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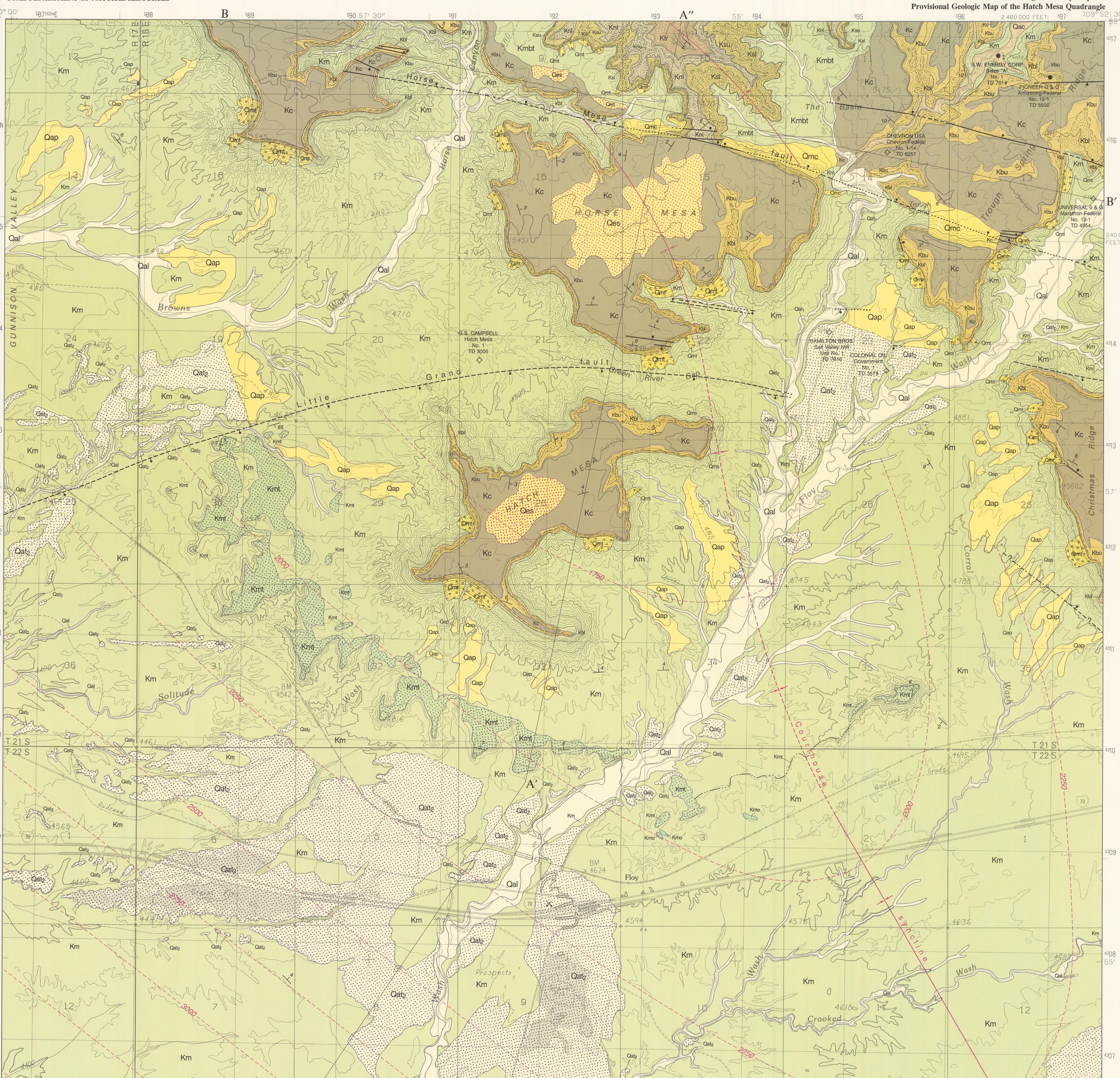


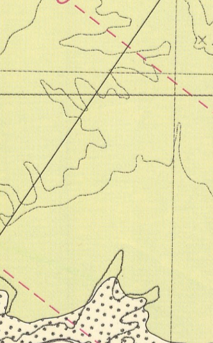
Base from U.S. Geological Survey,
Hatch Mesa Provisional 7.5′ Quadrangle, 1991

Field work completed by author, 1987-88
Cartography by J. Parker

SCALE 1:24 000

KILOMETERS · METERS · MILES · FEET

CONTOUR INTERVAL 40 FEET

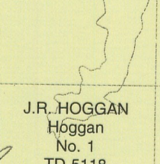


1994 MAGNETIC NORTH DECLINATION
AT CENTER OF SHEET

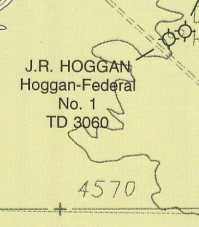
PROVISIONAL GEOLOGIC MAP OF THE HATCH MESA QUADRANGLE, GRAND COUNTY, UTAH

by
John P. Chitwood

1994



QUADRANGLE LOCATION



1 Tusher Canyon
2 Bobby Canyon South
3 Floy Canyon South
4 Green River NE
5 Crescent Junction
6 Green River SE
7 Dee Pass
8 Valley City

ADJOINING 7.5′ QUADRANGLE NAMES

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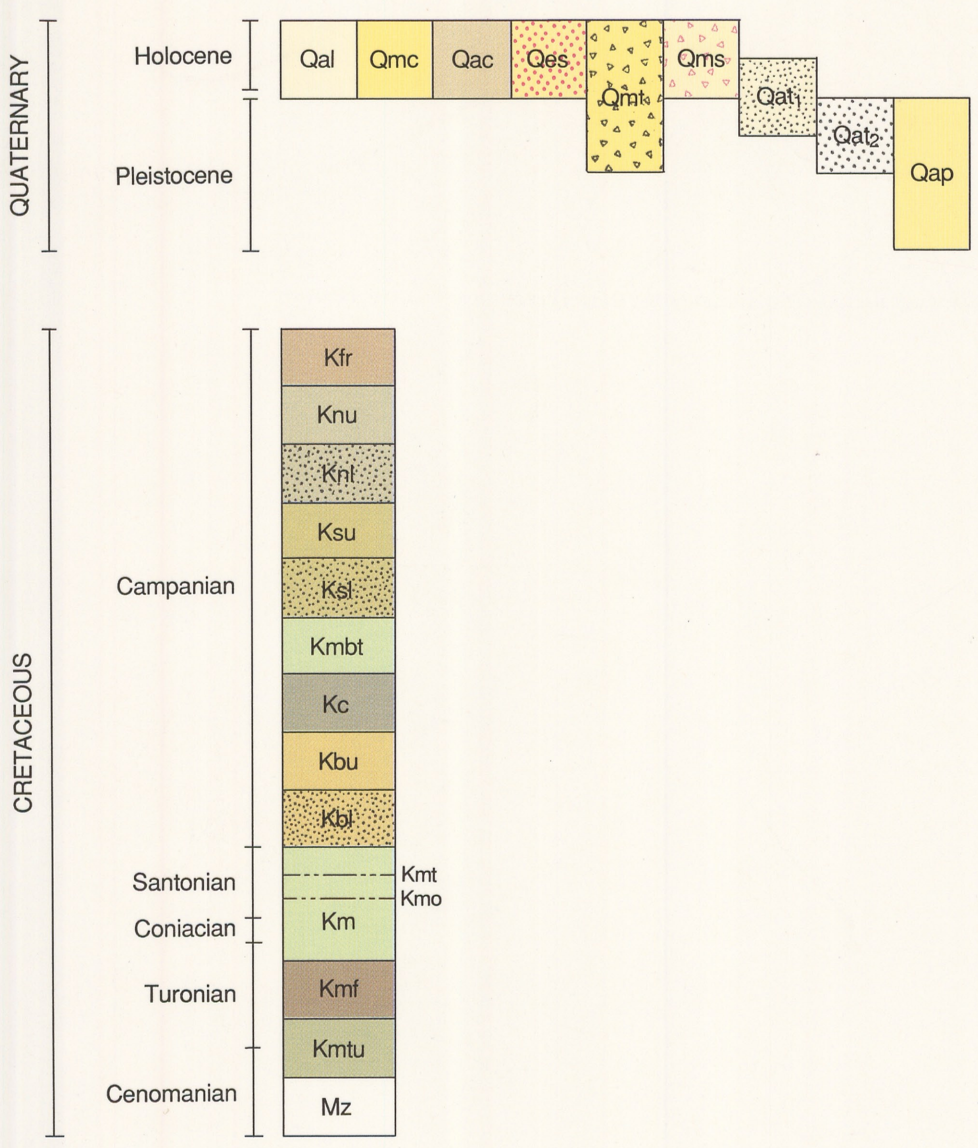
CORRELATION OF MAP UNITS

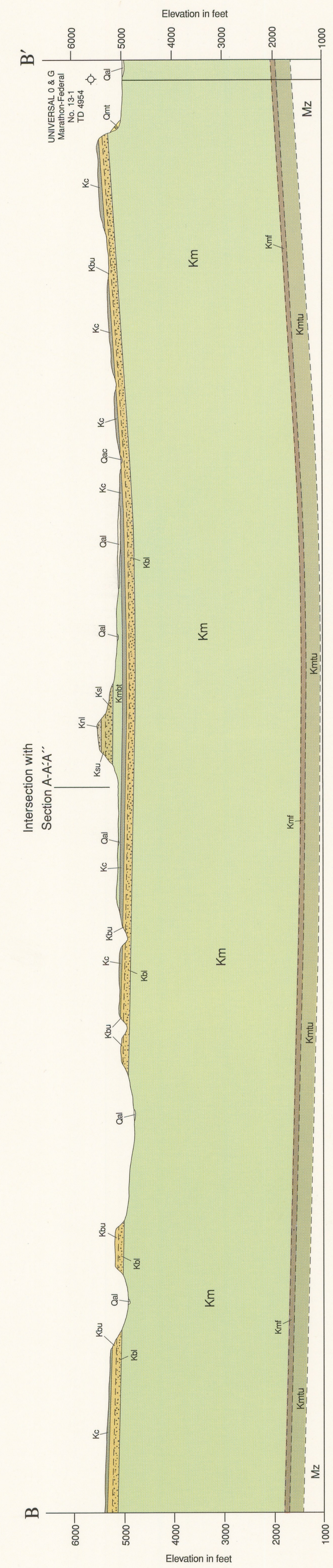


LITHOLOGIC COLUMN

FORMATION		SYMBOL	THICKNESS feet (meters)	LITHOLOGY
unconsolidated deposits		Q		
Farrer Formation		Kfr	463 (141)	
Neslen Formation	upper member	Knu	76 (23)	
	lower member	Knl	89 (27)	
Sego Sandstone	upper member	Ksu	70 (21)	
	lower member	Ksl	155 (47)	
Mancos Shale	Buck Tongue	Kmbt	142 (43)	
Castlegate Sandstone		Kc	76 (23)	
Blackhawk Formation	upper member	Kbu	71 (22)	
	lower member	Kbl	105 (32)	
Mancos Shale	turbidite	Kmt	50 (15)	
	oolitic ironstone	Kmo	6 (2)	
	main body	Km	3345 (1020)	
	Ferron Sandstone Member	Kmf	55 (17)	
	Tununk Member	Kmtu	200+ (60+)	

DESCRIPTION OF MAP UNITS

- **Qal** — Alluvium deposits - *Unconsolidated, round to angular, poorly to moderately sorted, very fine-grained sand- to boulder-sized particles; in intermittent stream deposits up to 12 feet (4 m) thick in canyons and washes.*
- **Qmc** — Colluvium deposits - *Unconsolidated, subangular to angular, poorly sorted rock debris on slopes and canyon walls; forms vegetated, partially stabilized slopes; up to 4 feet (1.2 m) thick in many places.*
- **Qac** — Mixed alluvium and colluvium deposits - *Poorly sorted deposits of mixed alluvium and colluvium up to 4 feet (1.2 m) thick in and along canyon stream beds.*
- **Qes** — Eolian deposits - *Unconsolidated, well-sorted, subrounded to rounded, very fine- to fine-grained sand transported and deposited by wind action; deposits are up to 3 feet (1 m) thick.*
- **Qmt** — Talus deposits - *Unconsolidated, angular, poorly sorted sandstone cobbles and boulders with minor amounts of finer sandstone and mudstone debris, deposited by mass movement (landslide) on slopes; deposits are up to 10 or more feet (3 m) thick.*
- **Qms** — Slump deposits - *Large blocks of consolidated bedrock which have separated from a cliff-face and moved in a mass downslope; up to 75 feet (23 m) thick.*
- **Qat1** — Younger terrace deposits - *Locally derived, poorly sorted, consolidated alluvial sand and gravel deposits up to 9 feet (2.7 m) thick; contains bivalve (notably Exogyra) fragments.*
- **Qat2** — Older terrace deposits - *Poorly to well-sorted, subangular to rounded, exotic (quartzite, chert, limestone) gravel, with a minor amount of locally derived sandstone gravel; cemented in many places; up to 18 feet (5.5 m) thick in canyons, generally thinner in the Mancos lowlands; gradational with pediment gravel deposits.*
- **Qap** — Pediment-mantle deposits - *Thin veneer of unconsolidated, poorly sorted, sand- to boulder-sized sandstone debris up to 1 foot (0.3 m) thick on gently sloping surfaces bevelled across nonresistant bedrock (Mancos Shale); dissected by streams in many places; the pediments are adjacent to the base of slopes along the Book Cliffs; gradational with older terrace deposits.*
- **Kfr** — Farrer Formation - *Interbedded, pale- to dark-yellowish-orange, very light-gray, and moderate-reddish-brown lenticular sandstone and gray to pale-olive mudstone; approximately 460 feet (140 m) thick.*
- **Knu** — Upper member of the Neslen Formation - *Interbedded, slope-forming mudstone, carbonaceous shale, coal, and ledge-forming sandstone; many sandstone beds are lenticular; contains the Chesterfield coal zone and many minor carbonaceous shale and coal zones; the Thompson Canyon sandstone bed crops out at the base of the unit; approximately 75 feet (23 m) thick.*
- **Knl** — Lower member of the Neslen Formation - *Interbedded, slope-forming mudstone, carbonaceous shale, coal, and ledge-forming sandstone; contains the Palisade coal zone in the lower part; approximately 90 feet (27 m) thick.*
- **Ksu** — Upper member of the Sego Sandstone - *Slope-forming, interbedded, yellowish-brown, silty mudstone and sandstone. The basal part is a coarsening-upward sequence similar to those in the lower member of the Sego Sandstone, but lacking a middle cliff-forming sandstone; the upper part is a fining-upward sequence; approximately 70 feet (21 m) thick.*
- **Ksl** — Lower member of the Sego Sandstone - *Interbedded, gray to yellowish-brown, silty mudstone, yellowish-brown to very light-gray sandstone, and reddish-brown bivalve coquinas; generally cliff-forming, the unit forms ledgy slopes in many places, and contains three coarsening-upward sequences, each consisting of a basal transition zone, middle sandstone zone, and upper bioturbated sandstone or bivalve coquina; approximately 155 feet (47 m) thick.*
- **Kmbt** — Buck Tongue of the Mancos Shale - *Medium- to dark-gray, bentonitic, gypsiferous mudstone. Slope-forming in many places, the unit forms "badlands" topography where not overlain by sandstone; approximately 140 feet (43 m) thick.*
- **Kc** — Castlegate Sandstone - *Sandstone with minor mudstone; yellowish-orange sandstone in lower part, upper sandstone is light gray; prominent cliff-forming unit; approximately 75 feet (23 m) thick.*
- **Kbu** — Upper member of the Blackhawk Formation - *Slope-forming interval of interbedded yellowish-orange sandstone, grayish-brown to grayish-black mudstone, carbonaceous mudstone, and minor coal; approximately 70 feet (21 m) thick.*
- **Kbl** — Lower member of the Blackhawk Formation - *Cliff-forming interval of pale- to dark-yellowish-orange sandstone interbedded with gray mudstone in the lower part; massive sandstone in the upper part; uppermost part of the massive sandstone is light gray; approximately 105 feet (32 m) thick.*
- **Km** — Mancos Shale (main body) - *Medium- to dark-gray, slope-forming, gypsiferous, bentonitic mudstone; interbedded pale-yellowish-orange sandstone in upper part; forms sparsely vegetated "badlands" topography; approximately 3,345 feet (1,120 m) thick.*
- **Kmt** — Turbidite sandstone in the Mancos Shale - *Locally prominent, cuesta-forming lens of interbedded grayish-orange sandstone and gray mudstone; massive, parallel-laminated, and climbing-ripple internal bedding forms are prominent in the sandstones; approximately 30 feet (9 m) thick.*
- **Kmo** — Oolitic ironstone in the Mancos Shale - *Dark-reddish-brown, calcareous, well-sorted, medium sand-size oolitic ironstone, overlain by thin olive-gray to dark-yellowish-orange silty mudstone; caps isolated knobs of Mancos Shale near the middle of the quadrangle; approximately 5 feet (1.5 m) thick.*
- **Kmf** — Ferron Sandstone Member of the Mancos Shale - *Cuesta-forming, interbedded, dark-yellowish-orange, platy sandstone and gray mudstone; occurs in the lower part of the Mancos Shale; approximately 55 feet (17 m) thick.*
- **Kmtu** — Tununk Member of the Mancos Shale - *Medium- to dark-gray, slope-forming, gypsiferous, bentonitic mudstone; forms sparsely vegetated "badlands" topography; the upper 200+ feet (60+ m) is exposed in the quadrangle.*
- **Mz** — Subsurface strata - *Strata shown in cross-sections but not exposed in the quadrangle; includes the basal part (up to 100 feet [30 m]) of the Mancos Shale, the Dakota Sandstone, and the upper part of the Morrison Formation in many places.*

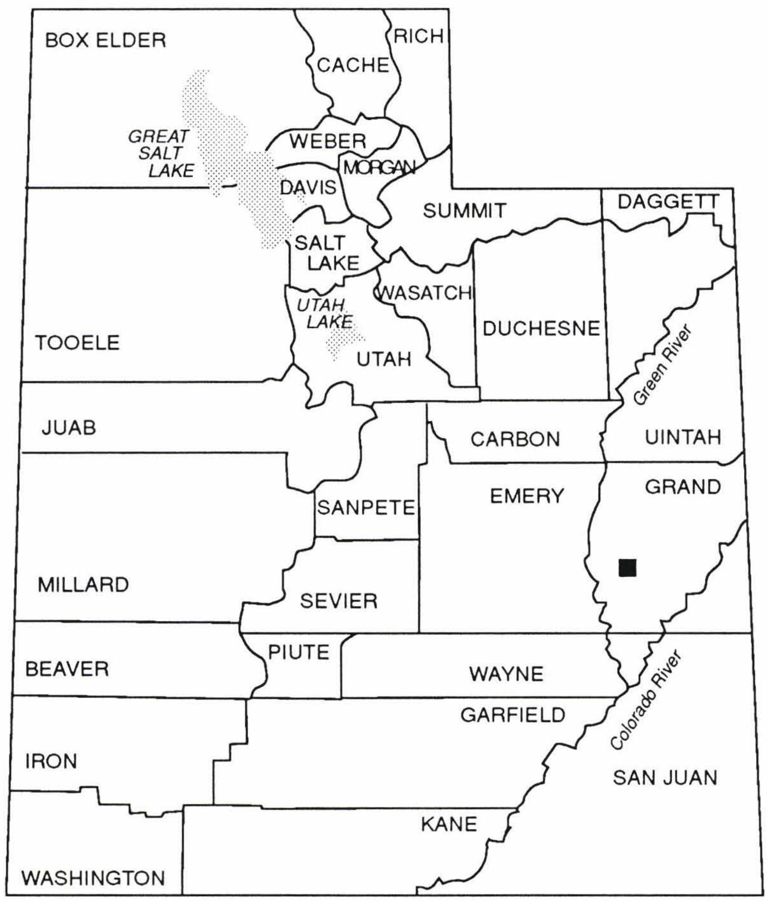


MAP SYMBOLS

- CONTACT - *Dashed where approximate.*
- NORMAL FAULT - *Dashed where inferred; dotted where covered; bar and ball on downthrown side; queried where uncertain.*
- SYNCLINE AXIS - *Dashed where location inferred.*
- 3000 STRUCTURAL CONTOUR - *Contour interval 250 feet; dashed where location inferred; drawn on base of Dakota Sandstone; datum is mean sea level. Contours not shown on northern part due to complex structure and sparse data. Modified from Williams (1964).*
- APPROXIMATE TRACE OF Kmt OUTCROP
- STRIKE AND DIP OF BEDDING - *Inclined.*
- GRAVEL PIT
- OIL WELL
- DRY HOLE

PROVISIONAL GEOLOGIC MAP OF THE HATCH MESA QUADRANGLE, GRAND COUNTY, UTAH

by
John P. Chitwood
Kansas State University,
Manhattan, Kansas



MAP 152 **1994**
UTAH GEOLOGICAL SURVEY
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UTAH GEOLOGICAL SURVEY
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Salt Lake City, Utah 84109-1491

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PROVISIONAL GEOLOGIC MAP OF THE HATCH MESA QUADRANGLE, GRAND COUNTY, UTAH

by
John P. Chitwood[1]
Kansas State University, Manhattan, Kansas

ABSTRACT

The Hatch Mesa quadrangle is located in Grand County, Utah about 15 miles (24 km) east of the town of Green River. The quadrangle is traversed by the Book Cliffs escarpment, which marks the boundary between the Uinta Basin and Mancos Shale Lowland sections of the Colorado Plateau physiographic province.

As sea level fluctuated repeatedly in an interior Late Cretaceous sea, sandstones and shales were deposited along the western seaway margin, leaving a record of alternating marine and nonmarine depositional environments in the quadrangle. Regressive episodes are recorded by the Ferron Sandstone Member of the Mancos Shale, the deltaic Blackhawk Formation and the fluvial-deltaic Castlegate Sandstone, and by the Sego Sandstone. Between these units are the open-marine main body, Tununk, and Buck Tongue Members of the Mancos Shale. In the Hatch Mesa area, the final regressive episode of the interior Cretaceous seaway is recorded by the Sego Sandstone, the coal-bearing Neslen Formation, and the fluvial Farrer Formation. Within the upper Mancos Shale a cuesta-forming, broadly lenticular sandstone unit deposited by turbidity currents crops out south of Hatch Mesa. Quaternary units include alluvium, colluvium, gravel terraces, pediment-mantle, eolian sand, slump, and talus deposits.

The quadrangle overlies the northern part of the ancestral Paradox structural basin, and is between the Uncompahgre uplift to the east and the San Rafael Swell to the west. Northwest- to southeast-trending, normal-faulted, horst blocks in the north part of the quadrangle may have been formed by dissolution and collapse of salt in the underlying Pennsylvanian Paradox Formation. Many faults exposed in the Book Cliffs in the northern part of the quadrangle continue southeast to the salt-cored Salt Valley anticline and are subparallel with faults in Precambrian basement rocks. The northwest-plunging Courthouse syncline enters the quadrangle from the southeast.

Geologic hazards include rock falls, flash floods, and expansive clays in the shales. Numerous attempts to locate hydrocarbon deposits in the quadrangle have yielded one producing oil well. Coal deposits in the quadrangle are thin and limited in areal extent.

INTRODUCTION

The Hatch Mesa quadrangle is located in Grand County, Utah along the south-facing Book Cliffs. Hatch Mesa, for which the quadrangle is identified, apparently was named after the Hatch Ranch, whose dilapidated and abandoned headquarters is located east of the mesa, near the southeast corner of section 27, T. 21 S., R. 18 E. The Book Cliffs mark the boundary between the Uinta Basin and Mancos Shale Lowland sections of the Colorado Plateau physiographic province. The quadrangle overlies rocks deposited in the ancestral Paradox basin. Cliffs, ledgy slopes, canyons, and mesas dominate the rugged topography in the northern part

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of the quadrangle. Rolling "badlands" topography, with common flat benches and gently dipping cuestas, prevails in the middle and southern parts of the quadrangle. Elevations in the quadrangle range from 6,091 feet (1,856 m) in the Book Cliffs to approximately 4,360 feet (1,329 m) where Floy Wash exits the southwest corner of the quadrangle. Surface drainages flow southwest, eventually draining into the Green River.

Detterman (1955) mapped the quadrangle at a scale of 1:24,000, by aerial photo interpretation. The quadrangle was also mapped by Williams (1964) at a scale of 1:250,000 as part of the Moab 1° x 2° geologic map. Numerous studies have reported on the stratigraphy, structure, and geology of the region. Pertinent studies include those of Baker (1935), Dane (1935), Rich (1935), Fisher (1936), McKnight (1940), Spieker (1949), Young (1955, 1957), Kelley (1958), Fisher and others (1960), Doelling and Graham (1972), Van de Graaff (1972), Gard (1976), Baars and Stevenson (1981), Fouch and others (1983), Ryer (1983), Swift and others (1987), Franczyk (1989), and Chitwood (1990).

STRATIGRAPHY

Late Cretaceous strata and Quaternary surficial deposits are exposed in the Hatch Mesa quadrangle. With the exception of Ordovician and Silurian units, Precambrian to Cretaceous strata apparently underlie the quadrangle (Baars, 1966; Stokes, 1986). Upper Cretaceous, Jurassic, Triassic, Permian, and Middle Pennsylvanian strata were penetrated by the Phillips (now Southwest Energy) Blaze "A" No. 1 well in section 12, T. 21 S., R. 18 E., in the northeast part of the quadrangle.

Cretaceous System

Cretaceous formations exposed in the quadrangle (from oldest to youngest) and their exposed thicknesses are: Mancos Shale, 3,600 feet (1,100 m); Blackhawk Formation, 176 feet (54 m); Castlegate Sandstone, 76 feet (23 m); Buck Tongue of the Mancos Shale, 142 feet (43 m); Sego Sandstone, 225 feet (68 m); Neslen Formation, 165 feet (50 m); and the Farrer Formation, 463 feet (141 m) (Chitwood, 1990).

As the sea level of the interior Cretaceous seaway (Mancos sea) fluctuated, sandstones and shales were deposited along its western margin, leaving a vertical stratigraphic record of alternating marine and nonmarine depositional environments. The shoreline of the interior Cretaceous seaway migrated (in a generally east-west direction) across the quadrangle several times. Eventually the seaway retreated for the final time and erosional detritus from the Sevier orogenic belt spread eastward into the Hatch Mesa area, covering the marine deposits.

Mancos Shale

The oldest unit exposed in the Hatch Mesa quadrangle is the Mancos Shale. The Mancos is divided into four members which are, in ascending order: the Tununk Member (Kmtu), the Ferron Sandstone Member (Kmf), the main body of the Mancos Shale (Km), and the Buck Tongue of the Mancos Shale (Kmbt). The Buck Tongue is separated from the main body by the Blackhawk Formation and the Castlegate Sandstone. The Mancos Shale members are all marine deposits. The basal contact of the Mancos Shale with the underlying Dakota Sandstone crops out just southwest of the quadrangle.

The Phillips (now Southwest Energy) Blaze "A" No. 1 oil well in SW ¼ NE ¼ SW ¼ section 12, T. 21 S., R. 18 E., encountered the Dakota Sandstone at a depth of 3,534 feet (1,077 m) and the upper contact of the Mancos Shale is approximately 130 feet (39 m) above the well head. Therefore, the Mancos Shale is approximately 3,700 feet (1,128 m) thick, considering the 10° dip in the vicinity of the well. Approximately 3,600 feet (1,100 m) of the Mancos Shale crops out in the quadrangle; the lower 100 feet (30 m) of the formation crops out just southwest of the quadrangle.

Tununk Member (Kmtu): The upper 200 feet (60 m) of the Tununk Member of the Mancos Shale, which is approximately 300 feet (90 m) thick in the Hatch Mesa area, is exposed in the southwest corner of the quadrangle. Olive black when fresh, the slope-forming, noncalcareous gritty mudstone of the Tununk Member turns dark gray where weathered.

The contact with the overlying Ferron Sandstone Member (Kmf) is placed at the horizon where the mudstone becomes silty. The coarsening upward transition zone which demarcates the overall gradational contact between the Tununk and Ferron Members is placed entirely within the Ferron Member.

Ferron Sandstone Member (Kmf): In the southwest corner of the quadrangle, the Ferron Sandstone Member of the Mancos Shale forms northwest-trending (N. 50° W.) cuestas that dip approximately 4° to the northeast (plate 1). The Ferron is approximately 57 feet (17 m) thick in this locality.

The Ferron contains two cuesta-forming zones of interbedded sandstone and mudstone separated by slope-forming, dark-gray to olive-black mudstone. Both cuesta-forming intervals contain yellowish-brown mudstone interbedded with noncalcareous, dark-yellowish-orange, laminated to platy, very fine-grained sandstone, which is overlain by a thin layer of secondary gypsum (satin spar) in many places. Sandstone beds increase upward in thickness and frequency in each cuesta. A coarsening-upward transition zone capped by a conglomerate containing medium-pebble-size chert, medium-grained quartz sand, shark teeth, and cephalopod (?) fragments underlies the lower cuesta-forming interval. The more easily erodible dark-gray mudstone that separates the two interbedded sandstone and mudstone intervals is responsible for dividing the Ferron into two escarpments. In many places, the upper escarpment has eroded up to 50 feet (15 m) farther down the dip-slope than the lower escarpment.

The Ferron Sandstone Member was deposited during an overall regressive episode (Ryer, 1983; Ryer and McPhillips, 1983; J.K. Balsley, unpublished notes, 1986). Ryer (1983, p. 208) inferred that the Ferron Sandstone Member is a sequence of vertically stacked, fourth-order, transgressive-regressive cycles at a third-order regressive maximum. In the quadrangle, the Ferron contains two regressive sandstone sequences separated by a transgressive mudstone.

Main body of the Mancos Shale (Km): The main body of the Mancos Shale is more accurately described as a mudstone. Generally calcareous, it lacks fissility in most places. The main body is dark gray on fresh surfaces and weathers to light gray. Yellowish-brown siltstone and fine-grained sandstone interbeds are widely spaced in the thick mudstone unit. The main body is nearly 3,350 feet (1,021 m) thick.

Weathered exposures commonly exhibit a "popcorn" texture imparted by ubiquitous closely spaced desiccation cracks. J.K. Balsley (unpublished notes, 1986) attributes the "popcorn" texture of the shale's weathered crust to the expansion of clay in the mudstone. Many fractures up to 0.25 inches (6 mm) thick within the mudstone are filled or partly filled with secondary fibrous gypsum (satin spar). Dark-yellowish-orange to orange bentonitic beds are locally interbedded with the mudstone. Interbedded thin siltstone and sandstone beds are present throughout the Mancos Shale, but sandstone beds occur with greater frequency and thickness in the upper part.

Willis (1986) noted that "dense, quartzitic" sandstones, as well as lighter, friable sandstones resembling those in the Blackhawk Formation, crop out in the upper Mancos Shale in the Sego quadrangle nearly 20 miles (32 km) east of the Hatch Mesa quadrangle. Several of these "quartzitic" sandstones occur in the upper main body in the Hatch Mesa quadrangle. A 4-foot-thick (1.2 m) "quartzitic" sandstone is a locally prominent ledge former in the Book Cliffs escarpment, approximately 160 feet (49 m) below the top of the main body. The ledge is traceable west of the quadrangle but was not observed to the east.

The main body of the Mancos Shale was deposited in an open marine environment (Fisher and others, 1960; J.K. Balsley, unpublished notes, 1986) during a westward transgression of the Late Cretaceous interior seaway across east-central Utah.

Sandstone beds in the upper few hundred feet of the main body increase upward in thickness and frequency. Some beds are laterally discontinuous, but many exhibit increasing lateral continuity. This part of the Mancos Shale is a transition zone that formed during the regression of the Late Cretaceous sea (J.K. Balsley, unpublished notes, 1986). Storm deposition became more frequent as the prograding shoreline encroached from the west. The transition zone is a coarsening-upward sequence, mudstones become silty, and very fine-grained sandstone beds increase upward in frequency, thickness, and lateral continuity. The uppermost part of the main body is a sandstone sequence with a few minor mudstone partings that grades into the overlying Blackhawk Formation, signalling the end of Mancos open marine conditions and the onset of the Blackhawk deltaic environment.

The main body is relatively uniform in lithology with two notable exceptions, an oolitic ironstone (Kmo) and a local turbidite sandstone sequence (Kmt), that crop out in the upper part of the main body. Where present, interbedded sandstones and siltstones are thin, usually less than 2 inches (5 cm) thick, platy, laterally continuous, very fine-grained, and locally form low cuestas with a few feet of relief. The thin sandstone and siltstone beds may represent short-lived regressive episodes.

Oolitic ironstone (Kmo): A dark-reddish-brown, thinly bedded, calcareous, well-sorted, medium-grained, oolitic ironstone crops out in parts of section 3, T. 22 S., R. 18 E. Swift and others (1987, p. 429) described the oolites as quartz and collophane clasts embedded in oolitic hematite coatings. The ironstone deposits are elongate, up to 100 feet (31 m) long, and 4 to 6 feet (1.2 to 1.8 m) thick.

The ironstone has a sharp basal contact with underlying gray mudstone of the main body of the Mancos Shale, and is overlain by an 8-inch (20 cm) thick, calcareous, olive-gray, silty mudstone, which weathers to dark yellowish-orange. Overlying the silty mudstone is a poorly sorted, winnowed, lag deposit containing subangular medium- to coarse-grained quartz sand, shark teeth, drum-shaped fragments of fish vertebrae, and molluscan debris (Swift and others, 1987). The lag deposit is only associated with the ironstone at one location, but is intermittently exposed elsewhere at the same stratigraphic horizon below the cuesta-forming sandstone.

East of the ironstone and winnowed lag deposits, in the S½ of sections 35 and 36, T. 21 S., R. 18 E., many small isolated knobs of Mancos Shale are capped by a resistant sandstone and overlying silty mudstone. These deposits are not mappable at a scale of 1:24,000. Up to 3 feet (1 m) thick, the sandstone is dark olive gray weathering to moderate yellowish brown, and is composed of very fine-grained quartz sand. Exhibiting a sharp basal contact with the underlying mudstone, the sandstone grades upward into calcareous, laminated, medium-dark-gray, silty mudstone, which weathers to dark grayish orange and is locally mottled. The sandstone and silty mudstone sequence crops out at approximately the same stratigraphic interval as the oolitic ironstone and winnowed lag deposits to the west.

These sandstone-capped knobs of mudstone appear to be erosional remnants of a locally extensive unit. The sandstone- silty mudstone sequence may be the open marine equivalent of the Emery Sandstone Member of the Mancos Shale as described by Fouch and others (1983).

The depositional environment of the oolitic ironstone is unclear. Chan and others (1987) proposed that the ooids may have been transported seaward during a regressive episode, and subsequently inundated by an ensuing transgression, or the ooids may have been transported offshore by storm currents. Nearby lithologic units may provide clues to the depositional setting of the ironstone. The occurrence of oolitic ironstone, at nearly the same stratigraphic interval as sandstone and silty mudstone beds (distal Emery Sandstone ?) that cap knobs of mudstone, suggests deposition of the ooids may be associated with a minor regressive episode. The overlying winnowed lag deposit and mudstone suggest that an ensuing transgression inundated the ooids, preserving them in the sea-floor mud. It appears that a combination of the depositional mechanisms discussed by Chan and others (1987) may explain the occurrence of the ooids in an offshore setting. Storm waves may have transported the ooids from the Emery (?) strandline, depositing them offshore near the distal fine-grained deposits of the Emery (?) regression. Current action capable of winnowing the lag debris deposited above the ooids may have eroded finer grained material originally deposited with and near the ooids, destroying the sedimentary record that connected the ooids to their paleoshoreline.

Turbidite sandstone (Kmt): Approximately 1,050 feet (320 m) below the base of the Blackhawk Formation, a sequence of interbedded sandstone and mudstone in the main body forms a laterally discontinuous, arcuate (map view) cuesta (plate 1). Sandstone beds display internal bedding forms associated with turbidite deposits. The sequence is approximately 33 feet (10 m) thick at its western terminus (section 30, T. 21 S., R. 18 E.) where it is abruptly truncated by the Little Grand fault. It reaches a maximum thickness of nearly 50 feet (15 m) just south of Hatch Mesa in section 33, T. 21 S., R. 18 E., and thins to the east, eventually pinching out in section 35, T. 21 S., R. 18 E. Strike and dip at the western terminus of the turbidite sandstone are N. 8° E., 5°SE and rotate counterclockwise along the cuesta to N. 12° E., 6° NW at the eastern terminus (plate 1). East of Floy Canyon road, the sandstone is exposed as an isolated ridge (plate 1). West of the road the unit is thicker and dips northeast under Hatch Mesa. A single dark-yellowish-orange sandstone bed, approximately 2 feet (0.6 m) thick, crops out along the west side of Floy Canyon road in sections 27 and 34, T. 21 S., R. 18 E. (plate 1). This sandstone bed appears to be a northeasterly extension of the turbidite sandstone.

The turbidite sandstone sequence is dominated by calcareous, grayish-orange, well-sorted, subrounded, medium-grained quartz sandstones. Where weathered, the sandstones are pale reddish brown. Some sandstones grade upward from medium- to very fine-grained quartz sand.

Thicknesses of sandstone beds vary throughout the sequence. The thickest (up to 5 feet [1.5 m]) crop out near the western terminus of the cuesta. Few sandstone beds are more than 2 feet (0.6 m) thick in the eastern part of the cuesta southeast of Hatch Mesa.

Internal bedding forms in the cuesta-forming sandstones include massive, parallel-laminae, and climbing ripples. Where all three of these bedding forms are present they generally progress upward from massive, to parallel-laminated, to climbing-rippled. Most sandstone beds are massive with the upper few inches displaying parallel laminae.

The basal contact of each sandstone bed within the sequence is sharp. Some sandstone beds contain mudstone rip-up clasts up to 1 inch (2.5 cm) in diameter near the basal contact. The upper contact of most sandstone beds with overlying mudstone is gradational, but may be sharp locally.

Intervening mudstones display parallel laminations of alternating dusky yellow, silty mudstone and dark-gray mudstone, which in many places are distorted and convoluted. Convoluted bedding planes appear to be areas of soft sediment deformation near the contact of the mudstone with the overlying sandstone.

Orientation of the cuesta-forming sandstone sequence suggests the unit was deposited in a northeasterly dipping offshore trough. The exact genesis of the trough is unknown, but it may be related to salt tectonics. Exposed sandstone beds do not represent the full breadth of the trough because they are truncated by the Little Grand fault. Sandstone beds were not observed on the upthrown side of the fault and appear to have been eroded. The thickest part of the sandstone sequence occurs southwest of Hatch Mesa, apparently along the trough axis. Near the trough axis, the sandstone beds dip 5° to 7° northeast. Dip orientations of sandstone beds on the trough flanks increase toward the axis as the lateral margins are approached (plate 1). Climbing ripples and the dips of sandstone beds near the axis are oriented to the northeast.

The cuesta-forming sandstone sequence cropping out below Hatch Mesa exhibits internal bedding forms associated with turbidite deposits, and is here referred to as a turbidite sandstone (Kmt). Swift and others (1987) pointed out that the same internal bedding forms may be induced by geostrophic storm currents (tempestite) instead of turbidite currents. The transporting medium of the sand is still openly debated. Regardless of whether the deposit is a tempestite or a turbidite, internal bedding forms suggest deposition under waning current conditions. The sandstone appears to be the distal seaward extension of storm-current deposition along a submarine distributary channel. Swift and others (1987) proposed that the source of the tempestite (turbidite) sand was the strandplain at the time of deposition of the Aberdeen Member of the Blackhawk Formation, located about 6 miles (10 km) northwest of Hatch Mesa.

Blackhawk Formation

Coal-bearing rocks in the Wasatch Plateau of central-Utah were defined as the Blackhawk Formation by Spieker and Reeside (1925). Together with the overlying Castlegate Sandstone, the Blackhawk Formation crops out across the northern part of the Hatch Mesa quadrangle as the cliff- and bench-forming sandstone along the southernmost exposures of the Book Cliffs. The contact with the underlying Mancos Shale is gradational, and is placed at the horizon above which sandstone comprises more than 50 percent of the lithology. The upper contact with the overlying Castlegate Sandstone is sharp and is placed at the top of the highest carbonaceous shale bed in the Blackhawk Formation. In the quadrangle the formation thickens from east to west, from approximately 176 feet (54 m) on Trough Spring Ridge in the SE ¼ section 14, to nearly 200 feet (61 m) on the west side of Horse Canyon in the SE ¼ section 8; both sections are in T. 21 S., R. 18 E. This trend is consistent with the regional westward thickening of the Blackhawk Formation. The formation is approximately 51 feet (16 m) thick near Sagers Wash (Willis, 1986) nearly 25 miles (40 km) east of the quadrangle, and nearly 714 feet (218 m) thick near Green River, Utah (Fisher and others, 1960), about 15 miles (24 km) west of the quadrangle.

In the Hatch Mesa quadrangle the Blackhawk Formation consists of two distinct lithologic zones. For mapping, the formation is informally divided into a lower (cliff-forming sequence) member (Kbl) and, an upper (slope-forming sequence) member (Kbu).

Lower member (Kbl): The lower member of the Blackhawk Formation, which is 105 to 115 feet (32 to 35 m) thick, is a sequence of massive cliff-forming sandstone. The member is composed of up to four deltaic facies: transition, lower shoreface, upper shoreface, and foreshore (J.K. Balsley, unpublished notes, 1986). Trace fossils such as *Helminthoida*, *Terebillina*, and *Ophiomorpha* are useful diagnostic tools for delineation of the deltaic facies, but were not observed in the quadrangle. In general, rocks in the quadrangle lack the abundant fossil record observable in other parts of the Book Cliffs.

The transition facies contains interbedded sandstone and mudstone. Generally pale yellowish orange, the well-sorted, subrounded, fine-grained quartz sandstone beds are separated by intervals of dark-gray to dusky yellow, commonly silty, mudstone.

Shale beds which are laterally continuous in the lower part grade upward into thin, discontinuous shale partings, and are altogether replaced where the interbedded shale and sandstone sequence grades into sandstone. Sandstone beds are laterally continuous to lenticular and contain sharp basal contacts and sharp to gradational upper contacts. The massive sandstone beds also contain plane-parallel lamination and cross-bedding (hummocky cross-stratification ?). The facies coarsens slightly upward from silty mudstone to very fine-grained basal sands of the overlying, cliff-forming, lower shoreface sandstone.

The lower shoreface facies is a 63-foot-thick (19 m) cliff-forming, well-sorted, subrounded, quartz sandstone, which coarsens upward from very fine- to medium-grained sand; dark yellowish orange where fresh, the sandstone weathers to dark reddish brown. Internal bedding forms are indistinct in many places, but the sandstone is cross-bedded throughout, with locally horizontal or inclined plane-parallel or wavy (hummocky?) bedding. A few vertically oriented burrows, attributed to polychaete annelid worms (J.K. Balsley, unpublished notes, 1986) are randomly located in the sandstone. The upper contact is defined in part by an abrupt color change to light gray in the overlying upper shoreface sandstone.

At the top of the lower member of the Blackhawk Formation, the upper shoreface and foreshore facies comprise a 20-foot-thick (6 m) interval of light-gray, cliff-forming sandstone.

The upper shoreface is represented in the lower 13 feet (4 m) of this interval, with plane-parallel and wavy (trough) cross-bedding, and moderately sorted, subangular to subrounded, fine- to medium-grained quartz sand.

Foreshore deposits complete the upper 7 feet (2 m) of the light-gray sandstone. Plane-parallel bedding and well-sorted, subrounded to rounded, fine-grained quartz sand with a trace of fine-grained black chert and feldspar are contained in the foreshore facies. The sharp upper contact of the cliff-forming lower member is placed where the basal grayish-black shale of the slope-forming upper member overlies the upper light-gray sandstone of the foreshore facies.

Upper member (Kbu): The lower and middle zones of the 71- to 85-foot-thick (22 to 26 m) upper member contain interbedded sandstones, mudstones, shales, and coals. The mudstones are medium dark gray to grayish brown or grayish black, depending on carbon content. Many fractures are filled with secondary gypsum (satin spar). Mudstone and shale beds are locally silty and contain unidentified carbonized plant fragments. Locally, carbonaceous shales contain thin seams of bony coal less than 1 foot (0.3 m) thick. Sandstone beds exhibit sharp basal and gradational upper contacts with adjacent mudstone, shale, and coal beds.

The upper part of the upper member contains a 13-foot-thick (4 m), massive, cliff-forming, well-sorted, fine-grained quartz sandstone overlain by 13 feet (4 m) of interbedded platy sandstone beds and carbonaceous shale. The uppermost 8 feet (2.4 m) of the sequence contains fissile, dark-gray carbonaceous shale with fossilized plant fragments. This shale has a sharp upper contact with the base of the overlying Castlegate Sandstone.

The Blackhawk Formation records a regressive episode of the Late Cretaceous interior seaway (Mancos sea) (Ryer, 1983; J.K. Balsley, unpublished notes, 1986). In the quadrangle the formation exhibits facies (transition, lower and upper shoreface, and foreshore) typically associated with wave-dominated delta deposits (J.K. Balsley, unpublished notes, 1986). The lower member is a littoral sandstone which records the eastward migration of the Blackhawk strandline. The upper member of the Blackhawk Formation is a lagoon deposit (Young, 1955, 1957) or a poorly developed delta-plain coal deposit (J.K. Balsley, unpublished notes, 1986).

Castlegate Sandstone (Kc)

The Castlegate Sandstone is the uppermost massive sandstone of the cliff-forming sequence of sandstones and interbedded shales that cap the southernmost Book Cliffs escarpment. East of the Green River the top of the Castlegate Sandstone commonly forms a dip-slope bench as the overlying less resistant Buck Tongue of the Mancos Shale is eroded (Fisher and others, 1960; Willis, 1986). The Castlegate bench in the Hatch Mesa quadrangle reaches widths up to 2,640 feet (805 m). Hatch Mesa, Horse Mesa, and Trough Spring Ridge in the northeast part of the quadrangle are examples of benches that are capped by the Castlegate Sandstone.

The Castlegate Sandstone is approximately 440 feet (134 m) thick near Castlegate, Utah, where the unit was named by Clark (1928). It thins to the east where it eventually pinches out in the Mancos Shale near the Utah-Colorado border (Abbot and Liscomb, 1956). In the western Book Cliffs the Castlegate Sandstone is coarse grained and easily identified where it unconformably overlies the Blackhawk Formation (Spieker and Reeside, 1925). Grain sizes in the Castlegate Sandstone fine eastward until they approximate those in the underlying Blackhawk Formation (Fisher and others, 1960). This is the case in the Hatch Mesa quadrangle. The thickness of the Castlegate Sandstone across the quadrangle reflects its regional eastward thinning throughout the Book Cliffs (Fisher and others, 1960). On the west side of Horse Canyon in section 8, T. 21 S., R. 18 E., the unit is nearly 86 feet (26 m) thick and thins to nearly 76 feet (23 m) in the vicinity of Trough Spring Ridge in section 14, T. 21 S., R. 18 E. (plate 1).

The lower 25 feet (7.6 m) of the unit is locally slope-forming and contains yellowish-orange to grayish-orange sandstone interbedded with olive-gray and gray mudstone. Up to 6 feet (2 m) thick, sandstone beds are generally laterally continuous and are commonly composed of well-sorted, subrounded, fine-grained quartz sand, with traces of black, very fine- to fine-grained clasts (carbonized plant fragments ?) in many places. Mudstone rip-up clasts occur near the base of many sandstones, most notably in the basal sandstone which unconformably overlies the uppermost carbonaceous shale of the Blackhawk Formation. Internal bedding forms in these sandstones include massive, planar-laminae, and wavy (hummocky) cross-bedding.

Mudstones in the lower slope-forming interval are generally thin, less than 1.5 feet (0.4 m) thick, and laterally continuous within the quadrangle. Black carbonized plant fragments up to 1 inch (2.5 cm) long are common, and in many places fractures are filled or partially filled by secondary fibrous gypsum (satin spar).

The middle part of the Castlegate also contains interbedded sandstone and mudstone units, but the sandstones are light gray to white, and friable. The basal 9 feet (2.7 m) of this interval is a cliff-forming, noncalcareous and friable, well-sorted, subrounded, medium-grained quartz sandstone. The sandstone is light gray when fresh but weathers grayish orange. Overlying this unit above a sharp contact is a 16-foot-thick (4.9 m), upward-fining interval of slope-forming, interbedded sandstone and mudstone.

The uppermost 25.5 feet (7.8 m) of the Castlegate Sandstone is a very light-gray, well-sorted, rounded, fine-grained quartz sandstone. The sandstone is thinly bedded and commonly displays indistinct trough (?) cross-bedding. Although friable, this sandstone is a prominent ledge-former. Locally, a thin seam less than 1 inch thick (2.5 cm) of bony (?) coal may be found 1 or 2 feet (0.3 to 0.6 m) below the sharp contact between the Castlegate Sandstone and the overlying Buck Tongue of the Mancos Shale.

In the Hatch Mesa area, the Castlegate Sandstone is a delta-plain deposit (Van de Graaff, 1972). The presence of mudstone, siltstone, and shale beds (usually containing carbonaceous material), and coal seams, interbedded with fine- to medium-grained sandstones, supports this interpretation.

Delta-plain swamps and marshes apparently were dissected by distributary channels (J.K. Balsley, unpublished notes, 1986) which transported sand to the shoreline systems east of the Hatch Mesa area. One such distributary channel scoured the Blackhawk Formation and is about 200 feet (60 m) wide. It is observed in the north face of Hatch Mesa in the NW ¼ section 27, T. 21 S., R. 18 E.

Buck Tongue of the Mancos Shale (Kmbt)

The Buck Tongue of the Mancos Shale is the uppermost open marine (Fisher, 1936, p. 15) unit exposed in the Hatch Mesa quadrangle. It grades into the lower sandy part of the Price River Formation nearly 20 miles (32 km) west of the quadrangle in the vicinity of the Beckwith Plateau (Fisher and others, 1960). Near the Utah-Colorado line, the Buck Tongue reaches a thickness of 350 feet (107 m) before merging with the main body of the Mancos Shale (Fisher and others, 1960).

In the Hatch Mesa quadrangle, outcrops of the unit are limited to the extreme north-central part where it is overlain by the Sego Sandstone (plate 1). The unit is approximately 142 feet (43 m) thick in the SW ¼ section 11, T. 21 S., R. 18 E.

The Buck Tongue weathers and erodes more easily than the resistant sandstone units below and above, resulting in a dip-slope bench formed on the underlying Castlegate Sandstone, and terminated by a locally northward (down dip) retreating escarpment of Sego Sandstone. Badlands topography is typical on the bench, whereas highly dissected steep slopes are common for exposures of the unit immediately below the Sego Sandstone.

The Buck Tongue has many characteristics of the main body of the Mancos Shale. In most places the shale lacks fissility and is better called a mudstone. Typically, the mudstone is grayish black to dark gray when fresh and weathers to medium gray. Desiccation cracks on weathered surfaces impart a "popcorn" texture to the mudstone. Fractures throughout the noncalcareous mudstone are lined with secondary fibrous gypsum (satin spar).

Lenticular zones of reddish- to yellowish-orange, blocky mudstone may be found locally in the unit. In many places, orange mudstone nodules the size and shape of footballs are found adjacent to the zone. The orange color of the zones may be imparted by weathered bentonite or ferruginous minerals.

The contact between the Buck Tongue and the underlying Castlegate Sandstone is sharp, suggesting a rapid transgression of the Late Cretaceous Mancos sea. The upper contact with the Sego Sandstone is gradational, progressing through an upward-coarsening transition zone that includes an assemblage of siltstone to very fine-grained sandstone beds which increase upward in thickness and frequency. The mudstone interbedded between these clastic beds is often pale yellowish orange due to high silt content. This gradational zone is similar to the transition zone of J.K. Balsley (unpublished notes, 1986), as described in the upper main body of the Mancos Shale. The transition zone marks the return to deltaic conditions as the eastward-advancing Sego strandline migrated across the quadrangle.

Sego Sandstone

Fisher (1936, p. 15) named the Sego Sandstone for exposures near Sego, Utah. In the Hatch Mesa quadrangle, the Sego Sandstone is generally a cliff-forming unit locally covered by colluvium from the overlying Neslen and Farrer Formations.

The unit has a gradational contact with the underlying Buck Tongue of the Mancos Shale. As the Buck Tongue is eroded, the Sego Sandstone is undermined and the Sego escarpment retreats down dip, forming a second escarpment above the prominent cliff-forming Blackhawk Formation and Castlegate Sandstone. The upper contact with the overlying Neslen Formation is also gradational. In the quadrangle the Sego is nearly 225 feet (68 m) thick.

In the Hatch Mesa quadrangle, three coarsening-upward sequences occur in the lower part of the Sego, and the upper part of the Sego contains interbedded silty mudstone, sandstone, and coquina beds. A complete coarsening-upward sequence characteristically contains a basal transition zone of interbedded silty mudstone and sandstone, a middle zone of cliff-forming sandstone, and an upper zone of bioturbated and/or fossiliferous sandstone or a coquina. In the Hatch Mesa quadrangle the Sego Sandstone is informally divided into a lower member (Ksl) and an upper member (Ksu). The lower member contains three complete coarsening-upward sequences and is normally a cliff-forming interval. The upper member contains one incomplete coarsening-upward sequence and interbedded silty mudstone and sandstone. In many places the upper member is a slope-forming interval.

Lower member (Ksl): The base of the lower member of the Sego Sandstone is placed at the base of a laterally continuous 3 to 6 foot (1 to 1.8 m) zone of interbedded 8- to 14-inch (20 to 36 cm) sandstone beds and thinner mudstones. The top of the lower member is placed at the top of the upper bioturbated sandstone of the uppermost complete coarsening-upward sequence. The lower member is approximately 155 feet (47 m) thick.

Each coarsening-upward sequence of the lower Sego has a basal transition zone of interbedded silty mudstone and sandstone beds, a middle zone of very light-gray, cliff-forming sandstone, and an upper zone of bioturbated and/or fossiliferous sandstone. The uppermost sequence in the lower member contains a very pale-yellowish-orange, silty to very fine-grained sandstone between the very light-gray sandstone and the bioturbated sandstone. The coarsening-upward sequences range in thickness from 43 feet (13 m) to 63 feet (19 m).

Transition zones of the sequences range from 13 feet (4 m) to 37 feet (11 m) thick. The zones are usually slope-forming but locally form cliffs and are similar to the transition zone observed between the main body of the Mancos Shale and overlying Blackhawk Formation. Sandstone beds increase upward in thickness, frequency, and lateral extent. Interbedded medium- to dark-gray mudstones are silty and decrease upward in thickness and frequency. Transition zone mudstones in the uppermost coarsening-upward sequence are carbonaceous in many places.

Lower Sego transition zone sandstones generally exhibit sharp basal contacts with underlying silty mudstones. Mudstone rip-up clasts up to 0.04 inch (1 mm) in diameter occur near the base of the sandstones in many places. Contacts with overlying silty mudstones are sharp in many places, but are gradational locally. Parallel laminated or massive, the silty sandstones are commonly pale yellowish orange, but are moderate reddish brown to very light gray in the transition zone of the uppermost coarsening-upward sequence. The lower transition zone sandstones are commonly lenticular. Upper transition zone sandstones are very fine grained and laterally continuous.

Each coarsening-upward sequence has a middle interval of very light-gray, fine-grained sandstone above the transition zone. These cliff-forming sandstone intervals range from 16 feet (5 m) to 18 feet (5.5 m) thick. The intervals are distinguished from the upper transition zone sandstones by an abrupt color change from pale yellowish orange to very light gray, and by the absence of interbedded silty mudstone. Internal bedding forms include indistinct wavy cross-bedding (trough and hummocky ?), massive bedding, and plane-parallel laminae (inclined in some places).

The lower and upper coarsening-upward sequences are capped by a 3-foot-zone (1 m) of bioturbated, fossiliferous sandstone. Light olive gray when fresh, the sandstone weathers moderate reddish brown. It contains randomly oriented burrows up to 0.4 inch (1 cm) in diameter and 10 inches (25 cm) long. Common unidentified bivalve (?) fragments up to 1.5 inches (4 cm) in length, with no obvious orientation, are grain-supported and comprise up to 15 percent of the capping sandstone.

The middle coarsening-upward sequence is capped by an 8-foot-thick (2.4 m), dark-reddish-brown, fossiliferous sandstone. Unidentified, disarticulated, whole, and fragmented bivalves up to 3 inches (8 cm) long have no obvious orientation and are normally grain-supported. Locally, the unit is a valve-supported coquina with fine-grained sand between the valves.

Upper member (Ksu): The upper member of the Sego Sandstone is a slope-forming unit containing interbedded silty mudstone, sandstone, and a bivalve coquina. The lower part of the unit is an incomplete coarsening-upward sequence and the upper part is a fining-upward sequence of sandstone overlain by an interval of interbedded sandstone and silty mudstone. In the quadrangle, the upper member is 70 feet (21 m) thick.

The incomplete coarsening-upward sequence of the upper Sego contains a basal transition zone and capping coquina, but lacks the middle very light-gray sandstone interval present in the three coarsening-upward sequences in the lower Sego. The lower 28 feet (8.5 m) is composed of interbedded mudstone and sandstone, similar to the basal transition zones of the three sequences described above. The contact with the underlying bioturbated sandstone is sharp. Sandstone beds are thicker (up to 5 feet [1.5 m]) than those in the lower Sego transition zones, and interbedded silty mudstones are up to 3 feet (1 m) thick. Both sandstone and silty mudstone beds decrease in thickness in the upper part of the zone.

A ledge-forming, calcareous, moderate-yellowish-brown, 9-foot-thick (2.7 m), bivalve coquina directly overlies the transition zone. The coquina is composed of whole and fragmented *Exogyra* valves (J.K. Balsley, personal communication, 1987). The valves are up to 4 inches (10 cm) long and their hinge lines are commonly horizontally oriented, imparting a platy appearance to the coquina. Spaces between valves are filled with silty to very fine-grained sandstone.

The upper 33 feet (10 m) of the upper Sego contains a slope-forming, fining-upward sequence of sandstone and interbedded sandstone and silty mudstone, and is covered in many places. The basal 17 feet (5.2 m) of the sequence is composed of pale-yellowish-brown, very fine- to fine-grained sandstone that is thinly bedded and has a platy appearance. The upper 16 feet (5 m) is composed of interbedded very fine-grained sandstone and silty mudstone.

The contact with the overlying Neslen Formation is placed at the base of the lowermost carbonaceous silty mudstone of the Palisade coal zone, which overlies the upper slope-forming interval of the upper member of the Sego Sandstone. Coal beds were not observed below this horizon and sandstone beds above the horizon are laterally discontinuous channel deposits rather than sheet sands.

The Sego Sandstone represents the final regression of the Late Cretaceous (Mancos) sea from Utah. Stacked sequences of back barrier and shoreface deposits of the Sego Sandstone were produced by alternating episodes of shoreline advance and retreat (Franczyk, 1989). Lithology and internal bedding forms in the coarsening-upward sequences generally correspond to the transition, upper shoreface, and foreshore facies of the deltaic Blackhawk Formation (J.K. Balsley, unpublished notes, 1986). The fining-upward sequence appears to be typical of microtidal barrier island coastline deposits (Franczyk, 1989).

Neslen Formation

Fisher (1936) named the major coal-bearing interval of the Price River Formation east of the Green River the Neslen coal-bearing member for its exposures in Neslen Canyon about 25 miles (40 km) east of the Hatch Mesa quadrangle. Fisher and others (1960) used the term Neslen Formation though they never designated a type section. Franczyk and others (1990) later defined a type section in Sego Canyon east of the quadrangle. In Neslen Canyon, Fisher (1936) defined four coal zones in the Neslen: Palisade, Ballard, Chesterfield, and one unnamed coal zone. Willis (1986) divided the Neslen Formation in the Sego Canyon quadrangle into lower and upper units; the Palisade and Ballard coal zones are in the lower unit, and the Thompson Canyon Sandstone Bed and the Chesterfield coal zone are in the upper unit. The terminology used by Willis (1986) is continued here.

The Neslen Formation contains mudstone, carbonaceous mudstone and shale, sandstone, and thin coal seams. In the Hatch Mesa quadrangle the exposures are limited to a few square miles in the north-central part of the quadrangle (plate 1). In section 11, T. 21 S., R. 18 E., the Neslen Formation is 149 feet (45 m) thick. The lower Neslen (Knl) is 76 feet (23 m) thick, and the upper Neslen (Knu) is 73 feet (22 m) thick.

Lower member (Knl): In the Hatch Mesa quadrangle the Palisade coal zone overlies the Sego Sandstone. The contact is placed at the base of the lowermost carbonaceous mudstone in the Palisade coal zone. Locally this contact may be gradational with the underlying interbedded mudstone and sandstone sequence of the upper Sego Sandstone. Regionally, the Neslen/Sego contact is sharp and conformable (Fisher, 1936; Franczyk, 1989).

The Palisade coal zone comprises the basal 13 feet (4 m) of the lower member of the Neslen Formation. The zone contains interbedded mudstone and shale, carbonaceous in many places, and coal. Shale beds are light to dark gray, with darker beds containing more carbonaceous debris. Coal lenses up to 0.4 inches thick (1 cm) and 4 inches long (10 cm) occur in zones in some of the carbonaceous shales. Laterally continuous coal seams up to 3 inches thick (8 cm) occur in the lower part of the coal zone. The Palisade coal zone contains no significant coal seams in the quadrangle.

The middle 50 feet (15 m) of the lower Neslen Formation is a slope-forming, mostly covered sequence of gray and brown shale, carbonaceous shale, mudstone, siltstone, sandstone, and thin bony coal seams. In many places, mudstone, shale, and carbonaceous shale beds contain resin flecks, and carbonaceous shale beds contain bony coal lenses less than 0.1 inch thick (2.5 mm). Ledge-forming sandstone beds up to 10 feet thick (3 m) are interbedded throughout the sequence. Some sandstone beds are laterally continuous throughout the quadrangle, but many are lenticular. The sandstones are generally pale yellowish brown or pale to dark yellowish orange where fresh, and weather to light gray or moderate reddish brown. Truncated, indistinct sets of trough cross-bedded laminae and inclined bedding are characteristic internal bedding forms of the sandstone.

The upper 14 feet (4 m) of the lower Neslen Formation consists of mudstone, shale, carbonaceous shale, siltstone, and coal beds of the Ballard coal zone. The most prominent coal seams are at or near the upper and basal contacts of the zone. The uppermost 3 to 4 feet (1 to 1.2 m) of the zone contains a coal seam 1.5 to 2 feet thick (0.4 - 0.6 m), and dark-gray carbonaceous shale. The basal 8 to 10 inches (20 to 25 cm) of the Ballard zone is a locally continuous coal seam. Between the upper and lower coal beds of the Ballard zone are interbedded gray mudstone, dark-gray carbonaceous shales, dark-yellowish-brown siltstone, and minor coal seams up to 3 inches (8 cm) thick. The Ballard zone is generally a covered slope-forming unit, but in many places it crops out in a cliff face below the overlying Thompson sandstone.

Upper member (Knu): The 20.5-foot-thick (6.2 m) Thompson Canyon Sandstone Bed (Thompson sandstone) is the basal unit of the upper member of the Neslen Formation. The base of the laterally continuous sandstone forms a sharp contact with the underlying Ballard coal zone. The lower 14 feet (4 m) of the unit is a ledge-forming, pale-yellowish-orange sandstone which contains moderately well-sorted, fine- to medium-grained quartz sand in the lower part, fining upward to well-sorted, fine-grained quartz sand in the upper part. Massive in many places, this interval also contains indistinct cross-bedding (trough and inclined) as well as parallel laminae. The upper 6.5 feet (2 m) of the Thompson is a very light-gray, friable, slope-forming sandstone. Composed of well-sorted, subangular to subrounded, fine-grained sand with a trace of carbonaceous clasts, this sandstone is noncalcareous, laterally continuous, and has a sharp upper contact with the basal carbonaceous shale of the overlying Chesterfield coal zone.

Alternative depositional mechanisms for the laterally continuous Thompson sandstone have been proposed. Franczyk (1989, p. F12) noted that it is correlative with the transgressive Anchor Mine Tongue of the Mancos Shale in the upper Sego Sandstone east of the Hatch Mesa area. Franczyk (1989) associated the Thompson Canyon Sandstone Bed with a brackish-water depositional environment created by the relatively short-lived Anchor Mine transgression. Willis (1986) suggested that the Thompson sandstone is a crevasse splay deposit caused by a break in a distributary channel.

Overlying the Thompson sandstone, the Chesterfield coal zone is approximately 16 feet (5 m) thick and contains interbedded mudstone, silty mudstone, carbonaceous shale and mudstone, sandstone, and coal. A 0.5-foot-thick (15 cm) coal seam crops out near the base of the unit. Both the coal seam and underlying carbonaceous shale contain olive-brown flecks of resin. Interbedded gray to brown mottled mudstone, gray silty mudstone, and very light-gray sandstone lenses comprise the middle 11 feet (3 m) of the zone. The upper 3.5 feet (1.1 m) contains a 2-foot-thick (60 cm) coal seam overlain by 1.5 feet (45 cm) of very dark-gray carbonaceous shale.

Above the Chesterfield coal zone, the upper 36 feet (11 m) of the upper Neslen consists of interbedded gray and brown mottled mudstone, dark-gray carbonaceous mudstone, lenticular sandstone, and coal seams; the sequence is dominantly gray and brown mottled mudstone. A solitary 4-foot-thick (1.2 m) trough cross-bedded, pale-yellowish-orange, lenticular sandstone near the middle is the only significant sandstone in the sequence. The sandstone is composed of moderately sorted, fine- to medium-grained quartz sand. Thin coal seams are interspersed throughout the sequence. The thickest coal seam is 1 foot (0.3 m) thick and crops out in the upper part of the sequence.

Locally, the upper Neslen is deformed and unconformable with the basal sandstone of the overlying Farrer Formation. One such local angular unconformity is exposed near the center of the W½ W½ section 11, T. 21 S., R. 18 E., in an area just north of the quadrangle. At this location an approximately 110-foot-wide (34 m) exposure of deformed strata crops out in a partially covered cliff face. The deformed strata are truncated by an overlying massive sandstone. A similar area of deformation crops out a few hundred feet west of the one described above, at the same horizon.

The deformation may have been produced prior to lithification of the sediments. Rapid deposition of sand by flooding meandering streams may have created sufficient overburden to cause underlying soft-sediment (mud and peat) deformation.

In eastern Utah, Franczyk (1989) described many facies in the Neslen, including: overbank, channel, crevasse splay, lacustrine, swamp, marsh, lagoon, and bay-fill deposits. Peat-forming environments of the Palisade, Ballard, and Chesterfield coal zones progressed from short-lived marshes behind barrier islands, to lagoonal, to freshwater coastal-plain, respectively. Apparently the shift from brackish to freshwater deposition follows the eastward prograding Sego strandline. Willis (1986) concluded that Neslen coals are upper delta-plain to lower fluvial-plain deposits.

The contact between the Farrer and Neslen Formations is placed at the base of the lenticular sandstone that truncates the deformed strata of the Neslen Formation. Above this horizon only minor coal seams, which form covered slopes in many places, are observed. This horizon is sharp and somewhat localized by its placement at the base of a lenticular sandstone. It is interpreted to represent a shift from a fluvial peat-forming environment of the upper Neslen to the non-peat-forming fluvial environment of the Farrer Formation. The presence of minor coal in the basal Farrer Formation indicates that the shift was gradual.

Farrer Formation (Kfr)

Fisher (1936) named an interval of non-coal-bearing rocks above the Neslen Formation, the Farrer non-coal-bearing member of the Price River Formation, after the nearby Farrer mine in Coal Canyon. The unit later became the Farrer Formation (Fisher and others, 1960), and a type section was defined by Franczyk and others (1990). A full thickness of the Farrer Formation, which is the uppermost Cretaceous unit in the Hatch Mesa quadrangle, is not preserved. A partial section of 463 feet (141 m) is exposed in a steep-faced peak in the S ½ section 10, T. 21 S., R. 18 E., near the north border of the quadrangle (plate 1).

The formation contains gray to pale-olive mudstone and shale interbedded with pale- to dark-yellowish-orange and very light-gray to moderate-reddish-brown lenticular sandstone. Locally the lower part of the formation is dominantly grayish yellow. Many mudstone and shale beds in the upper part of the formation are pale olive and give the formation an overall pale-olive or greenish cast.

Fisher and others (1960, p. 18) noted that the Farrer Formation is not sharply distinguished from either the underlying or overlying beds, and that "the olive green of the shale beds is the best criterion for placing the basal contact." In the Hatch Mesa quadrangle the base of the formation is placed at the base of the lenticular sandstone which truncates deformed strata in the upper Neslen Formation. This placement imparts a locally sharp contact at the base of a massive sandstone.

The lower part (nearly 100 feet [30 m]) of the formation is composed of slope-forming, interbedded mudstone and sandstone beds, about equal in number and thickness. Mudstone and shale beds in this interval are pale olive to gray, average 8 to 14 feet (2 to 4 m) in thickness, and form covered slopes between ledge-forming sandstones. Sandstone beds range from 5 to 23 feet (2 to 7 m) in thickness and are generally pale to dark yellowish orange, although a few are pale red. Basal sandstone beds are medium grained and upper sandstone beds very fine to fine grained. Nearly all sandstone beds are massive and commonly display indistinct cross-bedding and basal mudstone rip-up clasts.

Above the lower sequence of slope-forming, interbedded mudstone and sandstone is a nearly 210-foot-thick (64 m) interval of cliff-forming interbedded mudstone and sandstone. The mudstone beds are pale olive and range from 13 to 54 feet (4 to 16 m) in thickness. Thicker mudstone beds contain some interbedded sandstones up to 4 feet (1.2 m) thick. Sandstone beds in this interval range from 16 to 56 feet (5 to 17 m) in thickness. Most sandstones are pale to dark yellowish orange, but some are moderate reddish brown. Most sandstone beds contain fine-grained sand, however a 56-foot-thick (17 m) sandstone bed is composed of upward-fining, medium- to very fine-grained sand. All sandstone beds are well sorted, massive, and commonly display indistinct cross-bedding and basal mudstone rip-up clasts. Petrified wood was observed at the base of a lower sandstone in this interval.

The uppermost 140 feet (43 m) of the Farrer Formation exposed in the quadrangle is dominantly pale-olive mudstone with interspersed sandstone beds. Except for an 18-foot-thick (5.5 m) sandstone in the upper half of this interval, all sandstone beds are less than 5 feet (2 m) thick. The sandstones contain well-sorted, very fine- to fine-grained sand, and most are pale to dark yellowish orange, although a few are moderate reddish orange. The sandstone beds form very steep slopes in a dominantly mudstone and shale sequence.

The Farrer Formation is of fluvial origin (Fisher, 1936; Young, 1955; Fouch and others, 1983; Willis, 1986). Fluvial indicators in Farrer sandstones include: sharp basal contacts, basal mudstone rip-up clasts, fining upward sequences, and indistinct (trough cross-bedding and inclined laminae) internal bedding forms. Reconnaissance of exposures in adjacent quadrangles showed that the sandstones are broadly lenticular. The lower part of the formation contains rare, very thin, lenticular coal seams whereas underlying delta- to lower fluvial-plain deposits of the Neslen Formation contain laterally continuous coal beds.

Quaternary System

Alluvium (Qal)

Unconsolidated alluvial deposits in the quadrangle include clay- to boulder-size sediments in floodplains and stream channels (plate 1). One of the broader reaches of the Floy Wash floodplain, in the E $\frac{1}{2}$ section 34, T. 21 S., R. 18 E., was utilized by the now-abandoned Hatch Ranch for farming purposes. At that location the alluvium is dominated by clay and silt. Alluvial clay, silt, and sand occupy most of the washes in the quadrangle. Unconsolidated gravel derived from terrace deposits is present in many of the washes. Near and in the canyons of the Book Cliffs, cobbles, boulders, and cobble-size clasts of cemented bivalve fossils are common in the stream channel alluvium.

Colluvium (Qmc)

Canyon walls and mesa slopes are covered in many places by unconsolidated colluvial sand, gravel, cobbles, and boulders (plate 1). Colluvial slopes are partially stabilized by sparse vegetation and interclast space is commonly filled with clay, silt, and sand-size material. Downslope movement of colluvium is driven by gravity and enhanced by surface wash and freeze/thaw cycles.

Mixed Alluvium and Colluvium (Qac)

In the canyons alluvial and colluvial deposits are difficult to separate and are mapped as one unit (plate 1).

Eolian Deposits (Qes)

Eolian sand deposits consist of unconsolidated, very fine- to fine-grained sand derived mostly from local sandstones. Small isolated accumulations occur in the Book Cliffs, notably on the Castlegate Sandstone. The only eolian sand deposits large enough to map are on Horse Mesa and the bench of Castlegate Sandstone in the S ½ section 9, and the NE ¼ section 16, both in T. 21 S., R. 18 E. (plate 1). The Castlegate Sandstone appears to be the source of sand for these deposits.

Talus Deposits (Qmt)

Talus consists of unconsolidated, poorly sorted rockfall deposits generally devoid of vegetation. Talus deposits are dominantly composed of gravel, cobbles, and boulders of sandstone that blanket steep slopes beneath sandstone cliffs. Sand partially fills spaces between talus blocks, but finer sediment makes up a small percentage of the total volume. Talus deposits large enough to map are found on the steep slopes below the Blackhawk/Castlegate and Sego escarpments in the Book Cliffs (plate 1). Talus deposits are inferred to be largely the result of rockfalls and landslides.

Slump Deposits (Qms)

Numerous large blocks of consolidated sandstone, most containing some mudstone, have separated from the outcrop and moved downslope. Slump blocks (Qms) large enough to map are restricted to the Blackhawk escarpment on the northeast corner of Hatch Mesa (plate 1).

Terrace Deposits (Qat_1 and Qat_2)

Consolidated (in some places loosely cemented) gravel deposits of two different ages cap benches in the quadrangle. The younger terrace deposit (Qat_1) contains locally derived sandstone gravel and bivalve (notably *Exogyra*) fragments. This unit is exposed above Floy Wash in stream cuts south of Blaze Canyon at the base of the east slope of Horse Mesa in sections 14 and 23, T. 21 S., R. 18 E., (plate 1).

Older terrace deposits (Qat_2) cap small knobs of Mancos Shale in Floy Canyon and many benches in the lowlands south of the Book Cliffs (plate 1). In Floy Canyon the terrace deposits consist of poorly sorted, subangular, pebble- to boulder-sized, locally derived sandstone gravel; and exotic, varicolored, rounded chert and quartzite gravel. The exotic chert and quartzite clasts were derived from the Tertiary conglomerate of Dark Canyon (H.H. Doelling and G.C. Willis, personal communication, 1987), which is exposed higher in the Book Cliffs. Terrace deposits that cap benches in the Mancos lowlands consist of moderately well-sorted, sub- to well-rounded, dominantly chert and quartzite gravel. The deposits are up to 17 feet thick (5.2 m) in Floy Canyon and thin to a gravel veneer in many places in the lowlands. The benches appear to be erosional remnants of widespread Pleistocene (?) (Fisher, 1936) alluvial gravel plains.

Pediment-Mantle Deposits (Qap)

Gently sloping, dissected pediments extend from the base of the steep slopes below the Blackhawk/Castlegate escarpment in the Book Cliffs (plate 1). A thin veneer of detritus from the Blackhawk Formation and Castlegate Sandstone protects the underlying Mancos Shale from erosion. The detritus consists of unconsolidated pebble-size gravel and a few cobbles and boulders of sandstone. The most prominent pediments form a discontinuous apron at the base of Christmas and Trough Spring Ridges near the eastern border of the quadrangle (plate 1). Other pediments are found south and east of Hatch Mesa as well as in the northwest corner of the quadrangle. Pediments in the northwest part of the quadrangle are detached, up to 1.5 miles (2 km), from the base of the Book Cliffs escarpment (plate 1). All other pediments in the quadrangle are generally within 0.5 mile (0.8 km) of the Book Cliffs escarpment.

In sections 19 and 23, T. 21 S., R. 18 E., mapped pediment-mantle deposits grade into deposits of terrace gravel (Qat_2) with no discernable change in topography. At both locations, the terrace gravels thicken down gradient from the pediment-terrace interface; it appears that the pediments were in place prior to the deposition of the terrace deposits.

STRUCTURE

The Hatch Mesa quadrangle is in the southern part of the Uinta structural basin and overlies the northwest part of the ancestral Paradox basin. Structural trends associated with both basins are apparent in the quadrangle. The Book Cliffs, which cross the quadrangle, are the erosional escarpment on the southern flank of the Uinta Basin (Fisher, 1936; Hunt, 1956). In the quadrangle, strata north of the Book Cliffs dip gently northward 2 to 3 degrees, except where disturbed by high-angle normal faults. Most of the northwest-trending folds and faults in the quadrangle may be related to dissolution and migration of Pennsylvanian evaporite deposits in the Paradox basin.

Two Paradox basin folds, the Salt Valley anticline and Courthouse syncline, project into the Hatch Mesa quadrangle from the southeast. The Courthouse syncline is a broad, northwest-plunging, asymmetrical syncline (Doelling, 1988) adjacent to the southwest flank of the Salt Valley anticline (Fisher, 1936; Williams, 1964). The syncline forms gently dipping sandstone-capped cuestas in the southern half of the quadrangle. Southeast of the quadrangle, the Salt Valley anticline is a northwest-plunging anticline with a collapsed salt core. A system of northwest-trending normal faults in the northern part of the Hatch Mesa quadrangle is on trend with the Salt Valley anticline, but there is no surface expression of an anticlinal fold.

With the exception of the Little Grand fault, all major faults extend from the eastern border and die out before crossing the northern or western borders of the quadrangle.

Little Grand Fault

The Little Grand fault is traceable between Hatch and Horse Mesas to a stream cut near the southwest corner of section 23, T. 21 S., R. 18 E. (plate 1), where drag folding in the Mancos Shale indicates that the south block has been downdropped. Evidence for the fault is found in the above-mentioned stream cut, in the Green River Gap between Hatch and Horse Mesas, and in the N ½ of section 30, T. 21 S., R. 18 E., where the turbidite sandstone (Kmt) is abruptly truncated.

In the gap between Hatch and Horse Mesas, a thin siltstone bed in the Mancos Shale has been displaced downward approximately 30 feet (9 m) on the southeast side. Hand level sightings from the Blackhawk/Castlegate contact on Hatch Mesa across the gap to the same horizon on Horse Mesa did not reveal any noticeable displacement.

In the northwest corner of section 30, T. 21 S., R. 18 E., an isolated thin ridge of turbidite sandstone (Kmt) strikes parallel to the fault and dips 65°SE into the Mancos Shale (plate 1). Similarly oriented siltstone beds crop out west of the turbidite sandstone.

Horse Mesa Fault

A major fault enters the quadrangle in section 24, and dies out in section 8, both sections are in T. 21 S., R. 18 E. (plate 1). This high-angle normal fault bounds the north side of Horse Mesa and is here named the Horse Mesa fault. The fault begins in section 28, T. 21 S., R. 19 E., east of the quadrangle (Evans and Weeks, 1927). In section 15, T. 21 S., R. 18 E., the lower member of the Neslen Formation is down-dropped next to the Castlegate Sandstone, indicating a displacement of approximately 440 feet (134 m) at this location. Several high-angle, normal, splinter faults with displacement of tens of feet are subparallel to the Horse Mesa fault, forming small horsts and grabens.

Fault South of Christmas Ridge

Previous workers, notably Fisher (1936) and Detterman (1955), mapped a northwest-trending normal fault, downthrown on the northeast side, extending into the quadrangle in section 36, T. 21 S., R. 18 E., and terminating at Horse Mesa in the E ½ of section 21, T. 21 S., R. 18 E. I have traced this fault only as far as shown on plate 1. Fisher (1936) projected the fault from a fault that Evans and Weeks (1927) mapped just east of the quadrangle. He justified this projection primarily on the basis of deformation at the southern end of Christmas Ridge, in section 31, T. 21 S., R. 19 E., approximately 1 mile (1.6 km) east of the quadrangle. I could not find the trace of this fault cutting the Mancos Shale in a ground traverse covering parts of sections 23, 25, 26, and 36, T. 21 S., R. 18 E. (Chitwood, 1990).

Minor Faults

Several small normal faults are exposed in stream cuts in the Mancos Shale lowland east of Hatch and Horse Mesas. These faults may be more extensive than shown (plate 1) but were only traceable for short distances due to surficial cover.

Cause of Faulting

The west-northwest orientation of faults in the Hatch Mesa quadrangle may be controlled by pre-existing structures in the Paleozoic and Precambrian rocks at depth. The faults may have a two-stage history of movement. The initial faulting may have formed during Tertiary deformation related to fold or post-date folding. The second period of movement on the faults may be due to salt dissolution and collapse of the Salt Valley salt-cored anticline located just southeast of the quadrangle. The major period of collapse of the salt anticlines began in the late Tertiary in response to the uplift of the Colorado Plateau (Cater, 1970). Erosion associated with uplift produced deep canyons which breached the salt structures and exposed the salt to circulating ground water (Cater, 1970).

Although Quaternary deposits in the quadrangle are not faulted, salt dissolution and movement may be ongoing at the present time. Oviatt (1988) noted that Quaternary sediments in the collapsed core of the Salt Valley anticline are deformed. Colman (1983) and Goydas (1989) concluded that the Onion Creek diapir in Fisher Valley was active in Quaternary time.

ECONOMIC GEOLOGY

Oil is the only geologic resource presently exploited in the quadrangle. There has been exploration for coal, uranium, and vanadium. Gravel deposits have recently been quarried for highway construction, but no operations are presently active.

Hydrocarbons

Part of the Blaze Canyon oil field extends into the quadrangle in section 12, T. 21 S., R. 18 E. Spudded in 1966, Phillips (presently Southwest Energy's) Blaze "A" No. 1 well in the SW ¼ of section 12 is the only producing well in the quadrangle. As of November 1991, it produced a cumulative total of nearly 34,000 barrels of oil, primarily from the Jurassic Navajo Sandstone. Other wells drilled in the quadrangle (plate 1) were capped as dry holes. Hydrocarbon exploration efforts have targeted fault traps in the north part of the quadrangle.

Coal

The Hatch Mesa quadrangle is in or adjacent to the western part of the Sego coal field as described by Clark (1928) and Doelling and Graham (1972). Coal-bearing strata in the Hatch Mesa quadrangle include the Blackhawk Formation, Castlegate Sandstone, and Neslen Formation. The most significant coal deposits are in the Palisade, Ballard, and Chesterfield coal zones of the Neslen Formation. The Blackhawk Formation and Castlegate Sandstone contain a few very thin, lenticular, bony coal seams.

Coal seams in the Neslen coal zones of the quadrangle range from 0.5 feet (0.15 m) to 2 feet (0.6 m) thick. Doelling and Graham (1972) showed that the Chesterfield coal zone was prospected (Crescent Junction prospect) approximately 0.5 mile (0.8 km) north of the quadrangle in the S½ section 10, T. 21 S., R. 18 E.

With the exception of the Ballard coal zone, which is overlain by the Thompson Canyon Sandstone Bed, coal seams in the quadrangle are commonly overlain by unstable carbonaceous shale or thin sandstone. Generally less than 2 feet (0.6 m) thick, coal seams are bony, shaly, or otherwise impure in many places and occur in a very small area in the north-central part of the quadrangle.

The Neslen coal has a high ash (>10 percent), low sulfur (<1.0 percent) content and heat values ranging from 9,000 to 12,000 Btu/lb (H.H. Doelling, personal communication, 1990). In thin seam areas, like in the Hatch Mesa quadrangle, the coal is likely to carry more ash-contributing constituents, such as bone coal, carbonaceous shale, and rock partings.

Uranium and Vanadium

One prospect for uranium and vanadium is reported in the quadrangle. The High Boy site in section 13, T. 21 S., R. 17 E. consisted of bulldozer cuts and trenches in the Mancos Shale. A ground traverse of section 13 did not locate the site, but it is presumed to be small. No mineralization was observed.

Gravel

Significant gravel deposits exist in the quadrangle. Moderately sorted gravel composed of subangular to well-rounded, fine- to very coarse-gravel-sized quartzite, chert, and limestone derived from the conglomerate of Dark Canyon caps alluvial terraces (Qat_2) over a large part of the Mancos lowlands (plate 1). These deposits are up to 10 feet (3 m) thick in many places. Terrace deposits in the Book Cliffs canyons are similar except they are thicker in many places, and are poorly sorted, sand- to boulder-size sediment. Several gravel pits have been opened in the moderately sorted deposits. The Denver and Rio Grande Western Railroad exploited some of these, including the largest pit, in sections 4 and 9, T. 21 S., R. 18 E. The Utah Department of Highways opened and continues to utilize many of the pits. Several exploration trenches have been bulldozed into the gravel terrace south of the gravel pit in section 9.

GEOLOGIC HAZARDS

Risk to people and manmade structures from geologic hazards is minimized by the low level of development in the quadrangle. There are no settlements or permanent habitations in the quadrangle. Manmade structures are limited to the highway, secondary roads, and the railroad which traverse the quadrangle, and an oil well and supporting structures in the northeast part of the quadrangle.

Rock Falls, Landslides, and Slumps

Major risk areas for rock falls, landslides, and slumps are below the Blackhawk/Castlegate and Sego cliffs. Talus deposits (Qmt) occur in many places below these escarpments. Rock slumps large enough to be mapped (Qms) are found only along the Blackhawk/Castlegate escarpment on the northeast corner of Hatch Mesa (plate 1). Rock falls are also common on the slopes formed by the Neslen and Farrer Formations, and directly below the cuesta-forming turbidite sandstone (Kmt) sequence in the Mancos Shale.

Flash Floods

High surface runoff occurs on the sparsely vegetated sandstone benches and ridges in the Hatch Mesa quadrangle. North of the Book Cliffs escarpment, runoff from heavy rains is channelled into steep-walled canyons, increasing the chance of flash flooding. In the quadrangle, the Book Cliffs escarpment is cut by Horse, Blaze, and Floy Canyons (plate 1). With heavy rains, the risk of encountering a flash flood in these canyons is high. Flash floods erode deep cuts in existing roads at the base of the Book Cliffs, and may damage structures placed adjacent to canyon mouths.

Expanding Clays

Highways in the region are susceptible to damage from expansive clays in the Mancos Shale. Interstate 70 is deformed in many places. The risk of damage from expansive clays is presently limited to the roads and the railroad which cross the quadrangle. However, future development should consider this hazard.

Earthquakes

The risk of earthquake or seismic activity in the quadrangle is low. The Moab fault, about 10 miles (16 km) south of the quadrangle, is the closest major fault with Quaternary movement (Anderson and Miller, 1979). None of the faults mapped in the quadrangle cut the Pleistocene (?) terrace gravel (Qat_2).

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