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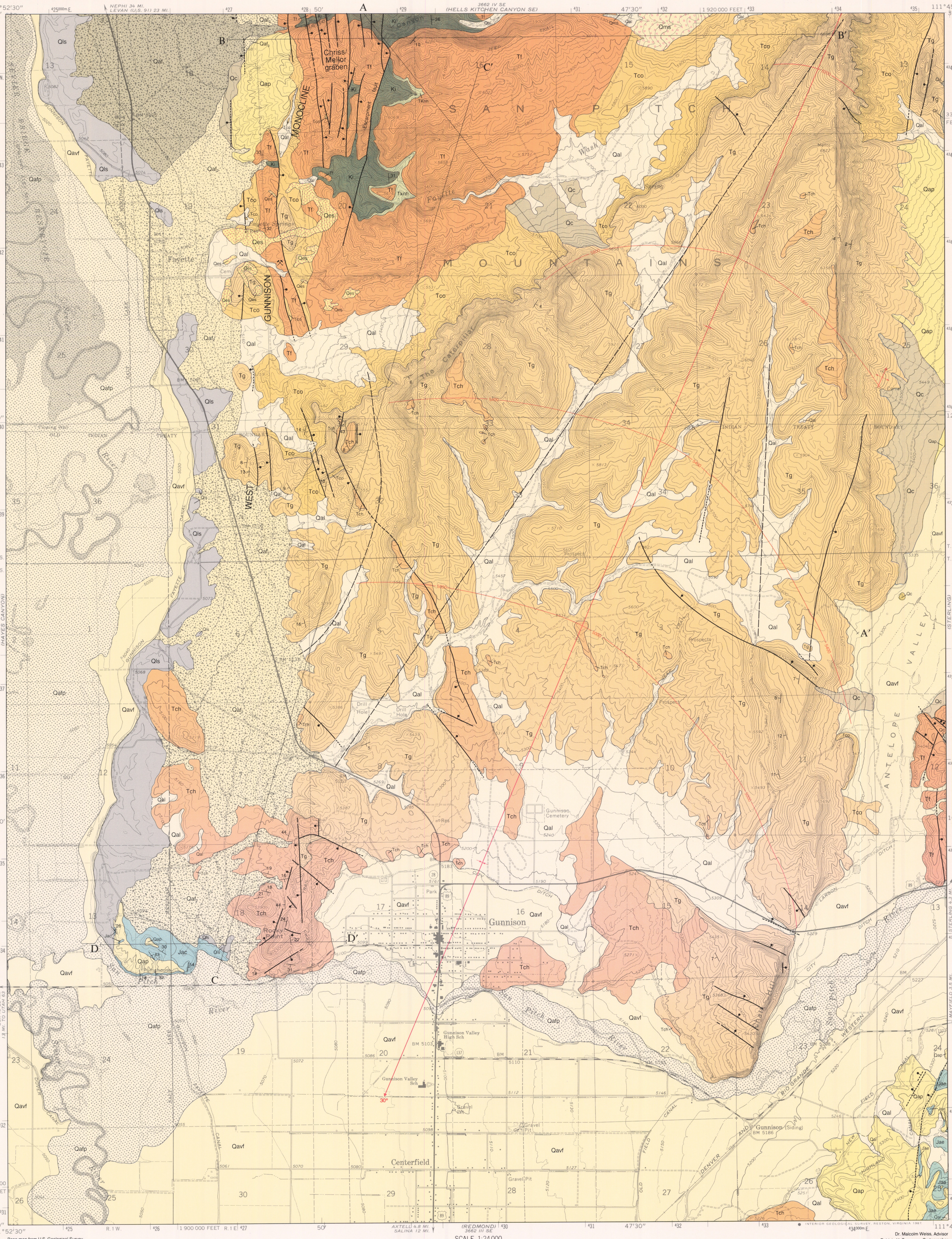


Base map from U.S. Geological Survey, Gunnison Quadrangle, 1966.

Dr. Malcolm Weiss, Advisor
Patricia H. Speranza, Cartographer

PROVISIONAL GEOLOGIC MAP OF THE GUNNISON QUADRANGLE SANPETE COUNTY, UTAH

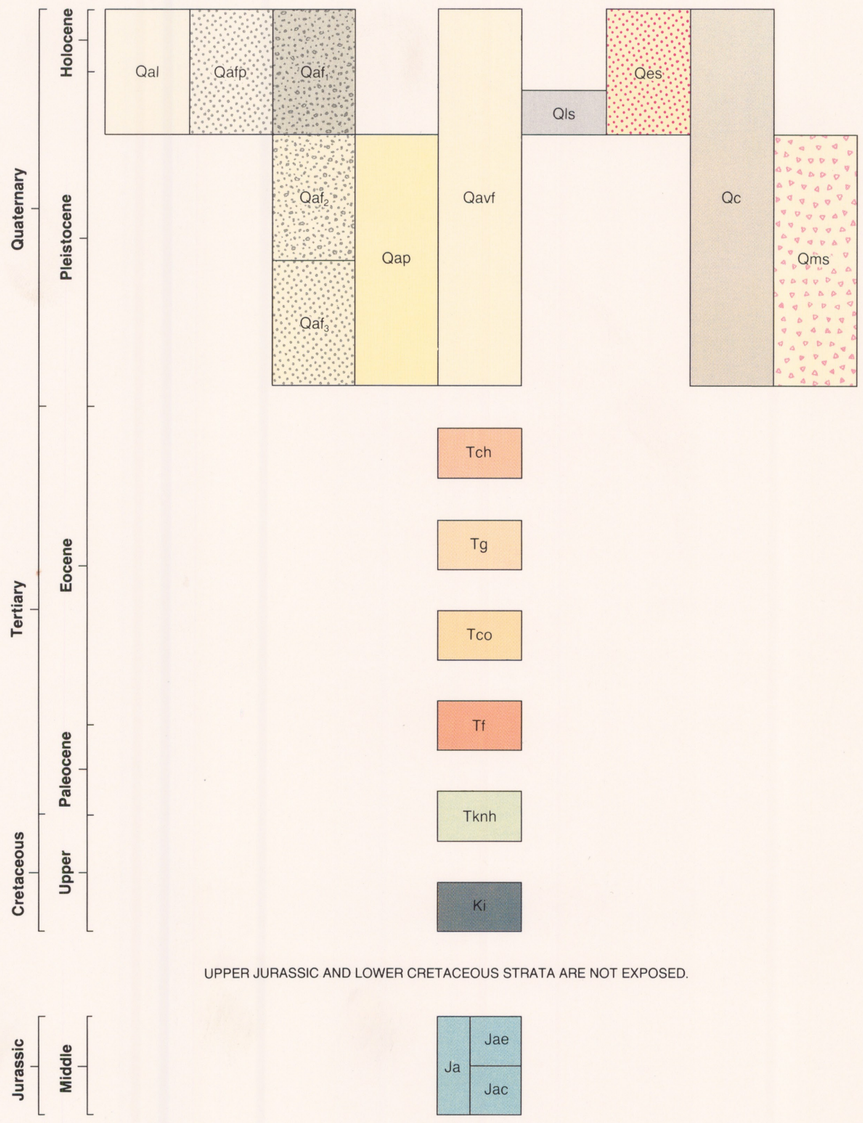
by

Stephen R. Mattox

1992

PERIOD	EPOCH/AGE	FORMATION	SYMBOL	THICKNESS feet (meters)	LITHOLOGY
QUATERNARY	PLEISTOCENE/HOLOCENE	Surficial deposits		0-300 (0-90)	
		Crazy Hollow Formation	Tch	0-300 (0-90)	
TERTIARY	EOCENE	Green River Formation	Tg	460-700 (140-210)	
		Colton Formation	Tco	200-540 (60-165)	
	PALEOCENE	Flagstaff Formation	Tf	340-650 (100-200)	
	MAASTRICHTIAN	North Horn Formation	Tknh	0-80 (0-25)	
CRETACEOUS	CENOMANIAN/TURONIAN EARLY CAMPANIAN	Indianola Group	Ki	8760 (2670)	
		NATURE OF CONTACT IS UNKNOWN			
JURASSIC	CALLOVIAN	Arapien Shale — Unit E	Jae	1200 (365)	
		Arapien Shale — Unit C	Jac	1700 (518)	

CORRELATION OF MAP UNITS



UPPER JURASSIC AND LOWER CRETACEOUS STRATA ARE NOT EXPOSED.

MAP SYMBOLS

- CONTACT - Dashed where location inferred
- HIGH-ANGLE NORMAL FAULT - Dashed where location inferred, dotted where covered; bar and ball on downthrown side
- ANTICLINE
- SYNCLINE - Showing plunge of axis
- 5000 STRUCTURAL CONTOURS - 400 foot contour interval; datum is base of Green River Formation
- LINEAMENTS
- 83 STRIKE AND DIP - Of bedding
- PROSPECT

DESCRIPTION OF MAP UNITS

Qal — Alluvium — *Light-brown, well-sorted mud, silt, and fine sand interbedded with fining-upward, poorly sorted sand and gravel.*

Qafp — Modern flood plain deposits — *Interbedded, well-sorted, fine to medium sand and poorly sorted, structureless, sand and cobbles along the San Pitch River, mud and silt along the Sevier River.*

Qaf1 — Young alluvial-fan deposits — *Poorly sorted and stratified mud, silt, sand, cobbles, and boulders in a fan of distinct morphology at the mouth of Mellor Canyon.*

Qaf2 — Old alluvial-fan deposits — *Coalesced fans of subdued morphology along the west front of the Gunnison Plateau containing mud to boulder-sized clasts.*

Qaf3 — Oldest alluvial-fan deposits — *Mud to boulder-sized clasts in fans isolated by normal faults up to 120 feet (36.5 m) higher than Qaf1 and Qaf2*

Qap — Alluvial cover on pediments — *Locally derived, weakly stratified, poorly sorted cobbles and boulders supported by a matrix of mud, silt, and sand overlying pediment erosional surfaces.*

Qavf — Valley-fill deposits — *Weakly stratified, moderately sorted, pebbles and cobbles supported by a matrix of mud, silt, and sand overlying a structureless, mud-rich layer.*

Qls — Lake Bonneville sediments — *Light-brown mud, silt, and fine sand, very thinly bedded, laminated, structureless, or rare festoon cross-stratification.*

Qes — Eolian sand — *Yellowish-brown, unconsolidated, structureless, well-sorted, fine sand that mantles hills east of Fayette.*

Qc — Colluvium — *Mud, silt, sand, cobbles, and boulders transported by gravity to the base of steep slopes and cliffs.*

Qms — Older mass-movement deposit — *Debris flows consisting of material from the Colton and Green River Formations, appearing as a hummocky and dissected mass.*

Tch — Crazy Hollow Formation — *Grayish-orange or white pebbly conglomerate and cross-bedded, salt-and-pepper sandstone that fines upward to moderate-red mudstones.*

Tg — Green River Formation — *Slope-forming, pale-olive to light-greenish-gray, calcareous mudstones overlain by medium-bedded, freshwater dolomitic limestones with rare tuff and stromatolitic layers.*

Tco — Colton Formation — *Variegated mudstone, thin, pale-green limestone, and yellowish-gray micaceous sandstone in Antelope Valley and Fayette Wash.*

Tf — Flagstaff Limestone — *Grayish-orange and medium-light-gray, dolomitic limestone with less numerous oncolitic and fossil-rich beds.*

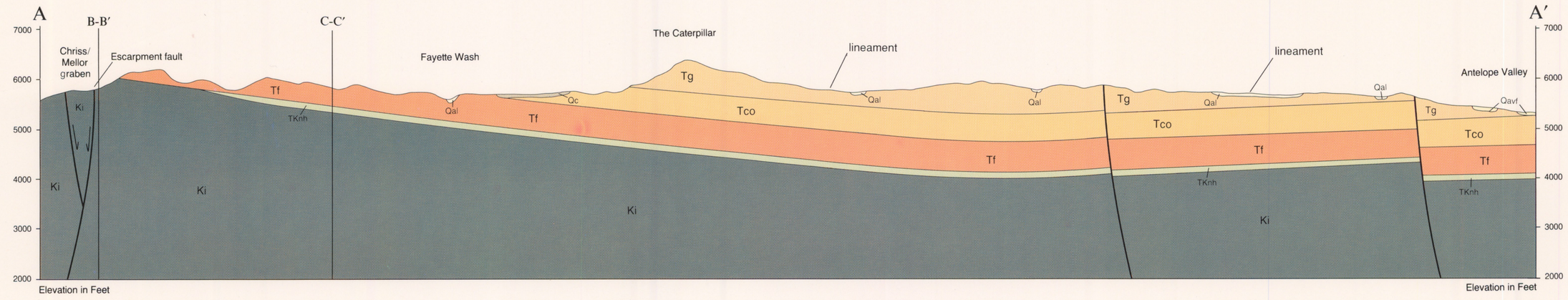
TKnh — North Horn Formation — *Slope-forming, reddish mudstones just to the east of the Escarpment fault.*

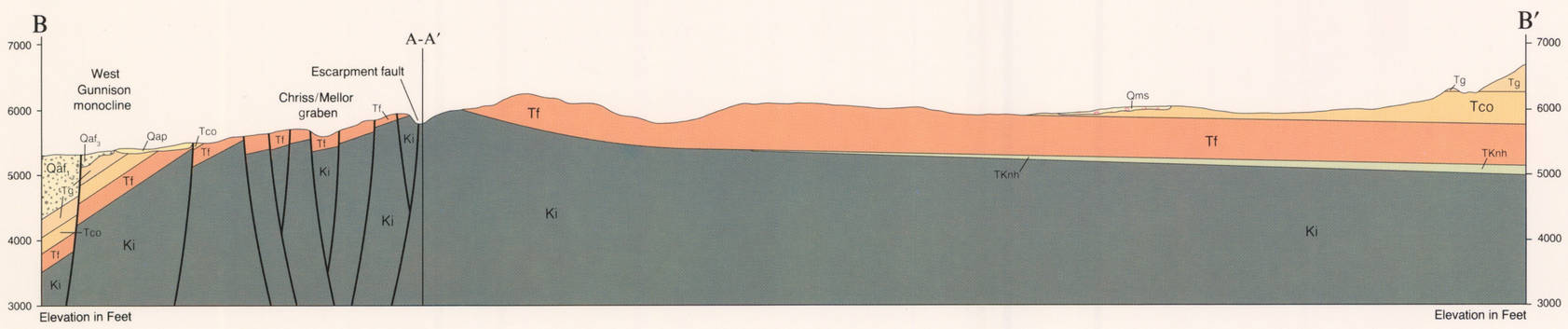
Ki — Indianola Group, undifferentiated — *Grayish, clast-supported conglomerate, grayish-orange sandstone, and pebbly sandstone, often with white to light-gray bleached zone at the top. Upper surface is a regional unconformity.*

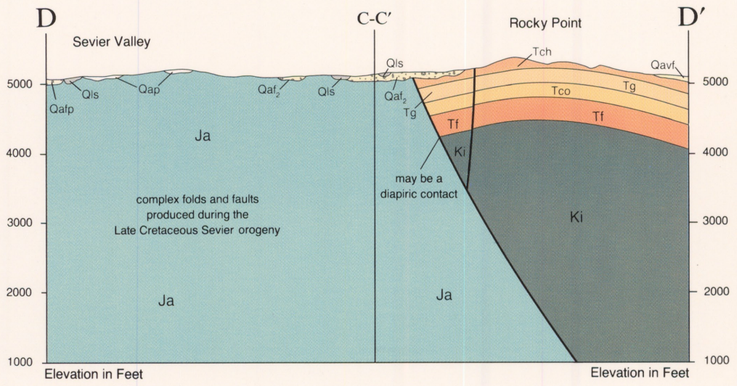
Ja — Arapien Shale, undifferentiated — *(shown only on the cross section) Pale-red to dark-reddish-brown, calcareous mudstones, yellowish-gray, laminated siltstones, and grayish-orange pink, very fine-grained, laminated sandstone.*

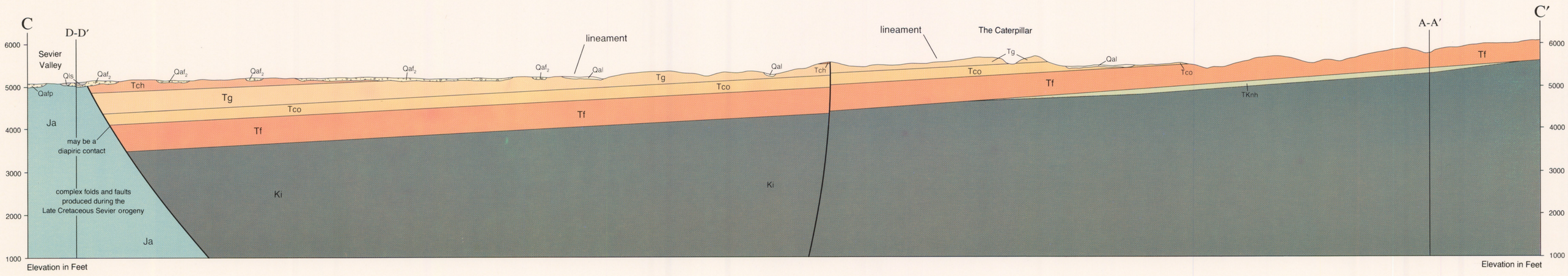
Jac — Unit C of the Arapien Shale (of Hardy, 1952) — *Yellowish-gray, calcareous siltstone and grayish-orange-pink, calcareous sandstone with less abundant olive-gray and pale-brown siltstone and shale beds and rare blotches of pale-red, calcareous mudstone.*

Jae — Unit E of the Arapien Shale (of Hardy, 1952) — *Massive, pale-red to dark-reddish-brown, calcareous mudstone.*









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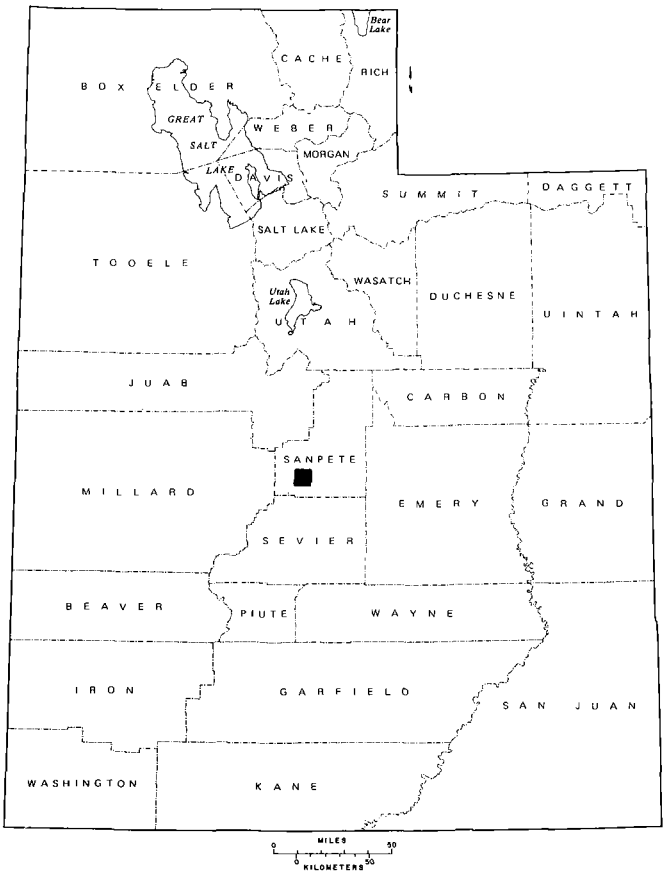
Stephen R. Mattox
Northern Illinois University



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PROVISIONAL GEOLOGIC MAP OF THE GUNNISON QUADRANGLE, SANPETE COUNTY, UTAH

Stephen R. Mattox
Northern Illinois University

ABSTRACT

Approximately 17,180 feet (5,240 m) of Middle Jurassic to Holocene rocks underlie the Gunnison quadrangle: 1,870 feet (570 m) of these strata are exposed. The oldest sequence, the Middle Jurassic Arapien Shale, records sedimentation under shallow marine conditions in an inland sea. During the Late Cretaceous, coarse clastic material was shed eastward from the Sevier orogenic belt into the western foredeep of the foreland basin to produce the second sequence, the Indianola Group (undifferentiated). Erosion followed, producing a regional unconformity. Deposition of a third sequence followed, consisting of fluvial and lacustrine units. Surficial deposits include stream alluvium, colluvium, flood-plain, valley fill, alluvial fan, and mass movement, plus alluvial cover on pediments, eolian sand, and Lake Bonneville sediments.

Structure in the quadrangle is dominated by the juxtaposition of Arapien Shale against gently dipping Tertiary strata or unconsolidated surficial deposits. The structural displacement required to generate this relationship is at least 10,300 feet (3,140 m) with most of the movement resulting from eastward-directed thrusting during the Late Cretaceous Sevier orogeny. The overlying coarse clastic sequence was deformed to produce broad, gentle folds; the western limb of a syncline underlies most of the quadrangle. A second syncline, defined by the Tertiary strata, is probably the result of relatively minor, secondary salt diapirism. Subsequent removal of evaporites within the Arapien Shale may have resulted in the development of a monocline along the margin of the plateau. The presence of two grabens suggests extensional tectonism has also played a role.

The southern termination of the Wasatch fault zone lies within the quadrangle; therefore, earthquakes are a potential hazard. No recent fault scarps were mapped. Damage from flooding has occurred in historical time.

Gravel is the only economic deposit currently being exploited. Additional deposits include dimension stone and metals.

INTRODUCTION

The Gunnison quadrangle is approximately 110 miles (175 km) south of Salt Lake City at the southwestern termination of the Gunnison Plateau (San Pitch Mountains) in Utah. The Sevier and the San Pitch Rivers cross the quadrangle just west and south of the plateau, respectively. U.S. Highway 89 connects the town of Gunnison to other points in Sevier and Sanpete Valleys. Utah State Highway 28 continues northward along the west margin of the plateau.

Dutton (1880) noted the Cretaceous and Tertiary strata and the synclinal nature of the Gunnison Plateau. Spieker and Reeside (1925) and Spieker (1946, 1949) defined the stratigraphic units and discussed the regional structural framework of central Utah. The quadrangle is the northeast portion of the 15-minute quadrangle mapped by Gilliland (1951; 1963). Adjacent mapping includes Mattox (1987) to the north, (Weiss (in preparation) to the east, Witkind (1981) to the south, Peterson (in preparation) to the west, and Willis (1991) to the southwest. Mattox (1986) describes in detail the Hells Kitchen Canyon SE quadrangle to the north, which is very similar to the Gunnison quadrangle in both stratigraphy and structure. This portion of central Utah is included on the 1:100,000 map of Witkind and others (1987). Authors have recently advanced diapiric and thrusting models to explain the complex geology of the region (Standlee, 1982; Witkind, 1982, 1983; Witkind and Page, 1984; Lawton, 1985; Villien and Kligfield, 1986; and Mattox and Weiss, 1987a and b).

STRATIGRAPHY

The exposed bedrock of the Gunnison quadrangle ranges in age from Middle Jurassic to Tertiary (Eocene) and has a total thickness of 5,300 feet (1,615 m). The oldest formation, the Jurassic Arapien Shale, is the only marine unit. Above the Arapien lies a package of continental sedimentary rocks that includes the Upper Cretaceous Indianola Group, the Upper Cretaceous-Tertiary North Horn Formation, the Paleocene-Eocene Flagstaff Limestone, and the Eocene Colton, Green River, and Crazy Hollow Formations. Surficial deposits include Lake Bonneville sediments, eolian sand, alluvial cover on pediments, mass-movement deposits, alluvial-fan deposits, floodplain and valley-fill deposits, colluvium, and stream alluvium.

Lithologic units exposed elsewhere on the plateau but absent in surface exposures in the quadrangle are the Late Jurassic Twist Gulch and the late Early Cretaceous Cedar Mountain Formations (Weiss and Roche, 1988). This sequence of strata lies above the Arapien and beneath the Indianola and is probably present in the subsurface of the Gunnison quadrangle. The nearest Twist Gulch surface exposures are 5 miles (8 km) to the northeast along the east front of the Gunnison Plateau (Witkind and others, 1987) and 15 miles (24 km) to the north at Little Salt Creek (McDermott, in preparation). In the Chevron U.S.A. #1 Chriss Canyon well, 14.5 miles (23.2 km) to the north of Gunnison, the Twist Gulch is 460 feet thick (140 m) and consists of reddish-brown shales, siltstones, and sandstones (Standlee, 1982). The Cedar Mountain Formation is exposed in southern Sanpete Valley, a mile (1.6 km) east of Antelope Valley. There, grayish-red, reddish-brown, and light-red mudstones are most common, plus rare cobble conglomerate, gray sparite, and white micrite beds (Weiss and Roche, 1988). The minimum thickness at this outcrop is 438 feet (133 m).

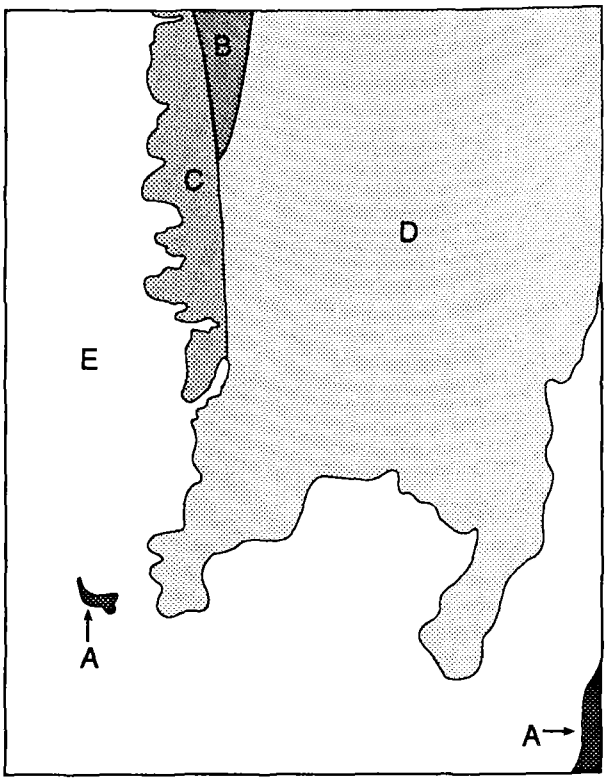

Figure 1. Simplified map of the Gunnison quadrangle showing principal structural and physiographic features: A) low hills of Jurassic Arapien Shale, B) valley defined by the Chriss/Mellor graben, C) west-dipping strata of the West Gunnison monocline, D) plateau uplands developed on a syncline of Tertiary strata, E) gently sloping or horizontal surfical deposits of the Sanpete and the northern Sevier valleys.

JURASSIC SYSTEM

Arapien Shale – The Arapien Shale (Ja) is exposed at two localities in the southern part of the quadrangle (figure 1). Where possible the formation is divided into the units of Hardy (1952) (units A through E; only units C and E are exposed in the Gunnison quadrangle); terminology follows the usage of Witkind and Hardy (1984).

A small, crescent-shaped hill 2 miles (3.2 km) west of Gunnison is cored by Arapien Shale and capped by Quaternary alluvial cover on pediments. Along one side, a steep bank of well-exposed Arapien has been cut by the San Pitch River. The most common rock types are yellowish-gray, calcareous, laminated siltstone, with low-amplitude ripples (less than one-quarter inch) (0.6 cm) common, and thin layers (less than 1.5 feet) (0.5 m) of resistant, grayish-orange-pink, very-fine-grained, calcareous, laminated sandstone. Less abundant olive-gray and pale-brown siltstone and shale are also present. Rare, pale-red, calcareous, laminated mudstone occurs as blotches. Hardy (1952) placed these rocks in his Unit C. Exposed thickness is estimated to be 1,700 feet (518 m).

The Arapien Shale is also exposed in the sparsely vegetated, rounded hills along the margin of the White Hills in the southeast corner of the quadrangle (figure 1). Pale-red to dark-reddish-brown, calcareous mudstones are part of Hardy's Unit E; no salt or gypsum was found at the surface of this exposure, though it is common elsewhere (Hardy, 1952; Willis, 1991). The massive nature of Unit E mudstone does not allow attitude or thickness measurements; however, assuming that the nearly vertical attitudes of Unit D just to the east in the Sterling quadrangle (Weiss, in preparation) continue westward, the exposed thickness of Unit E is approximately 1,200 feet (365 m).

CRETACEOUS SYSTEM

Indianola Group (undifferentiated) — The Late Cretaceous Indianola Group (undifferentiated) (Ki) is exposed in the Chriss/Mellor graben, along a major normal fault — the Escarpment fault of Mattox (1987), and in the deeply dissected

canyons just east of the fault. Light-gray, clast-supported conglomerate, typical of the Indianola, forms the walls of Mellor Canyon. There, pebbles and cobbles of red, purple, white, and banded orthoquartzite and medium- to light-gray limestone occur in a yellowish-gray matrix of poorly sorted, fine to coarse sand. The conglomerate is massive and commonly grades upward into pale-yellowish-brown to yellowish-gray sandstone that varies from poorly sorted, fine- to coarse-grained sand to well-sorted, medium-grained sand. The sandstone layers are 5 to 10 feet (1.5 to 3 m) thick, structureless or thinly bedded, continuous sheets or discontinuous channels. Attitudes are nearly horizontal in the Chriss/Mellor graben; immediately east of the Escarpment fault strata dip 26 degrees to the east.

The base of the Indianola is not exposed here nor farther north for about 15 miles (24 km). The 890 feet (270 m) of conglomerate measured by Mattox (1987) just east of the Escarpment fault represents the upper part of the Indianola. The complete thickness is probably similar to the 8,760 feet (2,670 m) in the Chevron U.S.A. #1 Chriss Canyon well (Standlee, 1982). In Mellor Canyon the top of the Indianola is marked by a pronounced angular unconformity with the North Horn Formation or Flagstaff Limestone. Here, two paleotopographic highs of Indianola Group carry no North Horn beds and the Flagstaff Limestone oversteps the North Horn to lie directly on the Indianola conglomerate. One of the paleotopographic highs occurs in lower Mellor Canyon, in sections 16 and 17, T. 18 S., R. 1 E. A second, of larger areal extent, is exposed in the Chriss/Mellor graben and extends to the north from section 20, T. 18 S., R. 1 E., about 3 miles (4.8 km) into the Hells Kitchen Canyon SE quadrangle.

Fouch and others (1983) assign a Turonian to Campanian age to the Indianola Group. Hardy and Zeller (1953) classified these same strata as the late Campanian Price River Formation. Based on regional clast size variation Witkind (1990) also assigns these conglomerates to the Price River. Based on detailed stratigraphic descriptions of several sections along the southwest front of the Gunnison Plateau, the Late Cretaceous conglomerates are here assigned to the Indianola Group. In a description of conglomerate clasts, Spieker (1949) noted "limestone, which is abundant in all but the uppermost Indianola conglomerates, and [which] reappears in the North Horn conglomerates, is commonly rare and locally absent" within Price River conglomerates. The percent of limestone clasts ranges from 21 to 40 in the lower to middle portion of the exposed Indianola strata in Mellor Canyon, confirming Spieker's observations (Mattox, 1986). In addition, the reappearance of a major angular unconformity beneath the North Horn Formation in Timber Canyon (Mattox, 1987) was not reported by Hardy and Zeller (1953). Conglomerates immediately beneath the unconformity are bleached and dip at relatively high angles (14 to 28 degrees) to the east. Unconformities between North Horn and Price River strata commonly show much less discordance. For example, in Red Canyon 5 miles (8 km) to the west the discordance is less than 5 degrees (Witkind and Page, 1984). The relatively high abundance of limestone clasts and the nature of the unconformity suggests that the conglomerates are part of the Indianola Group.

CRETACEOUS AND TERTIARY SYSTEMS

North Horn Formation — The North Horn Formation (TKnh) consists primarily of soft mudstone and is well exposed in the two deep canyons just east of the Escarpment fault. The best exposure is in NW¼SW¼ section 17, T. 18 S., R. 1 E., where a resistant cap of Flagstaff Limestone protects a 15-foot (4.5 m) section of reddish mudstone. Where unprotected the same mudstone forms a slope. Reddish-orange, fine-grained sandstone and red conglomerate form rare, interspersed ledges.

The fluvial North Horn Formation filled depressions on the late Campanian erosional surface developed on the Indianola conglomerate (Fouch and others, 1983); the distribution and shape of the Indianola paleotopographic highs dictated the location of North Horn deposition. The contact with the overlying Flagstaff Limestone is sharp and conformable. Constraining the age of the formation in central Utah has been difficult. For the Wasatch Plateau, Spieker (1946) used vertebrates and mollusks to assign a Late Cretaceous to early Paleocene age to the North Horn. Fouch and others (1983), on the basis of exposures in Sanpete Valley, assigned a Paleocene-Eocene age to the formation. Magnetostratigraphic studies currently in progress by T.L. Lawton (personal communication, 1989) suggest that the basal portion of the North Horn is Late Cretaceous in age at some localities on the Gunnison Plateau; early Tertiary ages have been determined for some of the finer grained rocks in the upper part of the formation. Until definite evidence is presented for the rocks in the Gunnison quadrangle, the author chooses to accept a Late Cretaceous (Maastrichtian) to Paleocene age for the North Horn Formation. The maximum thickness exposed in the quadrangle is 80 feet (25 m).

TERTIARY SYSTEM

Flagstaff Limestone — The Paleocene-Eocene Flagstaff Limestone (Tf) is exposed in fault blocks and canyons south of Mellor Canyon and in a road cut through a west-dipping slope along U.S. Highway 89 in the eastern portion of the quadrangle. The rocks east of the Escarpment fault form a southeast-facing dipslope which is also the west limb of a broad syncline developed in the Tertiary units. Intramicrite and micrite dominate the Flagstaff; the formation also contains some oncolitic and fossiliferous limestone beds. The grayish-orange and medium-light-gray intramicrites contain rounded carbonate clasts up to one-eighth inch (0.3 cm) in diameter. The micrites are dense and range from pale yellowish brown to light gray. Light-gray oncolitic limestone with oncolites up to one inch (2.5 cm) in diameter lies on the Indianola conglomerate in SE¼NW¼ section 20, T. 18 S., R. 1 E. Pinching out of the North Horn just to the east and the presence of oncolitic limestone support the existence of an Indianola paleotopographic high covered by lake-margin lithofacies (Weiss and Mattox, 1988). Gastropod-rich limestone occurs as float near the top of several Flagstaff hills and in places in the creek bed in SW¼SW¼ section 15, T. 18 S., R. 1 E.

Approximately 340 feet (103 m) of Flagstaff Limestone are poorly exposed in the south wall of Mellor Canyon. Godo (1979) measured 472 feet (144 m) of limestone in the north wall of the canyon which he believes to represent the lower-middle to lower-upper portion of the formation. An approximate maximum thickness of 650 feet (200 m) was determined east of the Escarpment fault using the geometry of the dipslope and the total lateral extent of the formation.

Colton Formation — Excellent exposures of the early Eocene (Spieker, 1946) Colton Formation (Tco) occur in a strike valley that separates the resistant limestones in the Flagstaff dipslope from the resistant Green River limestones which cap The Caterpillar. The formation thins to the southwest from a maximum thickness of 537 feet (164 m) in upper Fayette Wash (Volkert, 1980) to only 200 feet (60 m) near the plateau margin. The strata dip southeast approximately five degrees and form part of the west limb of the syncline. A large amphitheater in which the Colton is well exposed is in the extreme northeast corner of the map area (section 13, T. 18 S., R. 1 E.). The base of the section is not exposed. A small area of poorly exposed Colton crops out near the mouth of Antelope Valley. There, slope-forming mudstones and claystones are abundant and range from yellowish-gray and pale-yellowish-green to reddish-brown in color. White to light-gray, argillaceous, dolomitic limestone forms thin, discontinuous ledges. Limestone, very pale orange, dense and slabby, is laterally continuous and weathers to slopes covered by slabby float. Fine-grained, well-sorted, micaceous sandstone occurs in discontinuous channels up to 8 feet (2.4 m) thick. Volkert (1980) describes the lithofacies within the Colton in some detail. The Colton-Green River contact is conformable and placed at the top of the uppermost red mudstone, as suggested by Marcantel and Weiss (1968).

Green River Formation — The Eocene Green River Formation (Tg) covers most of the quadrangle. The best exposures are found along cuestas at the margins of the syncline: capping The Caterpillar, the ridge bounding the west side of Antelope Valley, and the east face of Chalk Hill. A roadcut 1.5 miles (2.4 km) north of Gunnison on Highway 28 also offers an excellent exposure. On the gentle slopes of the syncline only resistant limestone or chert layers have escaped cover by vegetation. The Green River Formation is divided into a lower mudstone lithofacies and an upper carbonate lithofacies. Slope-forming, pale-olive to light-greenish-gray, calcareous mudstones dominate the mudstone lithofacies. Interbedded white dolostones are clay-rich, structureless, and weather to thin ledges approximately 1 foot (0.3 m) in thickness. Pale-yellowish-orange micritic limestone is dense, thin bedded, and weathers to thin (less than 1 inch) (2.5 cm) platy slabs. The carbonate lithofacies consists of limestone, dolomitic limestone, chert, and volcanic tuff. Limestones of very pale orange contain minor amounts of clay and range from laminated to medium bedded. The limestones weather along irregular surfaces to produce slabby ledges. Laterally linked hemispheroid stromatolites are rare and occur in layers less than 3 inches (7.5 cm) thick. Thin beds of very-pale-orange, grain-supported, oolitic limestone form ledges that weather to platy float. Pale-yellowish-orange, dolomitic limestone is structureless and weathers to slabs up to 6 inches (15 cm) in thickness. Chert increases in thickness and abundance from 2 inch (5 cm) thick layers near the base of the carbonate facies to laterally continuous layers with a maximum thickness of 13 feet (4 m) near the top of the formation. Discernible internal structures are rare but, where present, suggest brecciation and replacement of carbonate beds. The chert is variegated with moderate reddish-brown beds most common and with less common white, light-gray, or light-blue layers. Rare beds of volcanic tuff occur near the base of the carbonate lithofacies in Chalk Hill. The tuffs are pinkish gray, contain conspicuous biotite, and seldom exceed one foot (0.3 m) in thickness. The high percentage of carbonate within these tuffs suggests they may be the result of airfall into the lake.

Conspicuously absent from the Gunnison quadrangle is the clastic/carbonate lithofacies recognized 5 miles (8 km) to the north in the Hells Kitchen Canyon SE quadrangle (Mattox, 1986, 1987). That facies consists of nearly equal amounts of sandstone and micritic limestone and records the close proximity of the latter quadrangle to the west margin of Lake Uinta. Detailed stratigraphic descriptions of the Green River Formation at four widely separated localities in the quadrangle (Chalk Hill, northern Antelope Valley, center of section 22, T. 18 S., R. 1 E., of upper Fayette Wash, and SE¼SE¼ section 29, T. 18 S., R. 1 E., of The Caterpillar) show that only a single, thin (6 inch) (15 cm), laterally discontinuous sheet of sandstone was found (upper Fayette Wash), suggesting that most Green River sediments were deposited offshore and away from clastic input. The significant similarity of the vertical succession of lithofacies at the four locations reflects the uniform depositional conditions that persisted across the area. The presence of stromatolites, oolites, and mudcracks implies shallow lake levels and intermittent subaerial exposure.

A complete section of Green River strata is well exposed in SE¼SE¼ section 29, T. 18 S., R. 1 E., of The Caterpillar. Total thickness is 460 feet (140 m) of which 316 feet (96 m) is mudstone facies. Using dip measurements and the spatial relations of the Tertiary strata in upper Antelope Valley, a maximum thickness of 500 to 700 feet (150 to 210 m) is estimated for the formation.

Crazy Hollow Formation — Pebbly conglomerate, salt-and-pepper sandstone, and reddish mudstone of the late Eocene Crazy Hollow Formation (Tch) are exposed along the high ridges west of Antelope Valley, along the crest of The Caterpillar, and in the low hills surrounding Gunnison. The best exposures are in SE¼SE¼ section 26, T. 18 S., R. 1 E., in SW¼SW¼ section 29, T. 18 S., R. 1 E., in SE¼SE¼ section 5, T. 19 S., R. 1 E., and at Rocky Point (section 18 and W½ section 17, T. 19 S., R. 1 E.).

One exposure (SE¼SE¼ section 5 - NE¼NE¼ section 8, T. 19 S., R. 1 E.) offers considerable insight into the nature of the Crazy Hollow (Mattox and Weiss, 1989). Here, a broad, shallow depression within the Green River was filled in by the first influx of clastic material. Attitudes of beds immediately outside and along the margins of the depression are parallel in

both units, which suggests both a conformable contact and that the depression represents original paleotopographic relief in the Green River basin, not an erosional channel into the lake basin (figure 2a). The lower portion of the depression has a sharp contact with the underlying Green River chert (replaced limestone) and is filled with grayish-orange, well-sorted, pebbly conglomerate. Pebbles consist of black, gray, and white chert, gray limestone, and lesser quantities of yellowish-orange limestone. The latter component tends to form angular clasts and probably represents minor erosion of soft, weakly cohering Green River lime mud during the first clastic influx. The basal conglomerate grades upward into an interbedded, pebbly conglomerate and sandstone layer, which fills the remainder of the depression, and then spreads out laterally into a sheet. Conglomerate decreases in abundance upward as large-scale cross beds become more common. The sandstone is grayish orange to light brown and, in a few places, bleached white. The sandstone is dominated by chert and limestone grains with minor amounts of lithics and feldspar.

Additional details of the transition from lacustrine to fluvial sedimentation are exposed along the margins of the depression (figure 2b). There, a thin tongue of Crazy Hollow sand interfingers with the Green River Formation, demonstrating coeval deposition of the two units. As the clastic influx increased, lacustrine sedimentation ceased and fine-grained clastics spread out laterally as sheets. Slope-forming, moderate-red, calcareous mudstones are common and exposed in the low hills northeast of Gunnison. Rare, pale-orange or very light gray, micritic limestones occur as resistant ledges less than 10 feet (3 m) in thickness. Total thickness of the formation is unknown. An incomplete thickness (no top) of 65 feet (20 m) was measured starting in SE¼SE¼ section 5, T. 19 S., R. 1 E., north of Gunnison and moving to the southeast. Although Rocky Point offers good exposures of the various Crazy Hollow lithofacies, chaotic faulting has foiled attempts to measure the thickness of the Crazy Hollow in that area, but it may be up to 300 feet (90 m) thick.

A late Eocene age is assigned to the Crazy Hollow in the Salina area based on radiometric ages and stratigraphic relations (Willis, 1985). Regional aspects of the Crazy Hollow are described in Norton and Weiss (1985) and Norton (1986).

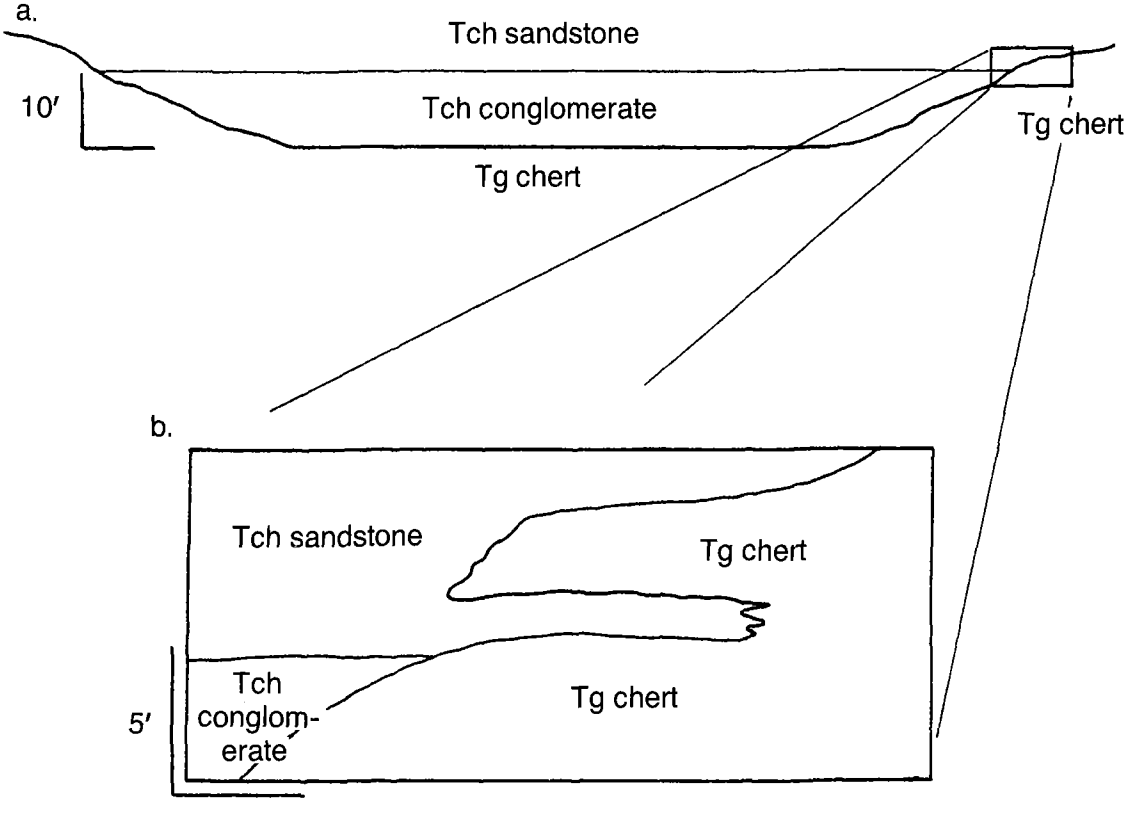

Figure 2. a. *Geometry of Crazy Hollow Formation clastics that filled paleotopographic relief within the Green River basin.* ***b.*** *Details of the interfingering between the Green River and Crazy Hollow Formations.*

QUATERNARY SYSTEM

Valley-fill deposits — A large area of the southern portion of the quadrangle consists of nearly horizontal valley-fill deposits (Qavf). Cox Rock Products, Inc. gravel quarry in N½ section 28, T. 19 S., R. 1 E. provides good exposures of the deposit. Pebbles and less abundant cobbles are supported in a matrix of mud and silt. Clasts reflect a Flagstaff Limestone source with some chert (Green River?, Crazy Hollow?) and quartzite from the Indianola. No volcanic clasts were found. The deposit is weakly stratified and moderately sorted. Thickness is approximately 30 feet (9 m). The top of a mud-rich layer is exposed beneath the thick gravel sequence. At the abandoned Hale gravel quarry in SW¼SW¼ section 21, T. 19 S., R. 1 E., the matrix contains more sand and rare, well-sorted pebble-rich, grain-supported layers. The lower, fine-grained, valley-fill deposits are interpreted to be of floodplain or lacustrine origin. The upper, coarse-grained deposits were probably derived from an early precusor to the modern San Pitch River. Although a Quaternary age is assigned to the valley-fill deposits, Tertiary beds are likely at depth.

Alluvial-fan deposits — A well-developed alluvial fan (Qaf_1) extends westward from the mouth of Mellor Canyon. The deposit probably represents a period of growth and coalesence in the late Pleistocene. Channels cut in the upper portions of the fan expose poorly sorted and poorly stratified mud, sand, and pebbles. Discontinuous sand and pebble layers are as much as one foot (0.3 m) in thickness. Boulders and cobbles are rare and are found only in the upper fan. The clasts, which are weakly cemented by calcite, reflect local bedrock in composition, with Flagstaff and Indianola clasts being most common. North of Rocky Point several fans have coalesced (Qaf_2) along the margin of the plateau. These fans are relatively older than those described above based on their subdued morphology and lower elevation. The oldest alluvial fan deposits are of similar composition and internal stratigraphy (Qaf_3) and have been uplifted and isolated by a fault at the mount of Mellor Canyon. Both the Qaf_2 and Qaf_3 deposits may contain Tertiary beds near their base.

Alluvial-cover on pediments — Pediments and their overlying alluvial cover (Qap) are found at four locations in the quadrangle. All pediments are dissected and provide small windows to the bedrock below. Erosional surfaces dip valleyward in each case. Clast composition reflects local geology. South of Mellor Canyon a pediment truncates the Flagstaff Limestone and the alluvial cover contains boulders and cobbles of Flagstaff Limestone, Green River chert, and Indianola conglomerate in a silty matrix with small amounts of sand and mud. The alluvial cover on the northwest flank of the White Hills consists of gravel of dark-gray and green limestone from the Flagstaff, bleached Crazy Hollow sandstone, and brown Green River chert. Cobbles are supported by a fine-grained matrix. The surface of the pediment slope deposit abuts against low hills of the Arapien Shale in the White Hills. A third pediment has also truncated the Arapien Shale just west of Rocky Point. The alluvial cover is poorly sorted, weakly cemented gravel containing clasts of Flagstaff Limestone, Indianola quartzite and limestone, and Green River chert; it is weakly stratified and shows westward imbrication. The lack of volcanic clasts suggests that most of the alluvial cover is locally derived from the San Pitch River drainage basin and not from the upstream portion of the Sevier River. The pediments at Rocky Point occur at two levels, 120 and 50 feet (36 and 15 m) above the present river level; alluvial cover at both levels is identical. A change in base level, normal faulting, or local salt diapirism may be responsible for the present vertical discontinuity between what appears to have once been a single pediment. Lake Bonneville sediments onlap the pediment slope deposits in section 13, T. 19 S., R. 1 E., suggesting a minimum age of Pleistocene. The fourth pediment has developed on Green River limestone in northern Antelope Valley.

Mass-movement deposit — A small area of Pleistocene mass-movement deposit (Qms) occurs in NE¼ section 15, T. 18 S., R. 1 E. along the north margin of the map. The deposit is the southern termination of a more extensive deposit to the north (Mattox, 1987). The surface of the mass is hummocky, dissected, and lacking typical landslide features (scarp, toe) thus implying a relatively old age (Pleistocene). The deposit includes debris derived from mudstones of the Colton and Green River Formations and chert and limestone from the Green River Formation.

Absent from the Gunnison quadrangle are Holocene mass-movement deposits such as those common to the north (Mattox, 1987; Auby, 1991; Banks, 1991; Biek, 1991; McDermott, in preparation). The low relief, limited faulting, and low number of springs in the Colton Formation may explain the absence of any young slides in the Gunnison quadrangle.

Colluvium — Unconsolidated, poorly sorted deposits of Colton and Green River mudstones and limestones (Qc) have been transported by gravity to the base of steep slopes along The Caterpillar and in Antelope Valley.

Lake Bonneville sediments — A low ridge of unconsolidated Lake Bonneville sediments (Qls) parallels the Sevier River near the west margin of the Gunnison quadrangle. Exposures in gulches reveal that the lake deposits rest on gently west-dipping alluvial-fan sediment; therefore, prograding alluvial fans filled ancestral Sevier Valley prior to transgression and infilling by Lake Bonneville. Subsequent erosion by the modern Sevier River and farming have created the present outcrop pattern. The Bonneville sediments are bounded on the west by the Gunnison-Fayette canal and they thin to the east and merge with the upper surface of the alluvial-fan deposits. The light-brown lacustrine sediment consists of fine sand to mud and is dominated by quartz with lesser amounts of feldspar, hornblende, and biotite. The sediments are commonly laminated or very thinly bedded. Structureless layers and layers displaying festoon cross stratification are rare. Erosional surfaces of minor amplitude are relatively common, occurring at intervals of 5 to 10 feet (1.5 to 3 m). Maximum thickness of the deposit is 40 feet (12 m).

Currey (1982) mapped the approximate location of Lake Bonneville in this portion of Sevier Valley, using a shoreline elevation of 5,105 feet (1,555 m). No Bonneville sediments have

been observed to the south (G.C. Willis, personal communication, 1987) indicating that the deposits of the Gunnison quadrangle are the southernmost known Bonneville remnants in Sevier Valley. Shoreline elevations in the map area approach 5,100 feet (1,554 m). In an effort to constrain the age of the lake at this high level, snail shells were collected from laminated silts approximately 2 miles (3.2 km) north-northwest of the town of Fayette. In order to collect enough sample, several layers across unconformities were sampled. After carbon-13 adjustment the snail shells and fragments provided an age of 13,290 ± 200 years B.P. (lab number Beta-24687). This age is young with respect to the Bonneville flood (14,500 years B.P., Currey and Oviatt, 1985) and is probably the result of contamination by young carbonate carbon in the ground water (C.G. Oviatt, personal communication, 1988). Although the date does not constrain the age of the lake near its maximum extent, it is a useful minimum-limiting date for the deposit and supports the classification of the sediments as part of the Bonneville alloformation and not the older (75,000 to 30,000 years B.P.) Alpine Formation of Varnes and Van Horn (1984).

Eolian sand — Well-sorted, yellowish-brown, fine sand (Qes) forms a discontinuous mantle on several low hills east of Fayette. The sand is structureless, unconsolidated and, for the most part, anchored by vegetation. Maximum thickness is at least 10 feet (3 m). The irregular distribution (plate 1) and high elevation (5,400 feet; 1,646 m) of these sand deposits suggest that they are the result of eolian reworking of Bonneville and valley-fill sediments.

Modern flood-plain deposits — Stratified deposits within the modern flood plain of the San Pitch River (Qafp) consist of well-sorted, thinly bedded, fine to medium sand; poorly sorted, structureless layers of granules and cobbles in a sandy matrix; and beds of moderately sorted cobbles and pebbles in a matrix of coarse sand. Modern flood-plain deposits of the Sevier River consist of mud and silt deposited during highstands of the Sevier Bridge Reservoir. Fine-grained sediment has filled oxbows in sections 24 and 25, T. 19 S., R. 1 E.

Alluvium — Depressions in the low-relief Green River hills have been filled by mud and fine sand of slopewash and fluvial origin (Qal). Along the margins of the plateau the deposits are gradational with alluvial-fan and valley-fill deposits and they reflect local sources. These deposits are unconsolidated and commonly stratified with layers up to 1 foot (0.3 m) in thickness. Interbedded poorly sorted cobble layers are up to 6 inches (15.2 cm) thick and fine upward to sand. Close to the plateau margin the colluvium has a minimum thickness of 8 feet (2.4 m).

STRUCTURE

The Gunnison quadrangle contains the southward-plunging nose of the syncline that forms this portion of the Gunnison Plateau. Although the general structure is simple, the plateau margins are structurally complex. West of Rocky Point and in the White Hills the Jurassic Arapien Shale is juxtaposed with Eocene strata or Quaternary sediments, suggesting that both margins of the Gunnison Plateau may be bounded by structural discontinuities with relief as great as 10,300 feet (3,140 m)(Mattox and Weiss, 1988). Another complex structure is the southern termination of the Chriss/Mellor graben, a major depression over 12 miles (19 km) in length (figure 1). A faulted monocline, the West Gunnison monocline, dips westward off the west flank of the Chriss/Mellor graben. Both structures are intimately associated with high-angle Basin and Range normal faults and the southern terminus of the Wasatch fault zone. Northern Antelope Valley may also be a graben. Nestled within the complex margins of the plateau is a broad, shallow syncline of Tertiary strata, which itself is underlain by a tighter syncline in the pre-Tertiary rocks (Weiss, 1982; Lawton, 1985).

STRUCTURALLY HIGH ARAPIEN SHALE

The Jurassic Arapien Shale is topographically above the surrounding Quaternary deposits and at the same topographic level as the Crazy Hollow Formation at two locations, west of Rocky Point and in the White Hills. Assuming that a complete stratigraphic sequence from Upper Jurassic Twist Gulch Formation to upper Eocene Crazy Hollow Formation underlies the Gunnison Plateau, and using the thicknesses reported for the Chevron U.S.A. #1 Chriss Canyon well, together with those observed in the Gunnison quadrangle, the stratigraphic displacement required to bring the Arapien to the surface at these two locations is on the order of 10,300 feet (3,140 m). The contact between the Arapien and the strata of the plateau is not exposed at the surface nor has it been penetrated by drilling. The emplacement of the Arapien Shale to such high structural levels may be the result of salt diapirism or eastward-directed thrusting; the author favors the latter model.

GRABENS

The Chriss/Mellor graben extends from Chriss Canyon, 10 miles (16 km) to the north, southward to Fayette Wash. The east margin of the graben is defined by the Escarpment fault, a major normal fault (Mattox, 1987). Displacement along the fault decreases to the south from approximately 2,400 feet (730 m) at Timber Canyon, 6 miles (9.6 km) to the north, to 2,100 feet (640 m) at Mellor Canyon. Near Fayette Wash displacement is on the order of 400 feet (120 m). The western boundary fault of the graben decreases in displacement from a maximum of 1,700 feet (520 m) at Timber Canyon to only a few tens of feet at Mellor Canyon. Horsts and grabens of only minor displacement dominate the internal structure of the graben and are well displayed in Mellor Canyon (plate 2, cross-section B-B').

The nature of Antelope Valley remains problematic. Witkind and others (1987) show a normal fault along the west margin of the valley which continues northward to the southern termination of a graben defined by a series of discontinuous normal faults. This graben, termed the Divide graben for its topographic expression, is described in detail by Mattox

(1987). In the northeast corner of the Gunnison quadrangle (section 13, T. 18 S., R. 1 E.) a fault along the west margin of northern Antelope Valley has a displacement of approximately 400 feet (120 m) and is a southern extension of the fault bounding the west side of the Divide graben. In detailed mapping along the west margin of the valley, no evidence was found to support the fault inferred by Witkind and others (1987) to be buried beneath surficial cover. Furthermore, one fault segment can readily be observed to pass from minor stratigraphic displacement to flexural deformation in NE¼ section 35 and SW¼ section 25, T. 18 S., R. 1 E. At the latter location a small north-northeast-trending anticline is on strike with the fault. The dip, thickness, and spatial relationship between the Tertiary units near the mouth of Antelope Valley clearly allow for nearly 550 feet (167 m) of Colton strata without faulting; Colton exposures near the head of the valley are thicker than 500 feet (150 m). These observations suggest that the northern part of Antelope Valley is a graben with decreasing structural displacement to the south. A similar pattern is seen for the Chriss/Mellor graben.

TERTIARY SYNCLINE

A syncline involving the Tertiary strata at the surface trends S. 23 degrees W. and plunges 3 degrees south. Along the west limb of the fold, Flagstaff, Colton, Green River, and Crazy Hollow beds dip 4 to 6 degrees to the southeast. The east limb, defined by Colton, Green River, and Crazy Hollow beds, dips westward from 2 to 12 degrees (dips increase to the south).

WEST GUNNISON MONOCLINE

A west-dipping monocline parallels the west margin of the Gunnison Plateau from 2 miles (3.2 km) north of Chriss Canyon, 13 miles (20.8 km) to the north, to an area 4 miles (6.4 Km) south of Mellor Canyon. The West Gunnison monocline (Mattox, 1987) is flanked on the east for most of its length by the Chriss/Mellor graben. Near the southern terminus of the graben (section 29, T. 18 S., R. 1 E.) the monocline consists of fault blocks which dip to the west at 30 degrees and repeat the same Flagstaff-Colton-Green River sequence (plate 2, cross-section B-B'). Near The Caterpillar, faulted Colton and Green River strata dip westward a maximum of 13 degrees. At the southern end of the fold (SE¼ section 6 and NW¼ section 5, T. 19 S., R. 1 E.) unfaulted Green River strata dip westward 16 degrees. The observation of unfaulted strata on strike with the monocline suggests an origin unrelated to faulting (or at least to faults expressed at the surface) and possibly a relatively older age for the monocline than Basin and Range normal faulting.

LINEAMENTS

Three major lineaments cross the region. They are not observed at the surface and are of such scale that they are readily apparent only on a Landsat image of the Gunnison Plateau enlarged to a scale of 1:253,000. The largest and most significant lineament trends N. 30 degrees E. across the entire plateau from north of Gunnison (section 8, T. 19 S., R. 1 E.) to the mouth of Maple Canyon in Sanpete Valley (section 21, T. 17 S., R. 2 E.). A major drainage has developed along this lineament. A north-south-trending lineament parallels Antelope Valley (section 2, T. 19 S., R. 1 E. and sections 35 and 26, T. 18 S., R. 1 E.) and is also defined by a major drainage. The third lineament is roughly colinear with the southern termination of the Escarpment fault and is further defined by a minor stream (sections 29 and 32, T. 18 S., R. 1 E. and sections 5 and 6, T. 19 S., R. 1 E.). The third lineament also marks a sharp structural discontinuity between the West Gunnison monocline and the Chriss/Mellor graben (SW¼ section 29, T. 18 S., R. 1 E. to SW¼ section 6, T. 19 S., R. 1 E.).

STRUCTURAL INTERPRETATION

The author believes that the following scenario reflects the geologic history of the Gunnison quadrangle. Eastward-directed thrusting during the Sevier orogeny thickened the Arapien Shale and emplaced it at high structural levels beneath Sevier and Sanpete Valleys (Spieker, 1936; Spieker, 1946; Standlee, 1982; Lawton, 1985; Villien and Kligfield, 1986). The overlying, competent Indianola conglomerate was warped into broad folds. Several paleotopographic highs of Indianola persisted after Late Cretaceous erosion only to be onlapped and eventually covered by the alternating fluvial and lacustrine Tertiary sequence. Sometime after Crazy Hollow lithification, mobilization (diapirism) of the Arapien Shale, emplaced at high structural levels during the Sevier orogeny, warped the Tertiary strata into gentle folds. A syncline was produced on the Gunnison Plateau; to the west, in northern Sevier Valley, an anticline was formed. Large-scale intrusion of the Arapien into and against Tertiary strata as envisioned by Stokes (1952, 1956, and 1982), Witkind (1982, 1983) and Witkind and Page (1984) would not be required. Subsequent extensional tectonism and/or dissolution of salt in northern Sevier Valley resulted in downwarping along the plateau margin and ultimately the West Gunnison monocline. Normal faulting sculpted the west margin of the plateau along the southern termination of the Wasatch fault zone. Within the plateau, Basin and Range faulting created the Chriss/Mellor graben. Beginning possibly as early as the Miocene and continuing to the present, local, isolated diapiric movements created topographic highs of Arapien Shale.

GEOLOGIC HAZARDS

EARTHQUAKES

The normal faults extending south of Mellor Canyon along the west margin of the plateau represent the southern termination of the Wasatch fault zone. Anderson and Miller (1979) believe that several of these faults were active in Holocene time, although fresh scarps were not found. Reconnaissance mapping of the Levan-Nephi segment of the Wasatch fault zone by Schwartz and Coppersmith (1984) indicates only one surface-faulting event since the early to middle Holocene. At

Deep Creek, 20 miles (32 km) north of Mellor Canyon, Schwartz and Coppersmith (1984) found alluvial-fan sediments offset by 8.2 feet (2.5 m). The movement has occurred since 7,300 ± 1,000 years B.P. At Pigeon Creek the same fault scarp displaces an alluvial fan dated at 1,750 ± 350 years B.P. In a compilation of earthquake data from 1840 to 1965, Cook and Smith (1967) report a single epicenter in the quadrangle near Rocky Point. They estimate that the earthquake had a magnitude between 3.0 to 3.9 on the Richter scale. A Gunnison resident (personal communication, 1986) described an intensity IV earthquake (Mercalli scale) that was probably the 4.4 Richter magnitude earthquake centered near Levan in 1963.

FLOODING

During years of normal precipitation, flooding presents only minor hazards in the upland portions of the quadrangle and along the San Pitch and Sevier Rivers. However, during years of unusually high precipitation or heavy spring runoff, flooding is a problem. In 1983 and 1984 flooding damaged a bridge crossing the San Pitch River east of Gunnison and threatened the bridge just south of town. Since then, channels have been widened, cleared, and riprapped in some areas. The eastern bridge has been replaced; the southern bridge has been reinforced. Flooding along the Sevier River poses little hazard but does encroach upon pasture land.

ECONOMIC GEOLOGY

SAND AND GRAVEL

The Cox Rock Products Inc. quarry is currently removing 300,000 to 360,000 tons of sand and gravel annually from the valley-fill deposits that occupy the north end of N½ section 28, T. 19 S., R. 1 E., east of Centerfield. The gravel consists dominantly of limestone clasts with minor amounts of sandstone. Other companies have extracted sand and gravel from the same deposit in the recent past.

Local residents dug a small pit into the well-sorted eolian sands east of Fayette (SE¼SE¼SE¼ section 19, T. 18 S., R. 1 E.) to provide fill material.

Pratt and Callaghan (1970) report a prospect for sand in the Crazy Hollow Formation one-half-mile (0.8 km) east of Gunnison (SW¼ section 15, T. 18 S., R. 1 E.).

The well-sorted silt and fine sand of the Lake Bonneville deposits have been used elsewhere as a commercial sand source for the manufacturing of cement blocks and concrete (Pratt and Callaghan, 1970). In the Hells Kitchen Canyon SE quadrangle to the north this material is used for fill.

DIMENSION STONE

Approximately 500,000 cubic feet of structureless, argillaceous limestone from the carbonate lithofacies of the Green River Formation have recently (post-1970) been quarried from the east-central portion of the quadrangle (SE¼ section 35, T. 18 S., R. 1 E., NE¼NW¼ section 2, T. 19 S., R. 1 E.). Numerous prospects to the southwest (section 3, T. 19 S., R. 1 E.) were probably in search of stone of similar quality. Some beds of the Flagstaff Limestone near Fayette Wash are dense and homogeneous and may be suitable for dimension stone.

HYDROCARBONS

Two dry wells are located in N½ section 8, T. 19 S., R. 1 E. approximately two miles (3.2 km) north-northeast of Gunnison. The wells are believed to have been drilled in the late 1940s by the Gunnison Oil Company. Palynomorph studies of cuttings from these two wells are currently being conducted by the Utah Geological Survey.

WATER RESOURCES

Young and Carpenter (1965) reported the average annual flow of the Sevier River near Gunnison to be 173,000 acre-feet (213,310,000 cubic meters). Outflow from the San Pitch River is minor due to diversion for irrigation and storage in Sanpete Valley. The Sevier River flows northward to Sevier Bridge Reservoir, which has a maximum capacity of 235,962 acre-feet (290,940,000 cubic meters)(Wooley, 1947). The largest spring in the area (Fayette Springs, NE¼SE¼ section 19, T. 18 S., R. 1 E.) provides domestic and some irrigation water to Fayette. Discharge is unknown. A spring near the base of Chalk Hill (NE¼ section 23, T. 19 S., R. 1 E.) is used for irrigation and has a discharge of 60 gal/min (3.7 decimeters per second) (Richardson, 1907). Richardson also reported a thermal spring on Rocky Point (SE¼ section 18, T. 19 S., R. 1 E.) with a discharge of 8 gal/min (0.5 decimeters per second). The spring shown on the geologic map in upper Fayette Wash (NE¼ section 22, T. 18 S., R. 1 E.) was dry during the summer of 1987. Young and Carpenter (1965) report a range in depth to the water table of 30 to 90 feet (9.1 to 27.4 m) in the valley-fill deposits. They defined the Gunnison/Sevier Bridge Reservoir basin which has a ground-water capacity of about 300,000 acre-feet (369,900,000 cubic meters) but only a part of that basin is within the Gunnison quadrangle.

METALS

Many prospects are scattered across the mapped area, with the largest concentration of pits near Fayette Springs, Rocky Point, and Chalk Hill. No active mines are in the quadrangle and the only developed site is the construction of a 125-foot (38 m) drift at Chalk Hill. Assays from numerous prospects for the Utah Geological Survey (unpublished data, 1978) show trace concentrations of Ag, Cu, Pb, Zn, Mo, and Au.

CEMENT

Bryce Tripp of the Utah Geological Survey suggested that the limestones of the Flagstaff and Green River Formations

might be potentially useful in the production of cement. Mattox (1986) used X-ray diffractometry to determine the calcite/dolomite ratios of 75 samples from various stratigraphic levels and lithologies of both formations and found only three fossil-rich limestones suitable for cement production, i.e., greater than 97 percent $CaCO_3$. The gastropod-rich Flagstaff Limestone in SW¼SW¼ section 15, T. 18 S., R. 1 E. might prove suitable for cement production.

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