UTAH GEOLOGICAL SURVEY
a division of
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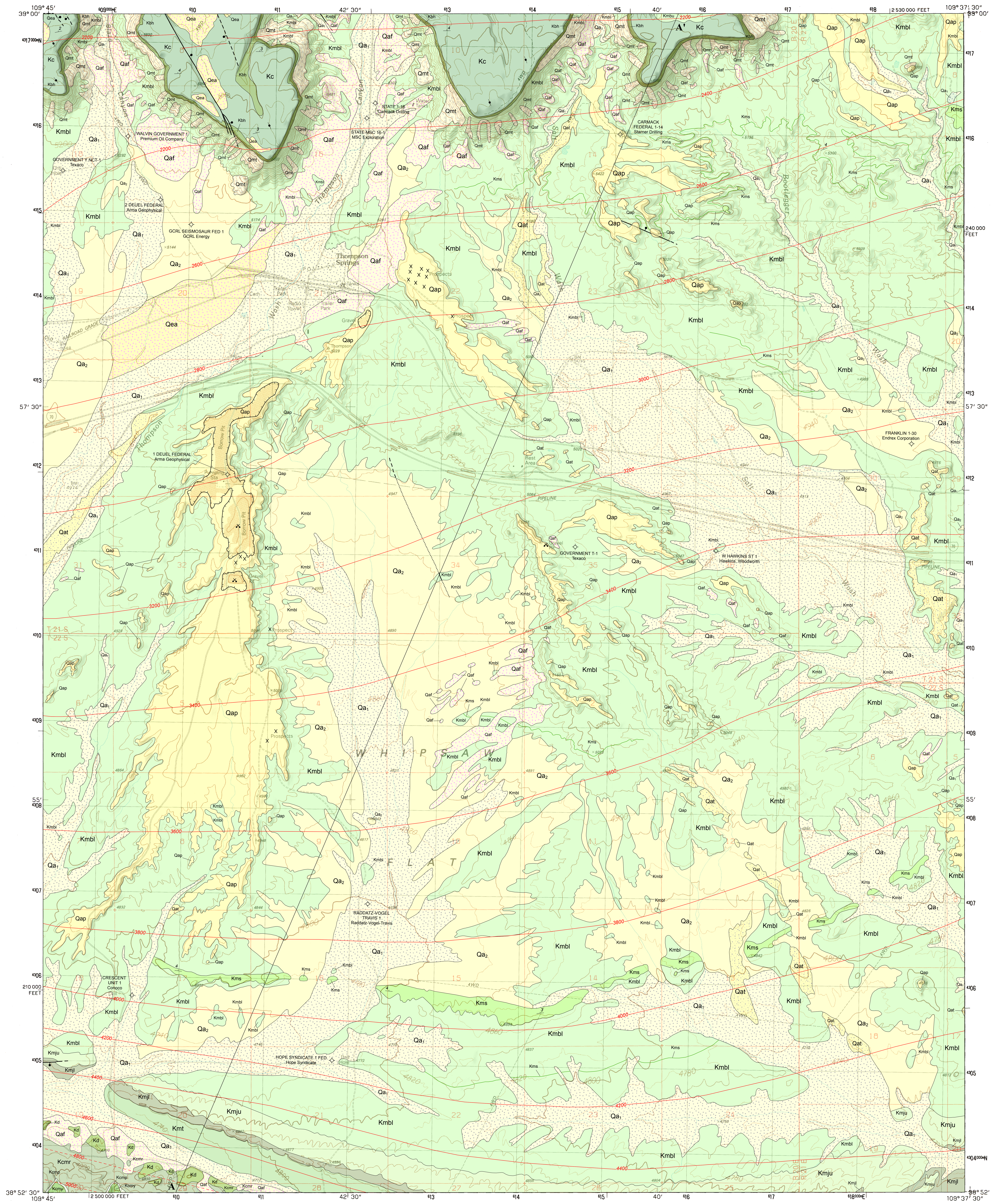

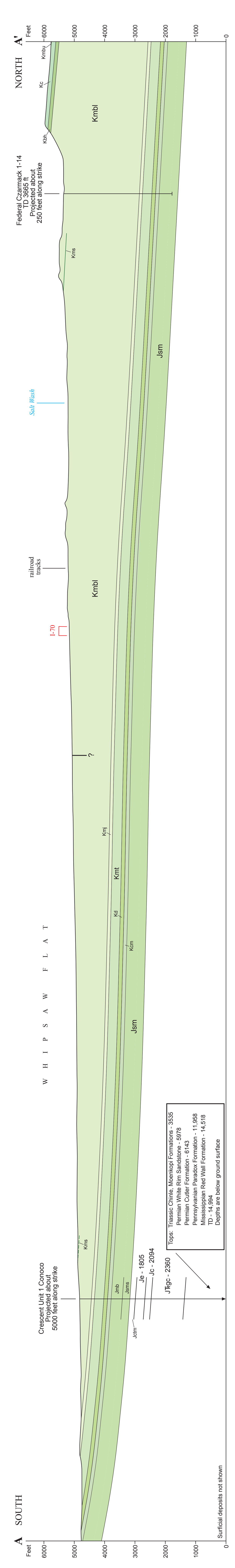

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For use at 1:24,000 scale only.

UTAH

QUADRANGLE LOCATION

SCALE 1:24,000

1 0.5 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 0.5 0 1 KILOMETER

CONTOUR INTERVAL 40 FEET
SUPPLEMENTARY CONTOUR INTERVAL 20 FEET

GEOLOGIC MAP OF THE THOMPSON SPRINGS QUADRANGLE, GRAND COUNTY, UTAH

by

Hellmut H. Doelling and Paul Kuehne

2009

11°18'
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 2009

Base from U.S. Geological Survey, Thompson Springs 7.5' Quadrangle,
Provisional Edition 1991
Projection: UTM Zone 12
Datum: NAD 1927
Spheroid: Clarke 1886

Project Managers: Grant C. Willis and Donald Clark
Cartographer: Jay Hill
ISBN 1-55791-812-0

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1	2	3
4		5
6	7	8

1. Floy Canyon South
2. Sego Canyon
3. Calf Canyon
4. Crescent Junction
5. Sagers Flat
6. Valley City
7. Klondike Bluffs
8. Mollie Hogans

ADJOINING 7.5' QUADRANGLE NAMES

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ABSTRACT

The Thompson Springs, Sagers Flat, and White House quadrangles are located in east central Utah along the Interstate 70 (I-70) corridor. The geology is dominated by the Upper Cretaceous Mancos Shale, which was deposited in the Western Interior Seaway. Exposed strata range in age from Late Jurassic to Late Cretaceous and include (in ascending order) the Brushy Basin Member of the Morrison Formation, Cedar Mountain Formation (Yellow Cat, Poison Strip Sandstone, and Ruby Ranch Members), Dakota Sandstone, Mancos Shale (Tununk, Juana Lopez [formerly mapped as Ferron Sandstone], and Bluegate Members), Blackhawk Formation, Castlegate Sandstone, and Buck Tongue Member of the Mancos Shale.

Strata generally dip northward toward the Uinta Basin. The Sagers Wash syncline angles west northwest across the north end of the White House quadrangle, and the edge of the Cisco dome is located in its northeast corner. A few low-displacement faults cut the area and some of the brittle sandstone formations are jointed.

Petroleum exploration has generally been unsuccessful, but gas and oil have been produced from wells on the Cisco dome. However, some deep tests have provided important subsurface information on the boundary between the ancestral Uncompahgre uplift and the Paradox Basin. Vanadium and uranium were produced in the Yellow Cat area south of the Sagers Flat quadrangle, and the favorable host rocks underlie these quadrangles. Pediment-mantle and terrace deposits have provided road metal aggregates for road and highway construction.

Inasmuch as the area is not developed, the importance of geologic hazards is diminished. Principal hazards include damage to highways and roads caused by flood-water erosion, debris flows, and heaving of soft shales.

INTRODUCTION

This text is included with the Thompson Springs, Sagers Flat, and White House geologic maps. These quadrangles are located in east-central Utah along the transportation corridor of east-west-trending Interstate 70, the Union Pacific Railroad, and the Northwest Pipeline Company. These heavily used transportation routes follow the broad pale gray badlands of the Mancos Shale, which one tourist described as "elephant hide." I-70 has one exit in each of the three quadrangles, at exits 187 (Thompson Springs), 193 (Sagers Flat), and 204 (near White House). These exits provide access to gravel roads north and south of the highway. Thompson Springs is a small village originally based on railroad support for the Sego coal field, which is located in the adjacent quadrangle to the north (Willis, 1986). When railroad steam engines were wood and later coal fired, Thompson Springs was a fuel and water stop along the main line of the former Denver & Rio Grande Western Railroad. Coal mining for railroad fuel was carried out from 1900 to 1954 and ended because the railroad changed to diesel fuel. Sagers Flat is a broad area south of I-70, east of exit 193. White House was a watering stop along the railroad and is near exit 204, which provides access to Moab via State Road 128.

Elevations in the three quadrangles range between 4260 feet (1299 m) and 6120 feet (1866 m) above sea level. The higher elevation is on a bench of the Castlegate Sandstone in the Book Cliffs and the lower elevation is near the confluence of Sagers Wash and Nash Wash in the southeastern corner of the White House quadrangle. Most of the area lies between 4500 feet (1370 m) and 5200 feet (1580 m) above sea level and consists of badlands with local benches of pediment mantle and terrace gravels.

The area is a desert and averages only 6 to 8 inches (15-20 cm) of precipitation (mostly rain) annually (Western Regional Climate Center, 2007). In years when tropical moisture moves in from the south, the amount received in a year can double. Summer thunderstorms are commonly violent and of short duration, producing flash floods that damage the secondary roads north and south of I-70. January day-time temperatures average 20° to 30°F (-7° to -1°C), and July temperatures average 80° to 100°F (27° to 38°C) or more.

Only small-scale geologic maps were available prior to this effort. Notable are the geologic map of the Moab 30' x 60' quadrangle at 1:100,000 (Doelling, 2001); the geologic map of southeastern Utah at 1:250,000 (Hintze and Stokes, 1964); the geology, structure, and uranium deposits of the Moab quadrangle, Colorado and Utah, at 1:250,000 (Williams, 1964); and the geologic map of Utah at 1:500,000 (Hintze, 1980). Willis (1986) mapped the adjacent Sego Canyon 7.5' quadrangle.

STRATIGRAPHY

Late Jurassic to Late Cretaceous rocks are exposed in the three quadrangles. These strata have an aggregate thickness of about 4350 feet (1330 m) and are dominated by the marine Mancos Shale, which covers 85 percent of the three-quadrangle outcrop area. Quaternary deposits include several varieties of unconsolidated clastic sediment laid down by water, wind, and mass movement processes. The unconsolidated clastic materials are the weathering products of the local bedrock and of bedrock exposed in the Book Cliffs region to the north.

Several dozen exploration holes have been drilled in the three quadrangles that provide information on geologic formations beneath the exposed rocks. The area is situated along the boundary between the Paradox Basin and the buried Pennsylvanian-Triassic Uncompahgre highland to the northeast. The region is partly underlain by the salt-bearing Paradox Formation, and the subsurface Uncompahgre fault angles northwest beneath the White House quadrangle. Most of the salt once contained in the Pennsylvanian Paradox Formation under these quadrangles has flowed diapirically southwesterly to salt-cored anticlines. The Pennsylvanian Honaker Trail, Permian Cutler, Triassic Moenkopi (TRm), and Chinle Formations (TRc) are unusually thick due to deposition in depressions caused by salt removal from the underlying Paradox Formation. The Moenkopi and older formations were eroded off the highland northeast of the Uncompahgre fault during the Triassic— drill holes have intercepted Proterozoic igneous and metamorphic rocks immediately beneath a thin layer of Late Triassic Chinle Formation. The Chinle and younger formations were deposited over both the highland and Paradox Basin, indicating that uplift and subsidence had ended or greatly slowed by the Late Triassic.

STRUCTURAL GEOLOGY

Most rocks in these three quadrangles dip 2 to 14 degrees generally northward, forming a broad, gently folded monocline. The northwest-trending Salt Valley anticline is present in the Crescent Junction, Valley City, and Klondike Bluffs quadrangles to the west and south (Doelling, 2001), and stratigraphic dips in the southwest corner of the Thompson Springs quadrangle are northeasterly and slightly steeper, reflecting the attitude of the northeast flank of the anticline. Rocks in the north half of the White House quadrangle are warped by a northwest-trending fold (Frahme and Vaughn, 1983). The axis of the Sagers Wash syncline angles across the quadrangle and Cisco dome impinges into the northeast corner (see cross sections).

Structure contours vary from slightly east-northeast-trending to west-northwest-trending, reflecting these subtle folds. A few previous investigators have placed fold axes across this undulating area (Walton, 1956; Woodward-Clyde Consultants, 1983). Two such fold axes have been named the Crescent Wash or Whipsaw Flat syncline and the Thompson anticline. These folds are broad shallow features that deflect strike measurements a few degrees and are not evident on casual observation, and therefore are not shown on the map.

Faulting is minor in the quadrangles. Benches of the Castlegate Sandstone in the Thompson Springs quadrangle are displaced by faults that produce shallow horsts and grabens, but these faults do not extend far to the south, and are not traceable in the Mancos Shale. A fault present in Whipsaw Flat is only recognizable on aerial photos. On the ground telltale calcite veinlets parallel the fault. However, because of the homogeneity of the Mancos Shale, the displacement cannot be ascertained. A fault cuts the northeast corner of the Sagers Flat quadrangle and is displaced down to the east. This fault is evident in the field and displaces Kms deposits. Most faults trend about N. 20° to 30° W. The Castlegate bench faults displace the rocks 50 feet (15 m) or less in the Thompson Springs quadrangle. The offsets of many faults are indeterminable because of the lack of key beds. High-angle joints parallel the faults that cut the Castlegate Sandstone.

A small fault (located in the northeast corner of section 23, T. 21 S., R. 20 E.) does not follow the trend of other faults. It strikes N. 70° W., is less than a half mile in length, has maximum displacement of a few tens of feet, and is down to the northeast.

The subsurface Uncompahgre fault underlies the White House quadrangle, probably paralleling and in close proximity to the Sagers Wash synclinal axis (cross section A-A'). The Late Triassic Chinle Formation probably overlies Precambrian granite on the northeast side of this fault. On the southwest side of the fault, an unusually thick section of Early Triassic, Permian, and Pennsylvanian formations underlies the Chinle Formation. Regionally, typical thicknesses of Mississippian, Devonian, and Cambrian rocks underlie the Pennsylvanian rocks and overlie Precambrian granite. Displacement across the Uncompahgre fault may be as much as 16,000 feet (4900 m) under the White House quadrangle (White and Jacobsen, 1983).

ECONOMIC GEOLOGY

Hydrocarbons

Several dozen drill holes have been drilled for oil and gas in the three quadrangles. A small amount of gas production has been realized from the White House quadrangle at the margins of the Cisco Dome gas field (Chidsey and others, 2004). The Cisco anticline or dome is a shallow field with reservoir beds in the thin sandstones (Kms) of the Mancos Shale and in the Dakota, Cedar Mountain, Morrison, and Entrada Formations (Morgan, 1999).

Several drill holes have tested deeper formations, but have not found produceable quantities of oil and gas. In the Thompson Springs quadrangle the Texaco Government T-1 hole, in SE1/4 NW1/4 section 35, T. 21 S., R. 20 E., was drilled 5202 feet (1586 m) into the Permian Cutler Formation, and the Conoco Crescent unit 1 hole, in NW1/4 SW1/4 section 17, T. 22 S., R. 20 E., was drilled to a depth of 14,984 feet (4568 m) into Mississippian rocks. In the Sagers Flat quadrangle, the Pacific Western Thompson 1 hole, in NW1/4 SW1/4 section 33, T. 21 S., R. 21 E., was drilled to a depth of 13,764 feet (4196 m) to test the Paradox Formation, and the Mobil American Petrofina 1-30 well, SW1/4 NE1/4 section 30, T. 21 S., R. 22 E., was drilled to a depth of 18,450 feet (5625 m) into Cambrian rocks. The Equity Oil No. 1 hole, in NW1/4 SW1/4 section 20, T. 21 S., R. 23 E., in the White House quadrangle, was drilled to a depth of 3810 feet (1162 m), ending in Precambrian granite.

The potential for finding additional gas and oil reserves is good in these three quadrangles. As noted in the structure section, anticlinal fold structures are subtle and difficult to find. Some of the thin Mancos sandstone beds (Kms) may pinch out updip and provide traps.

Coal and Humates

The Dakota Formation contains thin, lenticular, and generally impure coal beds that rank as subbituminous C or lower (Ellis and Hopeck, 1985). The coal beds are generally less than 2 feet (0.6 m) thick and have not generated much economical interest; however, the interval contains humates that have attracted attention (Willis, 1994). Humates are used in agriculture as a soil conditioner and are leached to produce liquids in health foods.

Sand and Gravel

The terrace and pediment mantle deposits contain valuable reserves of sand and gravel that have been exploited for the construction of Interstate 70. The larger of these pits are shown on the geologic maps. The deposits are generally 10 to 25 feet (3-8 m) thick. Other than for highway construction, little use has been made of these deposits inasmuch as there is no local market.

Vanadium and Uranium

Vanadium and uranium ores have been mined from the Yellow Cat area of the Thompson mining district, south of the three quadrangles. Deposits may underlie these three quadrangles as well, especially the Sagers Flat and Thompson Springs quadrangles. These deposits lie 525 to 725 feet (160-221 m) beneath the base of the Dakota Sandstone.

Ore deposits are present in the Salt Wash Member of the Morrison Formation. In the Mollie Hogans quadrangle, adjacent to and south of the Sagers Flat quadrangle, the deposits contain up to 0.5% U_3O_8 and 10% V_2O_5 (Stokes, 1952b; Stokes and Mobley, 1954). However, most ore produced in the past contained 0.15 to 0.25% U_3O_8 and about 1.5% V_2O_5. The ore bodies ranged in size from thin irregular layers less than 5 feet (1.5 m) wide and 15 feet (5 m) long to more than 200 feet (60 m) wide and 1400 feet (430 m) long, and are mostly about 3 feet (1 m) thick. Many ore bodies were simply mineralized fossil logs with aureoles of lower-grade ore. Carnotite, tyuyamunite, corvusite, and vanoxite are the chief ore minerals. These replace carbonaceous debris or are disseminated in the Salt Wash sandstones. Minerals commonly coat fractures.

Agate

Clear to blood-red agate is found in some of the mudstones of the Brushy Basin Member of the Morrison Formation in the southern parts of the Thompson Springs and White House quadrangles. The chalcedony occurs as shattered nodules along favorable horizons. Generally, these litter the surfaces below these horizons as angular pieces up to 3 inches (8 cm) across. Gray to lavender agate is sometimes found in the Cedar Mountain Formation as well.

Water Resources

The three-quadrangle area has a desert climate and is water poor. There are no permanent streams. The major drainage channels are generally dry; a few have intermittent flow a few months of the year as far south as Interstate 70. Springs are scattered across the area, but produce only small amounts of water. Most flow from sandstone formations or from sandstone stringers in the Mancos Shale. The shale bedrock is tight and transmits little water. Ranchers, who graze cattle here during the winter season, obtain water from a few wells drilled into the Dakota Sandstone, and dig and maintain small catchment basins on the Mancos Shale.

GEOLOGIC HAZARDS

Debris Flows, Mud Flows, and Flash Floods

The principal washes in the three quadrangles drain large areas of uplands, which are deluged by infrequent torrential summer rains. An inch or more of rain may fall in a few hours. These rains are generally spotty, but if they strike a drainage basin that has not received rain for several years, flash floods wash out accumulated debris. The principal washes may receive floods from several tributaries in a single event. The debris is washed downstream and generally causes significant damage to roads and road crossings, making them impassable until repaired, either by rutting and cutting deep channels through the roadway, or by dumping debris on it. Floodwaters generally flow less than a few hours unless they are sourced in the upper Book Cliffs. A series of heavy rains may soften the Mancos Shale outcrops to the point where mud may flow short distances. Roads on the Mancos Shale can become so muddy after a heavy rain that they become impassable, even if surfaced with gravel.

Small canyons are present in the southern parts of the quadrangles, which may become dangerous to hikers should flash floods develop. These canyons are not deep or confined, so hikers usually have time to seek higher ground. Geologic hazards are of less importance on these three quadrangles because few structures have been built upon them.

Rock Falls

Rock falls occur frequently beneath steep cliffs in the southern parts of the Thompson Springs and White House quadrangles. Most are unnoticed because the area is undeveloped.

Expansive Clays and Swelling Soils

Members of the Mancos Shale and shales in the Cedar Mountain Formation and Brushy Basin Member of the Morrison Formation contain clays that expand and swell upon wetting. Although a thick base was placed under the pavement of Interstate 70, which crosses the Mancos Shale, the pavement has been locally warped into closely spaced folds. Heavy truck traffic causes the shale to heave beneath the road base. Thompson Springs is the only settlement in the three quadrangles. Fortunately, most of the town is built on alluvium, but shale crops out around the area. Should the town grow, engineering measures would be necessary to ensure the integrity of buildings, roadways, and concrete flatwork constructed on the shale and clay soils.

Seismic Hazards

The Thompson Springs, Sagers Flat, and White House quadrangles are located in an area that has experienced no earthquakes greater than M_L 5.0 in historic time (University of Utah Seismograph Station, 2007). The quadrangles are in a low-risk zone with a 10% probability of an earthquake greater than M_L 5.0 within the next 100 years (U.S. Geological Survey, 2007). None of the quadrangle faults are known to be active, and no Quaternary deposits have been displaced (Black and others, 2003).

ACKNOWLEDGMENTS

The authors thank Utah Geological Survey geologists Douglas Sprinkel, Grant Willis, Donald Clark, Mike Hylland, David Tabet, Steve Bowman, and Sandy Eldredge who reviewed this document and made useful comments and recommendations.

DESCRIPTION OF MAP UNITS

QUATERNARY

Qa_1 **Younger alluvium** (Holocene) – Mostly light to medium gray, mud- to sand-dominated sediment with variable amounts of clay, silt, fine to granular sand, and pebble to boulder gravel; commonly contains large amounts of muddy sediment derived from Mancos Shale members; poorly to well sorted with coarsest parts closer to mountain front; includes alluvial and sheet wash deposits in active channels, flood plains, and broad low valleys between active channels; similar to, gradational with, and locally includes areas of older alluvium; generally less than 25 feet (8 m) thick.

Qa_2 **Older alluvium** (Holocene) – Mostly light to medium gray, mud- to sand-dominated sediment with variable amounts of clay, silt, fine to granular sand, and pebble to boulder gravel; commonly contains large amounts of muddy sediment derived from Mancos Shale members; poorly to well sorted with coarsest parts closer to mountain front; commonly incised to form terraces and benches 20 to 40 feet (6-12 m) above active channels in broad low valleys between active channels and along gentle slopes; similar to, gradational with, and locally includes areas of younger alluvium; the boundaries between deposits of younger and older alluvium are commonly subtle and gradational, and are generalized; generally less than 25 feet (8 m) thick.

Qaf **Alluvial fan deposits** (Holocene to late Pleistocene) – Poorly sorted, angular to subrounded, poorly to nonstratified gravel to boulders in a matrix of sand, silt, and clay (composition varies and corresponds to local source rocks); deposited where drainages decrease in slope near the foot of hills and cliffs, and where washes emerge from cuesta gaps and small canyons; commonly 15 feet (5 m) thick or less.

Qat **Alluvial-terrace deposits** (Pleistocene) – Poorly to moderately sorted gravel, sand, silt, and clay; cap benches and terraces 40 to 80 feet (12 to 24 m) above active channels along which they are aligned; contain detritus carried down from various formations of the Book Cliffs; mapped deposits commonly include colluvium draped down slopes along flanks of terrace remnants; similar to pediment-mantle deposits but generally better sorted and more closely associated with drainage channels; typically about 15 feet (5 m) thick, but locally thicker.

Qap **Pediment-mantle alluvium** (Holocene to Pleistocene) – Mostly poorly to moderately sorted, locally derived pebble and cobble gravel with considerable boulders, sand, silt, and clay; lower parts of deposits are partially to well-lithified (calcareous cement), clast-supported conglomerate and conglomeratic sandstone; commonly capped by eolian silt, sand, and calcic soil (caliche) up to stage VI of Machette (1985); blanket beveled benches and knolls between major drainage channels and cover areas of shale bedrock; form erosional remnants of broad surfaces inclined up-slope to the north to grade into the receding Book Cliffs; generally coarser to the north; similar to alluvial-fan deposits; remnants are 40 to 200 feet (12 to 65 m) above nearby drainages; oldest (highest) deposits probably up to about 400,000 years old based on volcanic ash in similar deposits to the east (Willis, 1994); generally 15 to 25 feet (5-8 m) thick, locally as much as 60 feet (18 m) thick.

Qea **Mixed eolian and alluvial deposits** (Holocene to Pleistocene) – Unconsolidated, wind-blown sand and silt interspersed with silt, sand, and gravel; locally reworked in small drainages and as sheet flow; older deposits locally have a well developed calcic soil (caliche) near the top; generally less than 10 feet (3 m) thick.

Qes **Eolian sand deposits** (Holocene) – Well-sorted, wind-blown, quartz sand deposited in sheets and small dunes; common in hollows in the Castlegate and Dakota Formations; generally less than 10 feet (3 m) thick.

Qmt **Talus deposits** (Holocene) – Poorly sorted, angular deposits that cover steep slopes of the Mancos Shale beneath the Castlegate-Blackhawk cliff in the north part of the Thompson Springs quadrangle; consist of rockfall blocks, boulders, smaller angular fragments, sand, and silt (only larger deposits mapped); generally less than 15 feet (5 m) thick.

CRETACEOUS

Kmbu **Buck Tongue Member of Mancos Shale** (Late Cretaceous [Campanian]) – Medium- to dark-gray marine shale that forms steep badland slopes; contains thin fine-grained sandstone at top; lower 40 feet (12m) is exposed near north edge of Thompson Springs quadrangle, 120 to 240 feet (37-73 m) total thickness to the north (Willis, 1986), thinning westward.

Kc **Castlegate Sandstone** (Late Cretaceous [Campanian]) – Pale-yellow-gray and light-gray, mostly fine-grained, cross-bedded to lenticular-bedded sandstone, interlayered with thin beds of mudstone, carbonaceous shale, and coal; cliff-and-bench forming; from 60 to 100 feet (18-30 m) thick, thinning eastward.

Kbh **Blackhawk Formation** (Late Cretaceous [Campanian]) – Pale-yellow-orange to light-brown, very fine-grained sandstone, interbedded with mudstone, carbonaceous shale, and thin coal beds; sandstone beds are resistant, thick to massive, and commonly bioturbated; contains trace fossils, leaf imprints, and rare shark teeth; sandstone forms ledges, shale and mudstone form steep slopes; ranges from 30 to 130 feet (9-40 m) thick, generally thickening to the west.

Mancos Shale

Kmbl, Kms, Kms **Bluegate Shale Member** (Late Cretaceous [Turonian-Campanian]) – Moderate-gray, fissile, marine shale (Kmbl) with a few mostly thin beds of light-brown sandstone (Kms mapped as single line where thin); forms broad areas of low relief, except at the foot of the Book Cliffs where forms a steep slope; also forms steeper slopes beneath local pediment-mantle gravel caps; sandstone beds are commonly fine to medium grained, gray, yellow gray, or orange brown, and are sparsely fossiliferous (pelecypods); sandstone beds form ledges or weather earthy, extend a few miles, and then disappear (only most conspicuous beds mapped); the Bluegate Shale includes the Prairie Canyon Member (Cole and others, 1997) that is not mapped separately; thickness from 3050 to 3250 feet (930-991 m) thick.

Juana Lopez Member – Undivided on cross sections; previously called Ferron Sandstone Member (for example: Williams, 1964; Gualtieri, 1988; Doelling, 2001); however, Molenaar and Cobban (1991) and Jim Kirkland (Utah Geological Survey, verbal communication, 2007) showed that these strata in eastern Utah are different in age and provenance from the type Ferron Sandstone in central Utah.

Kmju **Upper unit** (Late Cretaceous [Turonian]) – Mostly platy-weathering, thin-bedded to shaly, brown-gray, very fine grained, fossiliferous and bioturbated sandstone; forms a cuesta with a relatively wide dip-slope surface; about 40 to 60 feet (12-18 m) thick.

Kmjl **Lower unit** (Late Cretaceous [Turonian]) – Mostly platy-weathering, thin-bedded to laminated, brown-gray, very fine grained, commonly bioturbated, cuesta-forming sandstone overlain by very dark gray, fissile, carbonaceous shale; cuesta is about 25 to 30 feet (8-9 m) thick, carbonaceous shale is 20 to 30 feet (6-9 m) thick.

Kmt **Tununk Shale Member** (Late Cretaceous [Cenomanian-Turonian]) – Marine shale, light to medium gray-banded, generally forms gentle slopes, locally intermittently silty or sandy; contains *Exogyra levis* and *Pycnodonte newberryi* fossils about 20 feet (6 m) above the Dakota contact (Dane, 1935; Peterson and others, 1980); ranges from 200 to 300 feet (60-90 m) thick. The poorly displayed Coon Springs Sandstone Bed (not mapped) is 45 to 50 feet (14-15 m) below the base of the Juana Lopez Member.

Kd **Dakota Sandstone** (Late Cretaceous [Cenomanian]) – Sandstone, conglomeratic sandstone, conglomerate, carbonaceous shale, mudstone, and thin coal beds that are generally less than 2 feet (0.6 m) thick; sandstones are generally light brown to gray, medium to coarse grained, cross-bedded, and ledge forming; mudstones are gray and slope forming and are more common in the upper part; conglomerate is poorly to moderately sorted, pale-gray or yellowish gray with dense sandstone, black chert or quartzite clasts ranging from grit to 2 inches (5 cm) in diameter; locally petrified wood is present in conglomerate and conglomeratic sandstone; coal beds are lenticular and generally impure (Willis, 1994); 80 to 110 feet (24-34 m) thick, thinning slightly westward.

Cedar Mountain Formation – Members after Kirkland and others (1997, 1999).

Kcmr **Ruby Ranch Member** – Drab-green and pale-gray-purple (lavender), variegated mudstone, ribbon sandstone, and limestone; mudstone has abundant irregular carbonate nodules that form a desert pavement; contains dinosaur bone fragments; Ruby Ranch Member is Early Cretaceous (Aptian-Albian) in age according to fossil evidence and radiometric and stratigraphic relations (Kirkland and others, 1999; Kirkland and Madsen, 2007); approximately 100 feet (30 m) thick.

Kcmp, Kcmp **Poison Strip Sandstone Member** – (Mapped as single line where thin or forms vertical cliff.) Fine- to medium-grained sandstone with chert pebbles, trough cross-bedding, minor conglomerate lenses, and mudstone partings; forms resistant sandstone ledge that makes a prominent escarpment; contains dinosaur bone fragments and petrified wood; shown as a line on map where bed thins; from 12 to 24 feet (4-8 m) thick.

Kcmy **Yellow Cat Member** – Pale-gray-purple (lavender) to pale-green mudstone (non-smectitic) with thin sandstone and limestone beds; the base of the Yellow Cat Member is an unconformity that is locally marked by discontinuous calcrete layer(s) or a change from a brightly banded colored slope to a drab pale-green slope (Kirkland and others, 1997, 1999); includes fish, reptile, and dinosaur bone fragments; from 75 to 140 feet (23-43m) thick.

JURASSIC

Morrison Formation – Shown as a single unit on cross sections.

Jmb **Brushy Basin Member** (Late Jurassic [Tithonian]) – Mostly steep-slope-forming, colorfully banded (dominated by maroon shades but with variegated shades of orange, pink, red, brown, yellow, very light gray, lavender, and purple), muddy siltstone and claystone with widely spaced sandstone, conglomeratic sandstone, and limestone beds; forms steep slopes; many layers are smectitic clay derived from the hydrolysis and devitrification of volcanic ashes (Stokes, 1952a), and weather to a "popcorn" texture; 300 to 450 feet (90-140 m) thick.

SUBSURFACE UNITS

Jsm **Summerville and Morrison Formations, undifferentiated**

Jsms **Morrison Formation, Salt Wash and Tidwell Members, and Summerville Formation**

Jctm **Moab Member of Curtis Formation**

Jes **Slick Rock Member of Entrada Formation**

Jcd **Dewey Bridge Member of Carmel Formation**

JŦgc **Glen Canyon Group** (Navajo, Kayenta, and Wingate Formations)

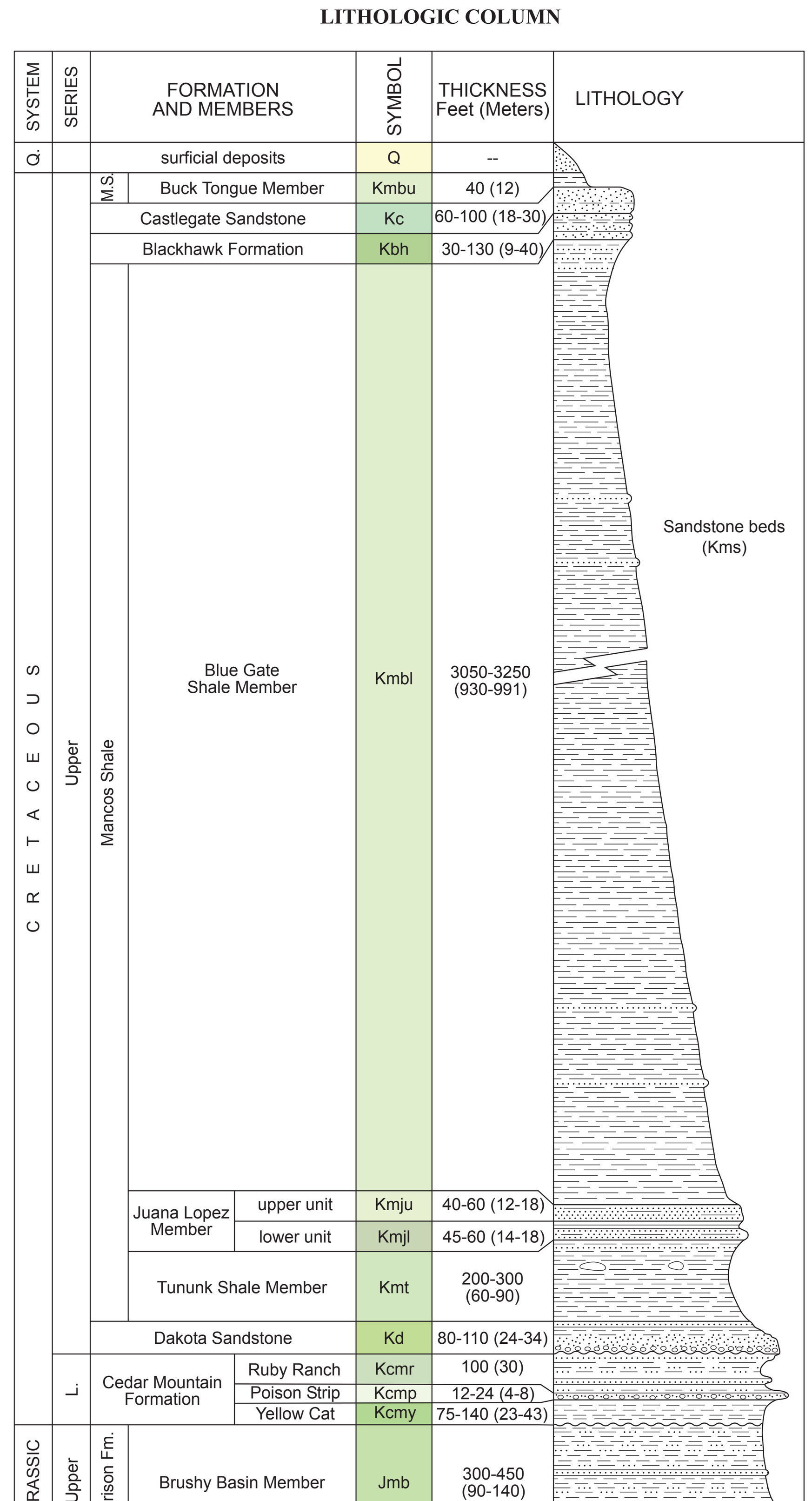
Ŧc **Chinle Formation**

Ŧm **Moenkopi Formation**

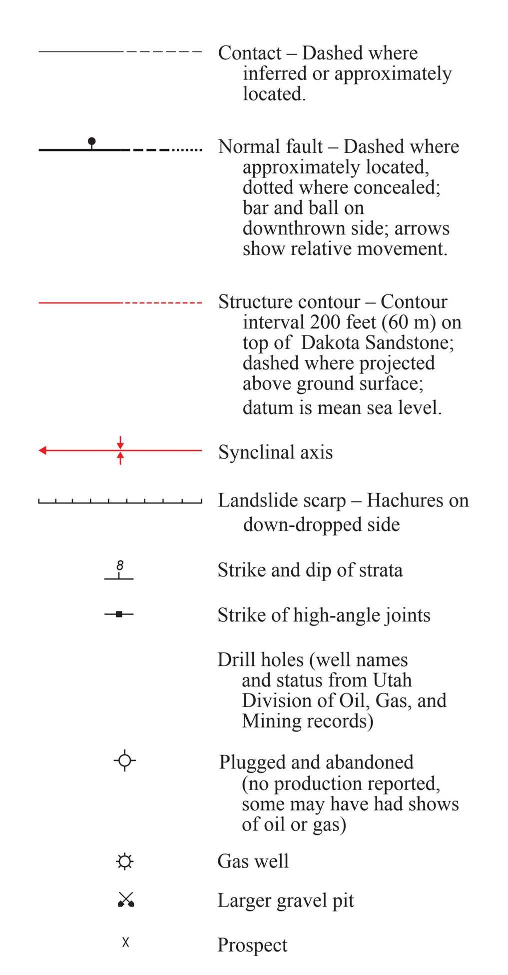
Paleozoic Rock – see units on cross sections

p€ **High-grade metamorphic and igneous rocks**

LITHOLOGIC COLUMN



GEOLOGIC SYMBOLS



REFERENCES

Black, B.D., Hecker, S., Hylland, M.D., Christenson, G.E., and McDonald, G.N., 2003, Quaternary fault and fold database and map of Utah: Utah Geological Survey Map 193DM, scale 1:500,000.

Cole, R.D., Young, R.G., and Willis, G.C., 1997, The Prarie Canyon Member, a new unit of the Upper Cretaceous Mancos Shale west-central Colorado and east-central Utah: Utah Geological Survey Miscellaneous Publication Report MP-97-4, 23 p.

Chidsey, T.C. Jr., Wakefield, S., Hill, B.G., Hebertson, M., 2004, Oil and gas fields map of Utah: Utah Geological Survey Map 203DM, scale 1:700,000.

Dane, C.H., 1935, Geology of the Salt Valley anticline and adjacent areas, Grand County, Utah: U.S. Geological Survey Bulletin 863, 179 p., scale 1:62,500.

Doelling, H.H., 2001, Geologic map of the Moab and eastern part of the San Rafael Desert 30' x 60' quadrangles, Grand and Emery Counties, Utah, and Mesa County, Colorado: Utah Geological Survey Map 180, 3 plates, scale 1:100,000.

Ellis, M.S., and Hopeck, J.T., 1985, Geologic map showing coal beds in the Dakota Sandstone, Harley Dome quadrangle and parts of the Bitter Creek Well, Westwater 4 SE, and Westwater 4 SW quadrangles, Colorado and Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1800, scale 1:50,000.

Frahme, C.W., and Vaughn, E.B., 1983, Paleozoic geology and seismic stratigraphy of the northern Uncompahgre front, Grand County, Utah, *in* Lowell, J.D., editor, Rocky Mountain foreland basins and uplifts: Rocky Mountain Association of Geologists, p. 201-211.

Gualtieri, J.L., 1988, Geologic map of the Westwater 30' x 60' quadrangle, Grand and Uintah Counties, Utah, and Garfield and Mesa Counties, Colorado: U.S. Geological Survey Miscellaneous Investigations Series Map I-1765, scale 1:100,000.

Hintze, L.F., compiler, 1980, Geologic map of Utah: Utah Geological and Mineral Survey Map A-1, scale 1:500,000.

Hintze, L.F., and Stokes, W.L., compilers, 1964, Geologic map of southeastern Utah: Utah State Land Board, scale 1:250,000.

Kirkland, J.I., Britt, B.B., Burge, D.L., Carpenter, K., Ciffelli, R., DeCourten, F.L., Eaton, J.G., Hasiotis, S., and Lawton, T.L., 1997, Lower to middle Cretaceous dinosaur faunas of the central Colorado Plateau – A key to understanding 35 million years of tectonics, sedimentology, evolution and biogeography: Brigham Young University Geology Studies, v. 42, pt. 2, p. 69-103.

Kirkland, J.I., Cifelli, R.L., Britt, B.B., Burge, D.L., DeCourten, F.L., Eaton, J.G., and Parrish, J.M., 1999, Distribution of vertebrate faunas in the Cedar Mountain Formation, east-central Utah, *in* Gillette, D.D., editor, Vertebrate paleontology in Utah: Utah Geological Survey Miscellaneous Publication 99-1, p. 201-217.

Kirkland, J.I., and Madsen, S.K., 2007, The Lower Cretaceous Cedar Mountain Formation, eastern Utah – The view up an always interesting learning curve, *in* Lund, W.R., editor, Field guide to geological excursions in southern Utah, Geological Society of America, Rocky Mountain Section 2007 annual meeting: Utah Geological Association Publication 35, 108 p., CD-ROM.

Machette, M.N., 1985, Calcic soils of the southwestern United States, *in* Wade, D.L., editor, Soils and Quaternary geology of the southwestern United States: Geological Society of America Special Paper 203, p. 1-21.

Molenaar, C.M., and Cobban, W.A., 1991, Middle Cretaceous stratigraphy on the south and east sides of the Uinta basin, northeastern Utah and northwestern Colorado: U.S. Geological Survey Bulletin 1787 P, 34 p.

Morgan, C.D., 1999, Petroleum geology of the Cisco Dome area, Grand County, Utah: Utah Geological Survey Oil and Gas Field Studies 19, 4 plates.

Peterson, F., Ryder, R.T., and Law, B.E., 1980, Stratigraphy, sedimentology, and regional relationships of the Cretaceous System in the Henry Mountains region, Utah, *in* Picard, M.D., editor, Henry Mountains symposium: Utah Geological Association Publication 8, p. 151-170.

Stokes, W.L., 1952a, Lower Cretaceous in Colorado Plateau: American Association of Petroleum Geologists Bulletin, v. 36, p. 1766-1776.

Stokes, W.L., 1952b, Uranium vanadium deposits of the Thompson area, Grand County, Utah: Utah Geological and Mineralogical Survey Bulletin 46, 51 p.

Stokes, W.L., and Mobley, C.M., 1954, Geology and uranium deposits of the Thompson area, Grand County, Utah, *in* Stokes, W.L, editor, Uranium deposits and general geology of southeastern Utah: Utah Geological Society Guidebook to the Geology of Utah, no. 9, p. 78-94.

U.S. Geological Survey, 2007, Earthquake probability mapping: Online, < http://eqint.cr.usgs.gov/eqprobl/2002/index.php>, accessed May 2007.

University of Utah Seismograph Stations, 2007, Historic earthquake information: Online, < http://www.seis.utah.edu/lqthreat/perseq.shtml>, accessed May, 2007.

Walton, P.T., 1956, Structure of the north Salt Valley Cisco area, Grand County, Utah, *in* Peterson, J.A., editor, Geology and economic deposits of east central Utah: Intermountain Association of Petroleum Geologists Seventh Annual Field Conference Guidebook, p. 186-189.

Western Regional Climate Center, 2007, Monthly average precipitation: Online, <http://www.wrcc.dri.edu/htmlfiles/ut/ut.ppt.html>, accessed October, 2007.

White, M.A., and Jacobson, M.I., 1983, Structures associated with the southwest margin of the ancestral Uncompahgre uplift, *in* Averett, W.R., editor, Northern Paradox basin, Uncompahgre uplift: Grand Junction Geological Society Field Guide, p. 33-39.

Williams, P.L., 1964, Geology, structure, and uranium deposits of the Moab quadrangle, Colorado and Utah: U.S. Geological Survey Map I-360, 2 plates, scale 1:250,000.

Willis, G.C., 1986, Provisional geologic map of the Sego Canyon quadrangle, Grand County, Utah: Utah Geological and Mineral Survey Map 89, 14 p., 2 plates, scale 1:24,000.

Willis, G.C., 1994, Geologic map of the Harley Dome quadrangle, Grand County, Utah: Utah Geological Survey Map 157, 18 p., scale 1:24,000.

Woodward Clyde Consultants, 1983, Geologic characterization report for the Paradox Basin study region, Utah study areas, volume VI, Salt Valley: Walnut Creek, CA, Woodward Clyde Consultants, 120 p.

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