-brown, reddish-orange, or brownish-gray sandstone, siltstone, and mudstone, with some interbedded reddish-brown to greenish-gray shale; locally contains thin gypsum veinlets and scattered chert nodules; some of the thicker sandstone beds are continuous and widespread; the contact with the underlying Entrada Sandstone is even and sharp; deposited in mudflats, inland sabkha, and shallow lacustrine environments (Peterson, 1994); about 130 to 180 feet (40–55 m) thick, averaging 150 feet (46 m) thick.

J-3 unconformity

Je **Entrada Sandstone** (Middle Jurassic, Callovian)—Pale-reddish-brown, yellowish-brown, to pale-gray, fine- to medium-grained, massive, cross-bedded, cliff-forming quartz sandstone; contains some sparsely disseminated, well-rounded, coarse quartz grains; commonly weathers into a smooth, low, rounded ledge or “slick rock”; deposited in eolian dune field (Peterson, 1994). On the source map (Lewis and Campbell, 1965) the Entrada includes about 150 feet (45 m) of strata. Since that map was published the lower and middle part of the Entrada in eastern Utah has been reassigned as the upper part of the Carmel Formation (Doelling, 2001, 2004), leaving only the uppermost part of the map unit in the Entrada. The restricted Entrada is 35 to 40 feet (11–12 m) thick.

Jc **Carmel Formation, undivided** (Middle Jurassic, Callovian-Bathonian) (combined Paria River and Winsor or Dewey Bridge Members, lower few feet include undifferentiated Page Sandstone)—Pale-yellowish-gray, gray, or brownish-gray, calcareous, fine to medium-grained, thin- to medium-bedded sandstone interbedded with medium-reddish-brown, reddish-gray, and greenish-gray mudstone, thin-bedded sandstone, and siltstone; forms broad ledgy slope with a few small cliffs in some areas; locally gypsiferous; lower contact with Page Sandstone is gradational and is picked at the top of the highest prominent eolian sandstone bed, which varies laterally; deposited in marginal-marine, sabkha, and tidal-flat environment near southeast side of an inland sea (Peterson, 1994); age based on dating of volcanic ash layers (Sprinkel and others, 2009; 2011); 80 to 200 feet (24–60 m) thick including the added strata as explained in Entrada and Page Sandstone discussions.

Page Sandstone (not mapped) (Middle Jurassic, Bathonian-Bajocian)—The Page Sandstone is a mostly eolian sandstone interval between the Carmel Formation and Navajo Sandstone that was defined by Peterson and Pipiringos (1979) after the source map was published. In this area the Page consists of two to three sandstone beds separated by Carmel-like slope-forming mudstone and siltstone beds; therefore, on the source map the lower sandstone is commonly mapped with the Navajo and the upper part is mapped with the Carmel (Lewis and Campbell, 1965). The contacts are commonly difficult to distinguish on aerial photographs, making them impractical to map for this project. The Page Sandstone consists of pale-yellowish-gray to pale-brownish-gray, planar and cross-bedded, fine-grained sandstone interbedded with Carmel-like beds. The basal contact is an unconformity identified in the field by scattered coarse grains and rare angular chert sand to small pebbles just above the contact, mud cracks, root casts, and alteration of intergranular cement. The age is based on dating of volcanic ash layers (Sprinkel and others, 2009; 2011). The Page Sandstone is 15 to 30 feet (5–10 m) thick, including the intervening Carmel-like beds.

J-1 unconformity

Jn **Navajo Sandstone** (Lower Jurassic, Toarcian-Pliensbachian)—Pale-yellowish-gray, moderate-reddish-brown, and moderate-reddish-orange, fine- to medium-grained, massive, cross-bedded sandstone; grains are primarily rounded to subrounded, frosted, well sorted and equant quartz; conspicuously cross-bedded with cross-bed sets that range up to 60 feet (20 m) thick; contains rare thin lenses of gray sandy limestone, dolomite, and siltstone; lower contact varies from sharp to gradational and intertonguing; forms rounded knobs, buttes, and mesa rims marked by large parallel to conjugate near-vertical joints; main part deposited in large sand desert (erg) with rare local interdunal playas (oasis-like setting); basal part deposited in sabkha with abundant wind-blown sand; about 300 feet (90 m) thick.

Jk **Kayenta Formation** (Lower Jurassic, Pliensbachian-Sinemurian)—Pale-reddish-brown, reddish-orange, and purplish-red, lenticular, medium- to thick-bedded with planar- to cross-bedded intervals, fine- to medium-grained sandstone, silty sandstone, and mudstone; interbedded with very thin to thin-bedded, moderate- to dark-reddish-brown siltstone and muddy sandstone with a few thin lenses of intraformational conglomerate and pinkish gray limestone; locally contains sparse fossil wood; sandstone beds vary from moderately well to moderately poorly sorted; weathers to alternating cliffs and steep ledgy slopes; deposited in fluvial-lacustrine environment with abundant eolian input (Peterson, 1994); lower contact is sharp to interfingering; 130 to 230 feet (40–70 m) thick.

JURASSIC-TRIASSIC—*Fossil evidence indicates the Jurassic-Triassic boundary is within the lower part of the Wingate Sandstone (Lucas and others, 1997).*

JTRw **Wingate Sandstone** (Lower Jurassic to Upper Triassic, Sinemurian-Rhaetian)—Pale- to moderate-reddish-orange to reddish-brown, massive, cross-bedded, very fine to fine-grained eolian sandstone; grains are mostly subangular to subrounded, well sorted, and frosted; faintly banded, and has a few thin lenses of silty sandstone; in most areas forms a single "wall" or massive, vertical to rounded cliff commonly streaked by dark-brown to almost black desert varnish; commonly cut by abundant penetrative near-vertical joints; common cross-bed bounding surfaces give the appearance of planar bedding; upper contact varies from sharp to very gradational and is placed at top of highest smooth, thick to massive eolian sandstone and below ledgy fluvial beds; locally a few medium to thick beds of orangish-brown Wingate-like sandstone are interbedded with reddish-brown siltstone and fine grained sandstone of the Kayenta Formation; 230 to 270 feet (70–82 m) thick.

TRIASSIC

TR-5 unconformity—*Pipiringos and O'Sullivan (1978) identified the Wingate-Church Rock contact as the regional J-0 (basal Jurassic) unconformity. However, Lucas and others (1997) cited evidence that the lower part of the Wingate is Late Triassic in age, and that the contact is gradational in areas where the Church Rock Member is present; therefore the presence of an unconformity at the Wingate-Chinle boundary is doubtful. More likely, a major unconformity (TR-5) is within the Chinle Formation at the base of or within the lower part of the Church Rock Member, and well below the top of Triassic-age rock (Lucas, 1993; Molina-Garza and others, 2003; Lucas and Tanner, 2007).*

Chinle Formation, undivided (Upper Triassic, Rhaetian-Carnian)—In the Elk Ridge area, the Chinle Formation consists of four to six members (in ascending order): Shinarump, Monitor Butte, Moss Back, Petrified Forest, Owl Rock, and Church Rock Members (not all present in some sections). The upper three members are lumped together for mapping (TRcu), the Monitor Butte and Moss Back Members are undifferentiated near the southeast corner of the map (TRcl), and the Shinarump is only locally present as lenticular channel-fill deposits. The Chinle was deposited in a fluvial-lacustrine lowland environment of an overall northwest-flowing trunk river system with tributaries that drained volcanic highlands to the west, south, and southeast in what are now California, Nevada, Arizona, and Mexico (Lucas, 1993; Dubiel, 1994; Lucas and others, 1997; Lucas and Tanner, 2007). As a result, Chinle strata consist of a complex intertonguing mix of volcaniclastic-bearing fluvial, lacustrine, overbank (floodplain), paleosol (fossil soil), and eolian sandstone, conglomerate, mudstone, siltstone, claystone, and minor limestone that vary significantly both laterally and vertically. The Chinle ranges from about 630 to 850 feet (190–260 m) thick (table 1). A major regional unconformity underlies the Shinarump Conglomerate Member, a local unconformity commonly underlies the Moss Back Member (or Petrified Forest Member where the Moss Back is not present), and another local unconformity is at the base of or within the Church Rock Member (Lucas and others, 1997).

TRcu **Upper members (Church Rock, Owl Rock, Petrified Forest Members)** (Upper Triassic, Rhaetian-Norian)—Combined into one map unit because the contacts between individual members vary due to changing lithologies, are grada-

Table 1. *Measured thicknesses in feet of members of Chinle Formation in the map area (from Stewart and others, 1972a).*

	Bridger Jack Mesa	Bears Ears	Cottonwood Creek	Milk Ranch Point
Member	Sec. 25,[1] T.32S., R20E.	Sec. 30,[1] T.36S., R.19E.	Sec. 35,[1] T.34S., R.20E.	Sec. 35,[1] T.36S., R.20E.
Church Rock	89	126	60	175
Owl Rock	406	387	425	365
Petrified Forest	0	86	80	110
Moss Back	129	135	51	78[2]
Monitor Butte	4	104	51	65
Shinarump	0	15	11	0
TOTAL (feet)	628	852	678	796

[1]quarter-section divisions not given in source; [2]includes some upper Monitor Butte beds.

tional, are distorted due to slumping, are mostly covered, or units thin or pinch out locally, making consistent mapping difficult; overall, unit forms a slope to ledgy slope commonly covered by talus that steepens upward to ledgy cliffs just below the massive Wingate Sandstone cliff. Map unit is generally between 480 and 530 feet (145–160 m) thick, but may vary more locally.

The Church Rock Member is commonly absent or thin, but where present it is pale- to moderate-reddish-brown, irregularly laminated to medium-bedded, planar to cross-bedded, interbedded, fine- to coarse-grained sandstone and siltstone with ripple laminations, mudcracks, and small-scale cross-beds; weathers to alternating steep slopes and cliffs; sandstone is mostly quartz; some is micaceous to arkosic; lenticular pebble and rip-up clast conglomerate beds are locally present near base; the Church Rock is similar in color and lithology to the overlying Wingate and forms a steep ledgy slope commonly draped with rock-fall debris that steepens upward to the Wingate cliff (see note on TR-5 unconformity above); 0 to 175 feet (0–53 m) thick (table 1).

The Owl Rock is dominantly pale-greenish-gray, pale-purplish-gray, and pale-reddish-gray, calcareous sandstone, mottled and locally brecciated limestone, and siltstone; it forms a low slope with scattered ledges and is commonly covered by talus; the unit is primarily stacked alluvial-plain calcrete paleosols (fossil soils); 365 to 425 feet (111–130 m) thick (table 1).

The Petrified Forest Member is dominantly variegated purplish-gray to reddish-brown, gray, greenish-gray, and yellowish-gray, smectitic and silicic claystone interbedded with resistant siltstone and medium-grained to locally pebbly sandstone beds, and was deposited in a fluvial-lacustrine environment supplied by drainages from volcanic highlands to the southwest; commonly contains petrified wood; weathers to a steep slope with a few sandstone and conglomerate beds that form ledges; commonly develops massive landslides that involve overlying units; 0 to 110 feet (0–33 m) thick (table 1).

Ꞧcl **Lower unit (combined Moss Back and Monitor Butte Members)** (Upper Triassic, Norian-Carnian)—Mapped only in southeast corner of quadrangle where beds typical of Moss Back and Monitor Butte Members interfinger; up to 150 feet (46 m) thick (Lewis and Campbell, 1959b).

Ꞧcms **Moss Back Member** (Upper Triassic, Norian)—The Moss Back Member is the most resistant unit of the Chinle in the Elk Ridge area and forms a broad bench with many roads; it is missing in the northeast corner, and is difficult to distinguish from the upper Monitor Butte in the southeast corner. The Moss Back consists of well-cemented, pale-brownish-yellow, commonly weathering to dark-brownish-gray to yellowish-brown, lenticular, cross-bedded, fine- to coarse-grained sandstone and thin lenses and beds of siltstone and pebble conglomerate; deposited in a broad fluvial channel system; forms cliff to steep ledgy slope; Lucas and others (1997) noted that clasts are mostly intrabasinal calcrete and siltstone rip-up fragments; 0 to 135 feet (0–41 m) thick.

TR-3 unconformity*—Lucas and others (1997) summarized evidence that an unconformity underlies the Moss Back Member (Petrified Forest Member where Moss Back is not present).*

Ꞧcmn **Monitor Butte Member** (Upper Triassic, Carnian)—Pale-greenish-gray, reddish-gray or grayish-purple, mottled, variegated mudstone with many lenticular, cross-stratified, gray, reddish-gray, and yellowish-gray sandstone and conglomeratic sandstone beds; has lenses of clayey fine-grained sandstone, limestone-pebble conglomerate, and rippled gray to dark-gray micaceous sandstone, and thin beds of calcareous shale to coal; commonly smectitic and weathers to soft punky "popcorn" texture; weathers to form steep slope with small cliffs to a low slope with scattered sandstone ledges; differs from Petrified Forest Member by more uniform greenish-gray color and larger number of sandstone beds; deposited in fluvial-lacustrine environment (higher energy than Petrified Forest Member); map unit may locally include thin unmapped lenses of Shinarump Conglomerate Member; unconformably overlies Moenkopi Formation where Shinarump not present; 0 to 104 feet (0–32 m) thick (table 1).

Ꞧcs **Shinarump Conglomerate Member** (Upper Triassic, Carnian)—Pale-yellowish-gray, greenish-gray, to reddish-brown, medium- to very coarse grained sandstone and conglomeratic sandstone, with minor lenses of greenish-gray to reddish-gray mudstone and siltstone; contains silicified and carbonized fossil wood and other plant debris; forms a ledgy cliff with thin slope intervals; lower contact is a regional unconformity; only present in a few areas where basal fluvial channels of Chinle unconformably overlie and are cut into Moenkopi Formation; forms prominent but discontinuous ledge; locally contains uranium associated with carbonaceous material, various clay minerals, copper, and molybdenum minerals; vanadium is very rare; 0 to 100 feet

(0–30 m) thick but averages about 15 feet (5 m) thick (table 1).

TR-1 unconformity—*Generally a sharp unconformable contact between the ledgy greenish-gray to brown lenticular beds of the Chinle Formation and the reddish-brown planar siltstone and sandstone beds of the Moenkopi Formation.*

Moenkopi Formation (Lower Triassic, Olenekian-Induan)—In the Elk Ridge area, the Moenkopi Formation is thin compared to areas to the northeast, northwest, and west (Stewart and others, 1972b; Hintze and Kowallis, 2009) and most members present in those areas are indistinct or not present in the Elk Ridge area where the Moenkopi consists of just two mappable members, the Hoskinnini Member and the upper member; the Moenkopi was deposited in tidal-flat, sabkha, and low coastal-plain environments (Dubiel, 1994).

ŦRmu **Upper member** (Lower Triassic, Olenekian-Induan)—Moderate- to dark-reddish-brown, thinly laminated to medium-bedded, interbedded, very fine to fine-grained sandstone and siltstone, with scattered thin beds of yellowish-green to greenish-gray claystone; micaceous; discordant gypsum veinlets are abundant; common ripple marks and mud cracks; has rare vertebrate tracks; contains scattered thin limestone beds; generally consists of upper ledgy slope, middle ledge to cliffy ledge, and lower ledgy slope intervals; color, bedding, and grain size distinguish upper member from Hoskinnini Member (upper member is slightly browner and less orange); measurements range from 178 to 238 feet (54–73 m) thick (Stewart and others, 1972b).

ŦRmh **Hoskinnini Sandstone Member** (Lower Triassic, Induan)—Pale- to moderate-reddish-brown to grayish-orange, very fine to coarse-grained sandstone; forms knobby cliffs; characterized by distinctive medium to coarse (to 0.2 inch [5 mm]) quartz grains scattered through the fine-grained sandstone and siltstone beds and by unusually poorly developed bedding with thin indistinct wavy lamination (Stewart and others, 1972b); interfingers with upper member (ŦRmu); deposited in a sabkha environment with abundant siliciclastic input (Dubiel, 1994); measurements range from 67 to 111 feet (20–34 m) thick (Stewart and others, 1972b); thins and interfingers into basal part of upper member to west (Willis, in press).

TR-0 unconformity—*A major unconformity produced by a worldwide sea-level drop; Upper Permian eroded or not deposited.*

PERMIAN

Cutler Group

The mostly Permian Cutler Group comprises about two-thirds of the bedrock exposures in the map area. The Permian was a time of diverse, rapidly changing, interrelated environments in southern Utah (Blakey and Ranney, 2008), making Permian deposits some of the more interesting to study, but more challenging to map (Baars, 1979, and papers therein; Condon, 1997; Anderson and others, 2010; Baars, 2010; Stevenson, 2010; Willis, in press). North of the Elk Ridge map area, Cutler strata consist of a single, thick, arkosic formation deposited as distal coalescing alluvial fans that spread southwest from the Pennsylvanian-Triassic Uncompahgre uplift (located on the Utah-Colorado border northeast of Moab) (Doelling, 2001, 2004). To the south, including in the Elk Ridge area, the arkosic facies grade into a series of distinct lithologic formations, and thereby the Cutler gains group status. These formations intertongue and record complex depositional environments that existed in the final stage of the Paradox basin, a broad basin located west of the ancestral Uncompahgre highland (Stanesco and others, 2000; Baars, 2010; Huntoon and others, 2010).

Nomenclature of Permian strata has changed since the source map was published in 1965. In the Elk Ridge area, three formations are recognized (descending order): Organ Rock Formation, Cedar Mesa Sandstone, and lower Cutler beds. These strata were deposited during semi-arid to moderately wet climatic conditions in fluvial, tidal-flat, and related environments marginal to the final stages of the shallow basin (Condon, 1997; Soreghan and others, 2002). To the north, lower Cutler beds grade into the Elephant Canyon Formation, which was deposited in mostly shallow-marine environments near the center of the basin (Huntoon and others, 1982); to the south the beds grade into the mostly clastic Halgaito Formation (Willis, 2004). The lower Cutler beds and Halgaito strata represent marginal-marine, tidal-flat, and lower alluvial-plain deposits with abundant eolian loess and sand input. The Cedar Mesa Sandstone was deposited in an eolian environment occasionally overrun by small rivers or streams, floodplains, and playas (Huntoon and others, 2010), and with marine influence in areas to the north (Baars, 2010). Organ Rock strata were deposited in a floodplain environment with abundant paleosols and local eolian dunes (Huntoon and others, 2010).

Po **Organ Rock Formation** (Lower Permian, Leonardian)—Dark-reddish-brown to grayish-red, horizontally bedded, micaceous siltstone alternating with fine- to medium-grained sandstone; in southern part of area includes light-brownish-pink, trough cross-bedded, medium-grained sandstone beds; in northern part intertongues with dark-purplish-brown arkosic sandstone beds that increase to north; much less resistant than Cedar Mesa – forms broad slope or bench that gradually steepens up-section to steep ledgy slopes and small cliffs where protected by overlying unit; thickness measurements range from 166 feet (51 m) in northern part to 309 feet (94 m) in southern part (Stewart and others, 1972b).

Pcm **Cedar Mesa Sandstone** (Lower Permian, Wolfcampian)—Light-grayish-orange, cross-bedded, fine-grained sandstone interbedded with lenses of reddish-brown to grayish-green sandy siltstone that increase in upper part; convoluted bedding common; weathers to massive cliffs with scattered ledges at siltstone beds and topped by a very broad bench due to erosion of Organ Rock Formation; about 1000 to 1200 feet (300–360 m) thick.

PERMIAN-PENNSYLVANIAN The position of the Permian-Pennsylvanian boundary in southeastern Utah strata has been debated for several decades (see Condon, 1997; Baars, 2010). Interpretations of data have been complicated by revisions to the internationally accepted definition of the time boundary (Davydov and others, 1995; Chernykh and Ritter, 1997; Anderson and others, 2010; Baars, 2010). It is now generally accepted that the lower part of the lower Cutler beds are Late Pennsylvanian in age, and the middle and upper part are Permian. Scott and Sumida (2004), working in the San Juan River area, used vertebrate fauna to place the period boundary in the lower part of the Halgaito (and thus, lower part of the lower Cutler beds), which supports this time-line placement. An unconformity proposed by Baars (1962, 2010) at the base of the Elephant Canyon Formation (approximately equivalent stratigraphic interval to lower Cutler beds in the Elk Ridge area) is probably not present.

PIPcl **Lower Cutler beds** (Lower Permian to Upper Pennsylvanian, Wolfcampian-Virgilian)—Medium-gray, thin beds of limestone and limey sandstone interbedded with thin- to thick-bedded, reddish-brown, calcareous, shaly siltstone and medium- and fine-grained calcareous sandstone that gives the unit overall a reddish appearance; includes few thin beds of chert and cherty limestone, and gray shale; locally gypsiferous; has sparse, generally poorly preserved marine fossils; generally forms ledgy steep slope below cliff of Cedar Mesa Sandstone; limestone beds decrease to south and not present in San Juan River area where unit is called Halgaito Formation (Willis, 2004) and increase to north where unit is called Elephant Canyon Formation (Huntoon and others, 1982; Baars, 2010); 300 to 450 feet (90–135 m) thick.

The source map in Lewis and Campbell (1965) called the lower Cutler beds the "Rico Formation." Noting that the Utah strata are distinctly younger in age than type area strata (Henbest, 1948), recent workers (for example, Condon, 1997; Doelling 2001, 2004) recommended abandoning "Rico Formation" and using the informal "lower Cutler beds" for strata between the Honaker Trail Formation and the Cedar Mesa Sandstone. Huntoon and others (1982) mapped approximately the same strata in the northwestern part of the Elk Ridge area as Elephant Canyon/Halgaito Formation transition beds (the Elephant Canyon to the north is dominantly carbonate beds and the Halgaito Formation to the south is dominantly sandstone, siltstone, and mudstone clastic redbeds).

PENNSYLVANIAN

Hermosa Group

IPht **Honaker Trail Formation** (Upper Pennsylvanian; Virgilian-Missourian)—Cyclically interbedded pale-gray to pale-yellowish-gray limestone, pale-yellowish-brown to pale-yellowish-gray siltstone to very fine grained sandstone, and medium- to very dark gray to black organic shale; weathers to dark-gray to grayish-brown cliffs separated by short slopes; dark-gray to black organic shale is primary slope-forming lithology in lower part of formation, whereas reddish-brown very fine grained sandstone, siltstone, and mudstone become more abundant in slopes of the middle and upper part of the formation; the upper contact is placed at the top of the highest thick, prominent, laterally continuous limestone bed, and below distinctly thinner lower Cutler limestone beds; in addition, the Honaker Trail has an overall gray appearance while the lower Cutler beds overall have a reddish-gray appearance; in the Dark Canyon area, the upper limestone bed of the Honaker Trail Formation is about 60 feet (20 m) thick; deposited in a cyclic marine environment (Wengerd, 1963; Ritter and others, 2002; Stevenson, 2010); about 800 feet (240 m) thick.

IPp **Paradox Formation** (Middle Pennsylvanian; Missourian-Desmoinesian)—Exposed in bottom of Cataract Canyon and lower parts of Dark and Gypsum Canyons. Consists of small deformed hills and knobs of dark-gray to black shale, and pale-gray to pale-yellowish-gray sandstone, limestone, and weathered gypsum that have highly contorted bedding and are commonly in angular contact with overlying strata, suggesting diapiric or loading-induced flowage and deformation; shale is fossil-poor, laminated to papery, highly organic, and locally sulfurous; about 300 feet (90 m) exposed, but deformation prevents precise measurement.

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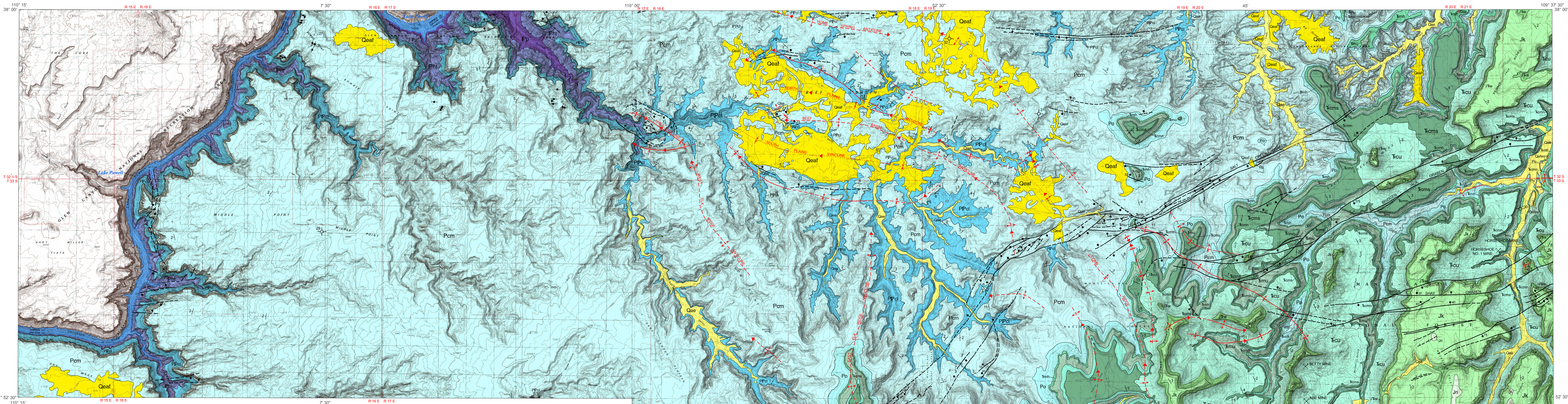
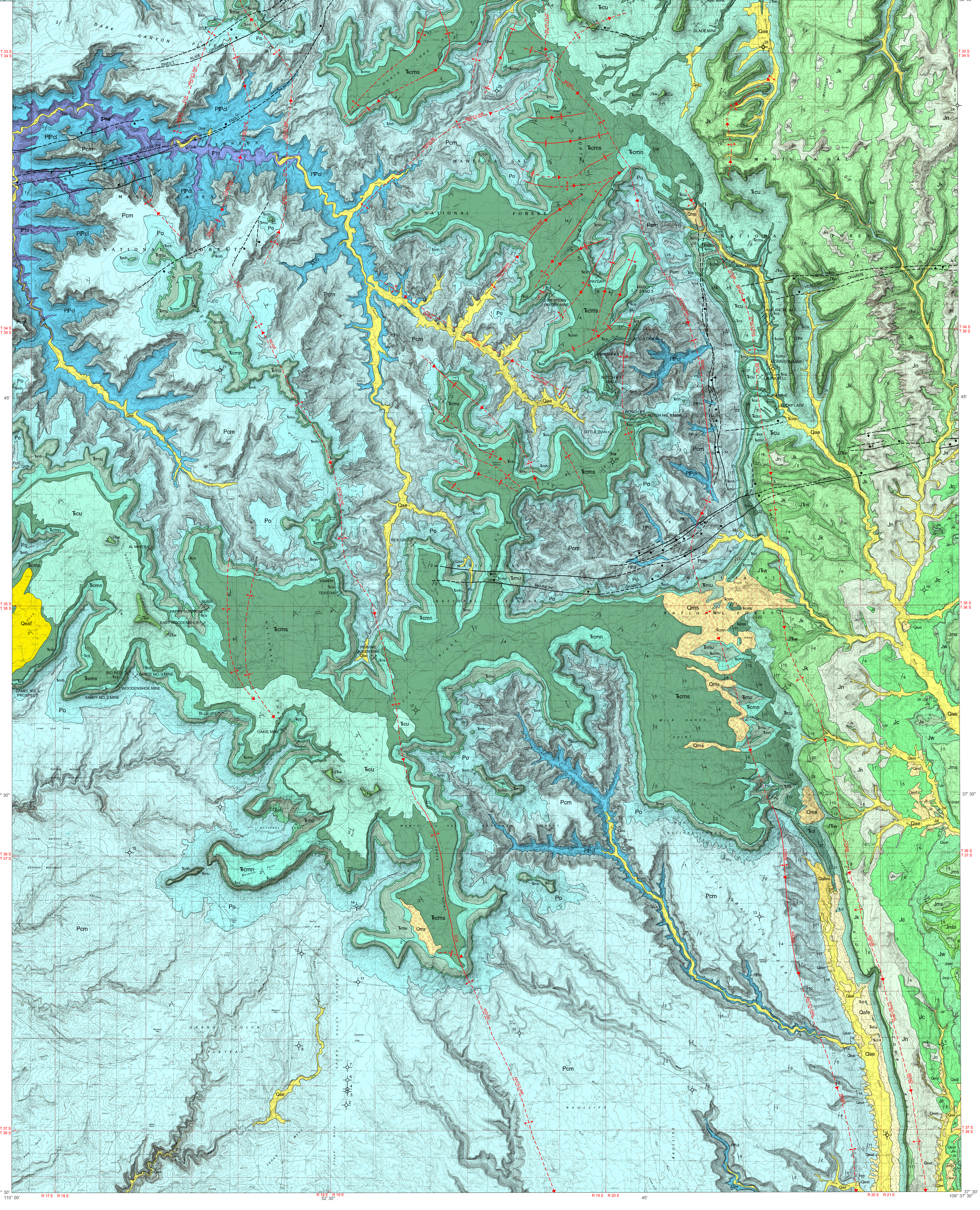
APPENDIX

Appendix. *Oil and gas exploration drill holes in map area.*

MAP ID	API	NAME	COMPANY	STAT*	LA/PA DATE	LONGITUDE	LATITUDE	ELEV. FT.	QTR_QTR	SEC.	TOWN	RANGE
1	4303710751	MOUNT PEALE-FEHR 1	MOUNT PEALE CORPORATION	PA	03/25/58	-109.65412	37.51786	4870 DF	NWNW	6	38S	21E
2	4303731427	CEDAR MESA 2	TEB INC	LA	11/13/89	-109.86786	37.52758	6632 GR	SENW	31	37S	19E
3	4303731424	CEDAR MESA 1	TEB INC	PA	08/17/88	-109.86746	37.53184	6640 GR	NENW	31	37S	19E
4	4303731389	CEDAR MESA 1	TEB INC	LA	05/04/88	-109.86741	37.53263	6651 GR	NENW	31	37S	19E
5	4303730116	MILK RANCH STATE 1	MOUNTAIN FUEL SUPPLY CO	PA	08/10/73	-109.73114	37.53222	6029 GR	NENE	32	37S	20E
6	4303731362	CYCLONE FLAT 1	TEB INC	PA	12/23/87	-109.86740	37.53546	6667 GR	SESW	30	37S	19E
7	4303731363	CYCLONE FLAT 2	TEB INC	LA	04/28/92	-109.86743	37.53947	6666 GR	NESW	30	37S	19E
8	4303731336	MORMON GIRL 1	TEB INC	LA	11/03/87	-109.88662	37.54627	6669 GR	NENW	25	37S	18E
9	4303710115	FEDERAL BRANNON 29-1	KIMBARK OPERATING	PA	04/24/75	-109.63230	37.54631	5383 KB	NENW	29	37S	21E
10	4303710636	FEDERAL 1	KUBAT, ED J	PA	02/04/58	-109.79944	37.55020	6601 DF	SWSW	23	37S	19E
11	4303731428	CYCLONE FLAT 9	TEB INC	LA	11/07/89	-109.86318	37.56634	6850 GR	SWSE	18	37S	19E
12	4303710761	MORMON FLAT GOVT 1	MOUNTAIN FUEL SUPPLY CO	PA	10/13/57	-109.88550	37.57523	6819 GR	NENW	13	37S	18E
13	4303710426	ARCH CANYON 1	GULF OIL CORPORATION	PA	10/30/59	-109.70445	37.58670	6298 KB	SENW	10	37S	20E
14	4303730056	FEDERAL 7-1	KIDD, WILLIAM B	PA	07/19/71	-109.86377	37.59021	7051 GR	NWNE	7	37S	19E
15	4303730789	WOODENSHOE 2	SUN EXPLOR & PRODUCTION CO	PA	06/22/82	-109.95350	37.60709	6585 GR	SWSE	32	36S	18E
16	4303730568	MAVERICK POINT 1	WORLDWIDE EXPLORATION	LA	01/27/81	-109.91766	37.62149	6895 GR	SWSE	27	36S	18E
17	4303710835	BEARS EARS UNIT 1	PAN AMERICAN PETROLEUM COR	PA	10/19/57	-109.84025	37.65183	8528 DF	SESE	17	36S	19E
18	4303711448	GOVT 1	YETT, TOMMY	LA	05/06/57	-109.69397	37.65859	6405 DF	NWNW	14	36S	20E
19	4303731244	S KETCHUM 32-1	U O & G INC	PA	06/16/86	-109.63882	37.68932	5919 GR	NESW	32	35S	21E
20	4303710846	ELK RIDGE UNIT 2	PAN AMERICAN PETROLEUM COR	PA	10/29/57	-109.76214	37.72980	8614 GR	SWSE	18	35S	20E
21	4303710659	DRY MESA GOVT 1	LEMM & MAIATICO	PA	09/02/60	-109.91776	37.75890	8213 GR	SWSW	2	35S	18E
22	4303711349	GOVERNMENT (489) 1-2	UNION OIL CO OF CALIFORNIA	PA	11/21/62	-109.69849	37.75903	6297 GR	SWSW	2	35S	20E
23	4303710727	GOVT 1	MIDWEST EXPLORATION CO	PA	11/05/27	-109.88089	37.79265	7139 GR	NWSW	30	34S	19E
24	4303710725	ABAJO 11-9	BURLINGTON NORTHERN	PA	10/09/76	-109.62504	37.84175	8266 KB	NWNW	9	34S	21E
25	4303710845	ELK RIDGE UNIT 1	STANOLIND OIL & GAS CO	PA	12/19/56	-109.80785	37.84659	8300 GR	SWSW	2	34S	19E
26	4303711094	DARK CANYON FED UNIT 1	SINCLAIR OIL CORPORATION	PA	07/18/58	-109.89760	37.86024	7945 DF	SWSW	36	33S	18E
27	4303730600	REDD RANCH 1-34	NATOMAS NORTH AMERICA INC	PA	04/16/82	-109.70204	37.86015	7279 GR	SESE	34	33S	20E
28	4303730783	REDD RANCH 1-34A	NATOMAS NORTH AMERICA INC	PA	04/19/82	-109.70203	37.86043	7279 GR	SESE	34	33S	20E
29	4303710740	LEAN-TO 2	MOBIL OIL CORPORATION	PA	02/15/60	-110.12643	37.92863	6250 GR	NWNE	11	33S	16E
30	4303730058	USA DU 2	PLACID OIL COMPANY	PA	08/09/71	-109.63824	37.93574	6042 GR	NESW	5	33S	21E
31	4303711247	CATARACT CANYON UNIT 1	TEXACO INC	PA	11/17/56	-109.83431	37.96673	7126 KB	NWSE	28	32S	19E
32	4303711248	CATARACT CANYON UNIT 2	TEXACO INC	PA	02/22/58	-109.87078	37.99094	6487 GR	SWSE	18	32S	19E

*Status: PA - plugged and abandoned; LA - location abandoned
From Utah Division of Oil Gas and Mining Records (accessed April 19, 2011)





UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources
in cooperation with
U.S. Forest Service

Plate 1
Utah Geological Survey Miscellaneous Publication 11-1DM
Geologic Map of Elk Ridge and Vicinity, San Juan County, Utah

LITHOLOGIC COLUMN

SYSTEM	Series	Stage	Group / Formation	FORMATION - MEMBER	SYMBOL	THICKNESS feet (meters)	MAJOR UNCONFORMITIES
Q.	Pl.-H.			alluvium, talus, slumps, landslides, eolian			
Jurassic	Upper	Kimm.	Morrison Formation	Salt Wash Member	Jms	100+ (30+)	
			San Rafael Group	Bluff Sandstone	Jmbl	0-140 (0-43)	J-5
		Ox.		Wanakah Formation	Jw	130-180 (40-55)	J-3
	Middle	Ca.		Entrada Sandstone	Je	35-40 (11-12)	
		Bath.		Carmel Formation (Page Sandstone not mapped)	Jc	80-200 (24-60)	J-1
	Lower	To. Pliens.	Glen Canyon Group	Navajo Sandstone	Jn	300 (90)	
		Sin.		Kayenta Formation	Jk	130-230 (40-70)	
		Ha.		Wingate Sandstone	JTRw	230-270 (70-82)	
Triassic	Upper	Rha. Norian	Chinle Formation	upper part (Church Rock, Owl Rock, Petrified Forest Members)	TRcu	630-850 (190-260); 480-530 (145-160)	TR-5
		Car.		Moss Back Member	TRcms (TRcl)	0-135 (0-41)	TR-3
				Monitor Butte Mbr.	TRcmn (TRcl)	0-104 (0-32)	
				Shinarump Congl. Mbr.	TRcs (TRcl)	0-100 (0-30)	TR-1
	Lower	Ol.	Moenkopi Formation	upper member	TRmu	178-238 (54-73)	
		In.		Hoskinnini Ss. Member	TRmh	67-111 (20-34)	TR-0
Permian	Lower	Leo.	Cutler Group	Organ Rock Formation	Po	166-309 (51-94)	
		Wolfcampian		Cedar Mesa Sandstone	Pcm	1000-1200 (300-360)	
				lower Cutler beds	PIPcl	300-450 (90-135)	
Pennsylvanian	Upper	Virgilian Missourian	Hermosa Group	Honaker Trail Formation	IPht	800 (240)	
	Middle	Desm.		Paradox Formation	IPp	300+ (90+)	

CORRELATION OF GEOLOGIC UNITS

Jurassic	Upper	Jms, Jmbl; J-5 unconformity; Jw
		J-3 unconformity
	Middle	Je, Jc
		J-1 unconformity
	Lower	Jn, Jk, JTRw
Triassic	Upper	TRcu (TR-5 unconformity); TRcms, TR-3 uncon, TRcmm, TRcs (TRcl) (TR-3 unconformity)
		TR-1 unconformity
	Lower	TRmu, TRmh
		TR-0 unconformity
Permian	Lower	Po, Pcm
Penn.	Upper	PIPcl, IPht
	M.	IPp

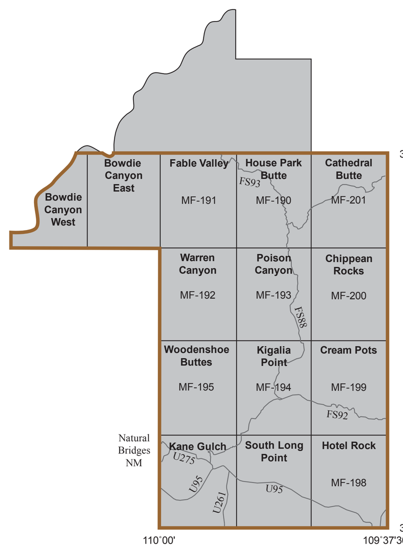
Holocene / Pleistocene (upper, middle): Qae, Qafe, Qafeo, Qeaf, Qeat, Qms

- **Qae** Alluvial and eolian deposits
- **Qafe** Mixed alluvial-fan, eolian, colluvial, and talus deposits
- **Qafeo** Older mixed alluvial-stream, alluvial-fan, colluvial, talus, and eolian deposits
- **Qeaf** Eolian, alluvial-stream, and alluvial-fan deposits
- **Qeat** Eolian sand over alluvial-terrace and other deposits
- **Qms** Mass-movement landslides and slumps

GEOLOGIC SYMBOLS

- Contact, includes approximately located
- High angle fault, dashed where approximately located, dotted where concealed, queried where uncertain, offset in feet where measured
- Anticline, dashed where approximately located, dotted where concealed
- Syncline, dashed where approximately located, dotted where concealed
- Anticlinal bend, dashed where approximately located, dotted where concealed
- Synclinal bend, dashed where approximately located, dotted where concealed
- Strike and dip of inclined bedding
- Joint, vertical or near vertical
- Mine - uranium, shaft, adit, prospects, or surface working from Utah Geological Survey Utah Mineral Occurences System (UMOS) records, accessed June 2011 (see ReadMe file)
- Petroleum exploration drill hole, plugged and abandoned, from Utah Division of Oil, Gas and Mining data through December 2010 (numbers refer to table 2 in text appendix)

See source map for cross sections



Source of mapping for this digital dataset (brown line). Ten 7.5' quadrangles were mapped at 1:24,000 scale in 1953–57 (MF *labels; Lewis and Campbell, 1958a-f;1959a-d). R.Q. Lewis, Sr., R.H.Campbell, R.E. Thaden, and W.J. Krummel, Jr., added new mapping and produced a map of the gray area at 1:62,500 scale that was published as plate 2 in Lewis and Campbell (1965). Grant Willis and Basia Matyjasik (Utah Geological Survey) modified and updated the 1965 map in 2009-11 (see Background, below).*

GEOLOGIC MAP OF ELK RIDGE AND VICINITY, SAN JUAN COUNTY, UTAH

by

Richard Q. Lewis, Sr.[1], Russell H. Campbell[1], Robert E. Thaden[1], William J. Krummel, Jr.[1], Grant C. Willis[2], and Basia Matyjasik[2]

2011
(digitized and modified from U.S. Geological Survey Professional Paper 474-B, 1965)

[1]U.S. Geological Survey (authors of 1965 map)
[2]Utah Geological Survey (modifications 2009-2011)

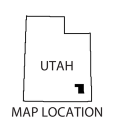
SCALE 1:62,500
Scale and spatial accuracy of digital data varies from 1:24,000 to 1:62,500

4 2 0 4 8 12 Kilometers
1 0.5 0 1 2 3 4 5 6 Miles

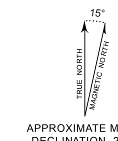
CONTOUR INTERVAL 40 FEET

Background

This geologic map and digital dataset were prepared from U. S. Geological Survey (USGS) mapping conducted in the 1950s as part of an effort to evaluate uranium resources during the "cold war." The 1950s maps were completed at 1:24,000-scale on rough base maps, and then recompiled in 1965 at 1:62,500 scale on a better base map. We (Utah Geological Survey) digitized the 1965 map and fit it to current 1:24,000-scale base maps. We improved the spatial accuracy of the map by adjusting contacts, faults, fold axes, and other geologic features using modern 1:24,000-scale topographic and orthophotoquad maps and aerial photographs. We also made minor modifications to the geology, including; (1) added a few bedrock outcrops and surficial deposits; (2) revised contacts around some bedrock and surficial deposits; (3) revised contacts between a few formations/members according to currently accepted definitions; (4) updated nomenclature and map labels; and (5) updated ages, correlations, and descriptions of some map units. Some desirable changes were impractical. For example, surficial deposits are much more abundant in some areas than depicted on the source map, but could not be remapped without excessive field work. Also, it was impractical to map the Page Sandstone (defined after the source map was published). This map has been updated in many ways, but it still does not meet all standards of a modern geologic map. Spatial accuracy of geologic features varies from 1:24,000 to 1:62,500.



MAP LOCATION



APPROXIMATE MEAN DECLINATION, 2011

Base compiled from U. S. Geological Survey 7.5' quadrangles, (1985-1987)

Projection: UTM Zone 12
Spheroid: Clarke 1886
Geologic data and base map in NAD 1927
GIS and cartography by: Basia Matyjasik and Lori Steadman
ISBN 978-1-55791-845-1

Utah Geological Survey
1594 West North Temple, Suite 3110
P.O. Box 146100, Salt Lake City, Utah 84114-6480
(801) 537-3300
geology.utah.gov