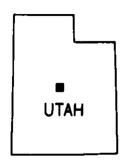
PROVISIONAL GEOLOGIC MAP OF THE HELLS KITCHEN CANYON SE QUADRANGLE, SANPETE COUNTY, UTAH

by Stephen R. Mattox



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UTAH GEOLOGICAL AND MINERAL SURVEY
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UTAH GEOLOGICAL AND MINERAL SURVEY

606 Black Hawk Way
Salt Lake City, Utah 84108-1280

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PROVISIONAL GEOLOGIC MAP OF THE HELLS KITCHEN CANYON SE QUADRANGLE, SANPETE COUNTY, UTAH

by Stephen R. Mattox[1]

INTRODUCTION

The Hells Kitchen Canyon SE quadrangle is located on the southwest side of the Gunnison Plateau (San Pitch Mountains) a little over 100 miles (160 km) south of Salt Lake City. The Gunnison Plateau is part of the High Plateaus of Utah which mark the transition from Basin and Range to the Colorado Plateau physiographic provinces. The map area is surrounded by the plateau to the north, east, and south; the Sevier Valley lies to the west (figure 1).

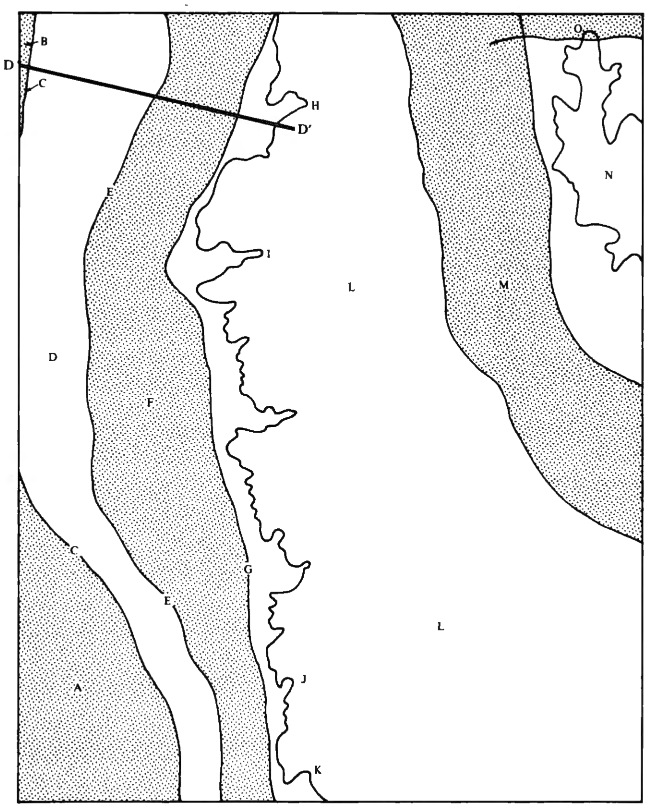

Figure 1. Simplified map of Hells Kitchen Canyon SE quadrangle showing principal structural and topographic features: A) Sevier Valley, B) Flat Canyon graben, C) Valley fault, D) West Gunnison monocline, E) western margin of the Chriss/Mellor graben, F) Chriss/Mellor graben, G) high escarpment of Indianola conglomerate created by normal movement on the Escarpment fault, H) Timber Canyon, I) Hells Kitchen Canyon, J) approximate location of North Horn Formation pinch-out east of the Chriss/Mellor graben, K) Mellor Canyon, L) high plateau, M) Divide graben, N) South Maple Canyon, and O) Dry Canyon graben.

Great insight into the geology of the High Plateaus was shown by John Wesley Powell, Edwin Howell, and by C. E. Dutton in Dutton's early report (1880), which includes excellent cross-sections of the Gunnison Plateau. Early work by Spieker (1946, 1949) detailed the structural history and stratigraphy of the area. Hardy (1948) was the first to map the Hells Kitchen Canyon area in detail. Adjacent and nearby areas were mapped by Babisak (1949), Gilliland (1951), Muessig (1951), and Vogel (1957). Hardy and Zeller's (1953) Chriss Canyon and Hells Kitchen Canyon SE map is the only previously published detailed map of the area.

STRATIGRAPHY

GENERAL

The outcropping rocks of the Hells Kitchen Canyon SE quadrangle range in age from Late Cretaceous to Tertiary (latest Eocene) and total about 4,100 feet (1250 m) in thickness. Jurassic strata are known to underlie the map area and crop out 5.5 miles (8.9 km) north of the quadrangle. The oldest exposed rocks belong to the Late Cretaceous Indianola Group (undifferentiated). Overlying the Indianola is the North Horn Formation which contains rock of Late Cretaceous and Tertiary (Paleocene) age. Sequentially above the North Horn are the Flagstaff, Colton, Green River, and Crazy Hollow Formations, all of early Tertiary age. Alluvial fans, fluviatile beds, and lacustrine sediments comprise the section. The fluctuations between these depositional environments are well recorded in pronounced facies changes, as well as the succession of formations. An angular unconformity and bleached zone mark the Indianola-North Horn contact. Flagstaff and Green River strata also lie unconformably on the Indianola in the western portion of the area. Nine Quaternary units include alluvial fans of four ages, recent and ancient mass movements, Lake Bonneville sediments, colluvium, and alluvium. No igneous rocks were observed; but Dr. J. L. Baer (pers. comm., 1984) has noted the presence of thin (approximately 6 inch or 15 centimeter) basalt dikes just east of the area.

JURASSIC SYSTEM

Jurassic rocks are not exposed in the map area but are important because of their possible tectonic significance.

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Accurate measurement of the thickness of the Jurassic section in central Utah is obstructed by three factors: (1) rocks assigned to the Arapien Shale cannot be directly traced to better known Jurassic stratigraphy; (2) facies changes and the general lack of fossils lead to correlation uncertainties; and (3) intense deformation and structural complexity are common (Standlee, 1982). Spieker (1946) estimates the presence of 5,000 to 7,000 feet (1424 - 2133 m) of Arapien Shale and 3,000 feet (914 m) of Twist Gulch Formation near Salina Canyon. Hardy (1952) believes the Arapien Shale to be a minimum of 3,000 feet (914 m) thick and reports 1,910 feet (582 m) of exposed Twist Gulch Formation in Salina Canyon. Summaries of two wells drilled on the Gunnison Plateau, the Dixel Resources #1 Gunnison State and the Chevron U.S.A. #1 Chriss Canyon, are shown in figure 2. Standlee (1982) indicates the thicknesses of the Arapien and Twist Gulch Formations in these wells closely approximate the original deposited thicknesses of these two units in the Gunnison Plateau region, 6,000 feet (1028 m) in the Dixel well and 6,190 feet (1886 m) in the Chevron Well.

CRETACEOUS SYSTEM

Indianola Group (undifferentiated)—The Cretaceous sediments of the Rocky Mountain area were deposited in an

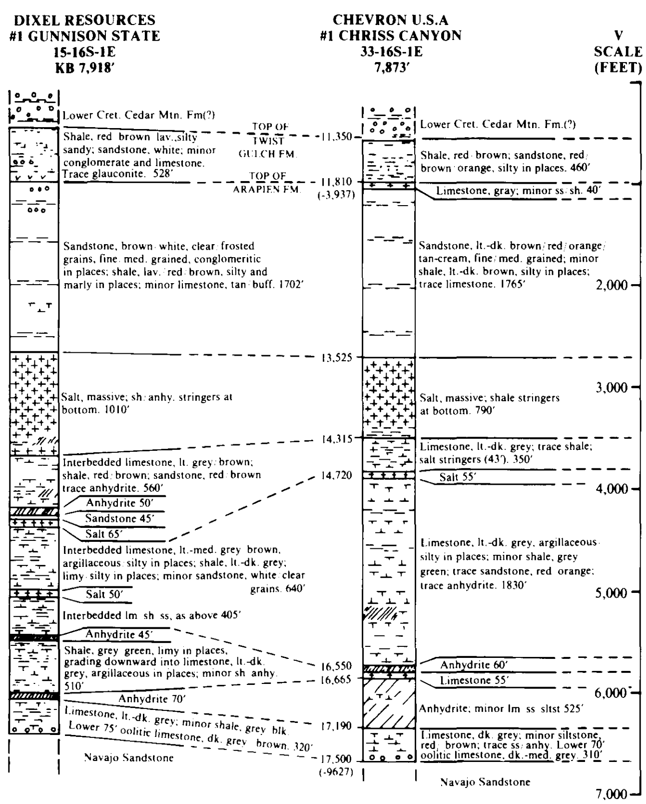

Figure 2. Logs of Jurassic rocks beneath the Hells Kitchen Canyon SE quadrangle. The Chevron well is located in the north-central part of the quadrangle, the Dixel Resources well is located 3.8 miles NNE of the quadrangle. From Standlee, 1982.

elongate, asymmetric trough termed a foreland basin (Dickinson, 1974). Dickinson and Snyder (1978) believe the basin began forming in the Late Jurassic as oceanic crust was subducted beneath the North American continent. The west margin of the basin was marked by several pulses of extensive eastward thrusting (Sevier Orogeny) which contributed to its subsidence. Erosion and eastward dispersal of the thrusted material created a thick accumulation of coarse clastics in central Utah during Cretaceous time. In the quadrangle the large cobbles and thick conglomerates (more than 8,000 ft or 244 m) of the Indianola Group (undifferentiated) imply close proximity to the active thrust belt.

The conglomerates of the Indianola Group (undifferentiated) are exposed in three main areas. Near the center of the quadrangle high cliffs composed of east-dipping Indianola conglomerate trend north-northwest. Lower hills of isolated Indianola fault blocks, some capped with patches of younger beds, occur in the Chriss/Mellor graben. West of this graben west-dipping Indianola beds are locally cross faulted and capped by younger beds.

Three rock types comprise the Indianola Group (undifferentiated): conglomerate (about 80 percent), sandstone (about 15 percent), and pebbly sandstone (about 5 percent). Clast-supported bimictic polymodal conglomerate dominates; the strata weather medium gray with the exception of uppermost bleached areas and a remineralized zone. Using the color chart of Goddard and others (1975), the bleached areas are commonly white (N9) to light gray (N7). The remineralized zone is variegated moderate red (5R5/4), moderate reddish orange (10R6/6), grayish purple (5P4/2), and dark yellowish orange (10YR6/6). Clast sizes range from fine pebbles (0.16 to 0.32 inch or 0.40-0.81 cm) to large cobbles (5.0 to 10.1 inches or 13-26 cm). The conglomerate is poorly sorted and has well-rounded clasts.

The most abundant clast type is very light gray, pink, red, purple, or light-brown orthoquartzite. Light- to dark-gray carbonate clasts are second in abundance. Rare light-gray, medium to coarse sandstone clasts are also present. Matrix is poorly sorted medium to coarse sand. Calcite is by far the dominant cement and only a single silica-cemented conglomerate horizon was observed. Bedding is massive (structureless) and the clasts show no preferred orientation or grading. The Indianola is generally cliff forming throughout the area. One notable exception is pinnacle-forming Indianola at the mouth of Hells Kitchen Canyon.

Sandstone is the second most abundant rock type in the Indianola. The sandstone beds are readily divisible into two groups: laterally continuous sheets and discontinuous lenses. Laterally continuous sandstones generally weather grayish orange (10YR7/4). The fresh color varies from olive gray (5Y6/1) to pale yellowish orange (10YR8/6). Fine-grained, well-sorted, subangular sand is most common. Fine to moderately sorted, subrounded to subangular sand is also present. The sheets have a modal thickness of 7.2 feet (2.2 m) and are thin bedded. A single massive sheet of sandstone 40 feet (12 m) in thickness is capped by 10 feet (3 m) of trough crossbeds. The base of the sheets are mostly irregular, although planar contacts are rather common. The sheet-like geometry, good sorting, and parallel beds of the laterally continuous sandstones suggest sheet-flood deposits (Reineck and Singh, 1980, p. 302) associated with an alluvial fan.

The discontinuous sandstone lenses weather pale yellowish brown (10YR8/6) to yellowish gray (5Y7/2). The fresh color is moderate orange pink (5YR8/4) or pale yellowish orange (10YR8/6). The sand is fine to coarse grained, poorly sorted, and subangular. Some moderately sorted sand is present. The lenses have an average thickness of 2.5 feet (0.8 m) and a range of 0.5 to 6.6 feet (0.2-2 m). Thin-bedded lenses are most common, but massive and trough crossbedded units are also present. Bases of the discontinuous sandstone lenses are irregular. These characteristics imply sheet-flood origin of sufficient energy to transport coarse sand from channels onto the piedmont surface. Sublitharenite is the most common type of sandstone in the Indianola followed by lithic arenite. Nearly all the samples are dominated by monocrystalline quartz. Lithic grains consist almost entirely of micrite (classification of Pettijohn and others, 1972).

The pebbly sandstone is mostly pale yellowish brown (10YR6/2) weathered and grayish orange (10YR6/4) fresh. Coarse pebbles are in a matrix of poorly sorted, subrounded, fine to coarse sand. Pebble abundance decreases upward. The average unit thickness is 8.9 feet (2.7 m) with a range of 2.1 to 13.9 feet (0.6-4.2 m). Bedding is dominantly massive (structureless) and irregular.

The maximum exposed thickness of the Indianola is about 990 feet (308 m) at Hells Kitchen Canyon and a section of 890 feet (271 m) was measured at Mellor Canyon. Records from the Chevron U.S.A. #1 Chriss Canyon well (NESW Sec. 33, T. 16 S., R. 1 E.) indicate a complete thickness of 8,760 feet (2670 m). This thickness agrees with that in the Dixel well (8,440 ft or 2573 m), which is located 3.8 miles (6.1 km) north-northeast of the Chevron well (Sec. 15, T. 16 S., R. 1 E.).

The basal contact of the Indianola Group (undifferentiated) is not exposed in the Hells Kitchen Canyon SE quadrangle. The upper contact is sharp and well exposed. The deeply dissected canyons east of the Chriss/Mellor graben show the Indianola in angular discordance with overlying strata. The average eastward dip of the Indianola is 14, 8, and 26 degrees in Timber, Hells Kitchen, and Mellor Canyons respectively. Overlying strata show an average eastward dip of 4 degrees. In the northern and central portions of the Chriss/Mellor graben the angular discordance is not as readily observed and in places the contact is believed to be disconformable. The isolated fault block in SESW Sec. 5, T. 17 S., R. 1 E. is capped by Flagstaff Limestone above Indianola conglomerates which dip 10 degrees east. Near the mouth of Timber Canyon the North Horn appears to overlie the Indianola disconformably. In the southern part of the Chriss/Mellor graben, strata of the Flagstaff and Green River Formations lie with angular discordance above the Indianola. The author believes the contact of the Indianola with overlying strata changes from angular discordance to discordance moving from the Chriss/Mellor graben to the center of the plateau due to folding of the older beds (cross section B-B′). The top of the Indianola is marked by bleached conglomerate, sandstone, or pebbly sandstone. Bleached conglomerate and pebbly sandstone are laterally extensive for hundreds of feet and are tens of feet thick. Bleached conglomerate and sandstone are continuous from Axhandle Canyon to the south for 1.5 miles (2.4 km) and show a distinct break from the reddish North Horn Formation. The bleached zone is present in portions of Mellor Canyon where the Indianola is overlain by the Flagstaff Limestone. In NENW Sec. 16, T. 18 S., R. 1 E., the upper Indianola sands are mineralized and are mottled pale yellowish brown to pale red. The bleached zone is also present in the northern half of the Chriss/Mellor graben where the North Horn overlies the Indianola; it was not observed in the southern half.

The age of the Indianola in the Gunnison Plateau is not absolutely known. The unconformity at the top of the Indianola is thought to be a middle Campanian regional unconformity associated with the Sevier Orogeny (Fouch and others, 1983) which suggests an early Campanian age for rocks immediately beneath them, and that the Indianola Group (undifferentiated) rocks are late Cenomanian to early Campanian in age (lower to middle Late Cretaceous).

CRETACEOUS AND TERTIARY SYSTEMS

North Horn Formation—Rocks of the North Horn Formation record the waning orogenic activity of the Sevier orogenic belt and the infilling of the western interior foreland basin. In central Utah the foreland basin was replaced by a series of local basins between the Sevier orogenic belt to the west and the San Rafael Swell to the east (Fouch and others, 1983). Transitions from piedmont slope to lacustrine settings create a wide variety of lithofacies.

The North Horn Formation of Hells Kitchen Canyon SE can be divided into two lithofacies based on color, lithology, and thickness. Along the high escarpment and in the deep interior canyons, a grayish unit of conglomerate, sandstone and limestone reaches a maximum thickness of 830 feet (253 m). The North Horn second lithofacies is typically a deep red color as found in Chriss/Mellor graben and in the low hills to the west. Sandstone and sandy limestone are the dominant rock types. The maximum thickness is 126 feet (38 m). Both units thin and pinch out to the south. East-southeast-dipping North Horn strata of the gray, eastern lithofacies make up the escarpment and head of Timber Canyon (plate 1). To the south at Hells Kitchen Canyon, North Horn conglomerates (330 ft or 100 m) cap an escarpment of Indianola conglomerate due to a rise in the Indianola erosional surface. The interior of the canyon also offers good exposures. The formation thins southward and pinches out north of Mellor Canyon. Exposures of North Horn in the Chriss/Mellor graben are rare. In Sec. 19, T. 17 S., R. 1 E., a thin layer of North Horn crops out above bleached Indianola conglomerates. The large fault in Sec. 19 exposes North Horn beds at its northern boundary and Indianola conglomerates to the south. Flagstaff Limestone caps the block. The lack of North Horn farther south establishes the approximate position of the pinch out in the Chriss/Mellor graben. Exposures of the red, western lithofacies are few in the West Gunnison monocline. A complete section is readily accessible near the mouth of Timber Canyon. West of the Chriss/Mellor graben the southernmost North Horn exposure is just northeast of the mouth of Hells Kitchen Canyon (SE Sec. 13, T. 17 S., R. 1 W.).

Lithologic variety characterizes the North Horn Formation in the quadrangle. Of ten identified rock types, five make up the bulk of the formation. In decreasing abundance the rock types are conglomerate, sandstone, oncolitic micrite, micrite, mudstone, sandy micrite, pebbly micrite, pebbly sandstone, intramicrite, and conglomeratic sandstone. Over 1,600 feet (488 m) of North Horn strata were measured in several stratigraphic sections. These record facies changes from fluvial, mountain fan, and lacustrine environments in the east to a fluviolacustrine environment in the west.

The North Horn of the escarpment and deep inner canyons is dominated by clast-supported bimictic polymodal conglomerate (conglomerate with carbonate and quartzite clasts). The weathered beds are pale yellowish brown (10YR6/2), grayish orange (10YR7/4), or medium gray (N5). A shift in color from gray to orangish gray is commonly observed moving up section from Indianola to North Horn strata. Clast size ranges from fine pebbles (0.16 to 0.32 inch or 0.4 - 0.8 cm) to large cobbles (5.0 to 10.1 inches or 12.7 - 25.6 cm). The conglomerate is poorly sorted with subrounded to rounded clasts. Orthoquartzite and carbonate clasts of nearly equal abundance comprise the North Horn conglomerates. The matrix is calcareous and consists of poorly sorted fine to coarse sand. Beds are massive (structureless) and generally on the order of tens of feet thick. The North Horn conglomerates form low cliffs (generally less than 20 feet in height), ledges, and slopes. The slope expression appears to be related to the thickness of the units and the nature of the enclosing beds. Figure 3 is a graphical representation of stratigraphic trends of North Horn conglomerates.

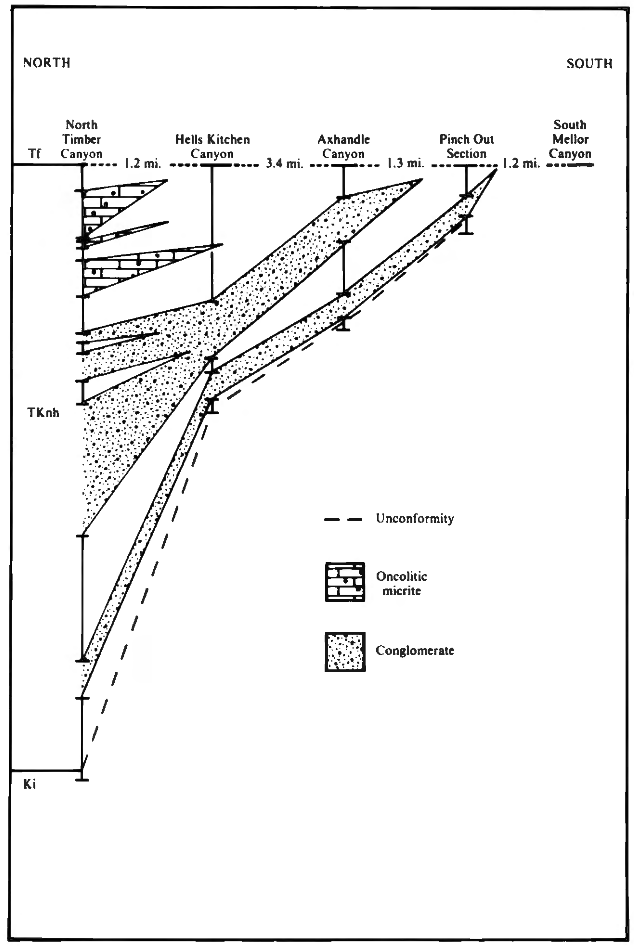

Figure 3. North-south stratigraphic trends of North Horn Formation conglomerates and oncolitic micrites along the high escarpment and deep inner canyons.

The second most abundant rock type is sandstone. Most North Horn sandstones are interlayered with or cap conglomeratic units. The weathered rock is commonly grayish orange (10YR7/4) to pale yellowish brown (10YR6/2). The fresh surfaces range from moderate orange pink (5YR8/4) to very pale orange (10YR8/2). Fine to medium or medium to coarse, moderately sorted sand is most common. Units are thin-bedded or massive. Planar cross-stratified and trough crossbedding occur but are relatively rare. Sandstones not associated with conglomeratic units show a variety of characteristics: colors range over shades of orange, gray, and brown; sorting is poor to moderate; massive beds are common; thin-bedded or planar cross-stratified layers are also present. Massive or planar cross-stratified sandstones occur as discontinuous lenses.

The sandstones of the North Horn Formation can be classified as lithic arenites, sublitharenites, and quartz arenites (Pettijohn and others, 1972). Monocrystalline quartz dominates the sand, followed by carbonate rock fragments. Polycrystalline quartz and chert occur in minor amounts. Feldspar, when present, makes up less than 3 percent of the rock.

Oncolitic micrite comprises a major portion of the upper North Horn strata in Timber Canyon. The massive beds weather medium light gray (N6) from a fresh color of brownish gray (5YR4/1). Elongated and rounded oncolites are generally between ½ - 1 inch (1.3 - 2.5 cm) in diameter. Rare elongate oncolites reach 1 foot (0.3 m) in length. Acid-resistant residues consist of sand and mud. Loose, rounded, frosted, medium quartz sand is most common. Size ranges from fine to coarse sand. Rare accessory grains of gray chert and magnetite are also present.

North Horn micrites show a wide variation in color. Rocks weather to grayish orange (10YR7/4), yellowish gray (5Y7/2), and moderate yellowish brown (10YR5/4). Fresh samples are medium light gray (N6), pale olive (10Y6/2), and pale red (5Y6/2). Relatively thin variegated beds contain shades of orange, gray, and purple. The rocks are predominantly limestone with lesser calcareous dolomites and dolomites. Insoluble residues commonly consist of mud and subangular, fine quartz sand. Accessory residues include pyrite and magnetite grains. Beds are massive, planar, continuous, and ledge forming, with thicknesses increasing up the section from 0.5 to 12 feet (0.015 - 3.6 m).

Grayish-red (10R4/2), grayish-purple (5P4/2), or light greenish-gray (GY8/1) calcareous mudstone forms planar, continuous slopes in Hells Kitchen Canyon and Timber Canyons. Beds are generally a few feet thick. Most laterally continuous covered slopes are believed to be similar mudstones with poor exposures.

Weathered sandy micrites are pale yellowish brown (10YR6/2) and very light gray (N8). Fresh surfaces are pinkish gray (5YR8/1) and pale yellowish brown (10YR6/2). Microcrystalline carbonate mud supports floating sand grains. Limestone is most common, but dolomites and calcareous dolomites do occur. Weight percent of insoluble residue ranges from 18 to 42 percent. The residue consists of mud to coarse sand with the modal size varying with each sample. Loose, subrounded, frosted quartz is most common. Chert and hematite grains are present but rare. Sandy micrite beds are massive, generally a few feet thick, and form ledges.

Pebbly sandstone units are interlayered with sandy micrites and micritic beds. Weathered rocks are pinkish gray (5YR8/1) or very pale orange (10YR8/2). Fresh surfaces are very pale orange (10YR8/2) or grayish orange (10YR7/4). The sands are poorly sorted and support fine to coarse pebbles of limestone and orthoquartzite. Oncolites occur in one bed. Beds are massive or contain trough crossbeds and thin planar beds. The pebbly sandstone weathers to ledges and slopes.

Intramicrites are light gray (N7), grayish orange (10YR7/4), or pale yellowish brown (10YR6/2). Intraclasts are rarely over 1 inch in diameter, with most being between 0.25 - 0.5 inches (0.6 - 1.3 cm). Intraclasts are composed of carbonate mud and, in rare cases, oncolites. The rock is composed of limestone. Insoluble residues consist of mud to coarse sand particles. Beds are massive, continuous, and ledge forming.

Pale yellowish-orange (10YR8/6) to grayish-orange (10YR7/4) conglomeratic sandstone occurs near the base of the Timber Canyon section. Large cobbles grade upward to sand. The beds are massive, continuous, and ledge forming.

Thin (less than 1.8 ft or 0.5 m) stromatolitic micrite beds are present at the top of the Timber Canyon section. The rock weathers to grayish orange (10YR7/4) from a fresh color of brownish gray (5YR4/1) and is composed of limestone with approximately 10 percent mud and sand residue.

The North Horn beds of the Chriss/Mellor graben and the low hills to the west consist of red conglomeratic sandstone, sandstone, mudstone, and sandy limestone with a maximum thickness of 126 feet (38 m). Conglomeratic sandstone dominates the section. The beds are composed of sandstone with interbedded conglomeratic lenses. The moderate to poorly sorted subrounded sand forms massive beds that weather to ledges. Calcareous cement is most common, with silica cement rare but present. Conglomerate lenses are clast supported, polymodal, and dominated by orthoquartzite cobbles. Sizes of framework clasts range from pebbles to large cobbles, with very coarse pebbles being most common.

Variegated, moderately sorted sandstones occur near the base of the section. The massive or thinly bedded units are laterally continuous and weather to ledges. Moderate reddish-brown (10R4/6) mudstone forms laterally continuous slopes and covered intervals are poorly exposed similar mudstones.

Sandy micrites and intramicrites increase up section. The percent of dolomite also increases up section as weight percent residue decreases. Pale yellowish-brown (10YR6/2) to moderate reddish-brown (10R4/6) sandy micrites contain fine to medium subrounded quartz grains. The massive beds are 1 to 3 feet (0.3-0.9 m) thick and cap fining-upward clastic sequences. Pale reddish-brown (10R5/4) to grayish-orange (10YR7/4) intramicrites top the section. Rocks are composed of dolomite with micrite and sandy micrite intraclasts up to 0.25 inch (0.6 cm) in diameter. Intraclasts show a relatively high concentration of hematite staining implying they were eroded from pre-existing red beds. An additional source of iron staining is provided by the oxidation of magnetite to hematite (Banks, 1985). Disseminated hematite of the carbonate cement may be of this origin. The beds are massive or thin bedded and ledge forming.

Birsa (1973) studied the North Horn sedimentary facies along the east front of the Gunnison Plateau and recognized four primary facies: a coarse clastic facies, a medium clastic facies, a fine clastic and carbonate facies, and a coarse to medium clastic transition facies. These are useful in interpreting North Horn facies in this quadrangle. The Timber Canyon strata along the high escarpment show two fluctuations between the coarse clastic facies and the medium clastic facies followed by the fine clastic and carbonate facies. The large influx of coarse clastics may represent pulses of tectonic activity during which alluvial fans extended into the area. Tectonically quiescent periods are reflected in the establishment of fluvial systems. The fine clastic and carbonate facies at the top of the section express the transition to fluviolacustrine and shallow water lacustrine conditions associated with the precursors of Lake Flagstaff.

North Horn strata near the mouth of Timber Canyon show a transition from the medium clastic facies to the fine clastic and carbonate facies. This change from fluvial to fluviolacustrine/lacustrine conditions is gradational with characteristic lithologies of both facies overlapping near the center of the section. Conspicuous lateral facies changes over short distances are not unusual in the North Horn exposures of the quadrangle.

Lateral facies changes, facies distribution, and stratigraphic thickness suggest an easterly source for most of the North Horn strata in the Hells Kitchen Canyon SE area. The formation also appears to thin against a structural high farther west—possibly in Sevier Valley.

Throughout central Utah the top of the North Horn Formation either grades into the Flagstaff Limestone or shows angular unconformity with younger beds including, locally, the Flagstaff. The contact is defined by red sandy micrites and intramicrites at the base of the Flagstaff. An additional criterion is the relative decrease in clastic units in the Flagstaff.

A Late Cretaceous-early Tertiary age for the North Horn Formation is indicated by Griesbach and MacAlpine (1973), and Newman (1974) using palynomorph, ostracode, and charophyte assemblages. No North Horn fossils were found, and a Maastrichtian to Paleocene age is tentatively assigned.

TERTIARY SYSTEM

Flagstaff Limestone—During early Tertiary time post-orogenic deformation of the Sevier orogenic belt was combined with Laramide block uplifts to produce the Flagstaff lacustrine basin (Stanley and Collinson, 1979). In the Hells Kitchen Canyon SE quadrangle the Flagstaff Limestone can be divided into two members (Godo, 1979). The lower member, here informally designated the dolomite-sandstone member, is characterized by grayish-orange, light gray, and yellowish-gray argillaceous limestone, micrites, and sandy micrites which form massive cliffs and ledges. A red lithofacies of the dolomite-sandstone member occurs along the west margin of the map area as well as along the west margin of the Gunnison Plateau. The lithology and composition is similar to the non-red rocks of the member. Common colors are grayish red (10R4/2) and pale red (10R6/2). The upper member, here informally designated the limestone-mudstone member, is characterized by thin-bedded, pale yellowish-brown and yellowish gray micrites and sandy micrites. Several varieties of sandstone occur in the dolomite-sandstone member in the western part of the mapped area.

Gently east- or southeast-dipping (2-4 degrees) Flagstaff strata cap the plateau and are easily seen from Utah State 28. This large area trends north-south through the center of the map area (figure 1). The plateau topography is gently rolling, and vegetation commonly obscures the formation. South Maple Canyon, to the northeast, offers good Flagstaff exposures. The Flagstaff Limestone caps low hills in the central and southern portions of the Chriss/Mellor graben and makes up most of the monocline bounding the quadrangle to the west. Beds of the monocline dip 15-43 degrees to the west.

Sandy micrite and micrite comprise most of the Flagstaff in the quadrangle. Intramicrites, biomicrites, and oncolitic micrites are also present. Pebbly sandstone and sandstone increase in abundance to the west. Sandy micrites are very pale orange (10YR8/2), pale yellowish orange (10YR8/6), or pale yellowish brown (10YR6/2). Fresh surfaces are very pale orange (10YR8/2), very light gray (N6), or yellowish gray (5Y8/1). In decreasing abundance the sandy micrites are composed of dolomite, dolomitic limestone, and calcareous dolomite. These compositions reflect the larger relative abundance of the dolomite-sandstone member which makes up the bulk of the formation in the quadrangle. Clastic material ranges from mud to medium sand. The sand grains are generally floating in the carbonate mud. Loose, subrounded, fine to medium quartz sand is most common. Chert and hematite are rare. Beds are massive, planar, continuous, and weather to ledges and cliffs.

Micrites weather to yellowish gray (5Y8/1), very pale orange (10YR8/2), or pale yellowish orange (10YR8/6). Fresh samples are yellowish gray (5Y8/1) or light gray (N7). Dolomite is by far the most abundant mineral, with lesser calcareous dolomite. Insoluble residues consist of terrigenous mud with lesser subrounded fine quartz. Massive, planar, and continuous beds weather to ledges and slopes. Thin-bedded units with planar and irregular bases are also present.

Pale yellowish-orange (10YR8/6) and grayish-orange (10YR7/4) intramicrites are composed of dolomitic limestone and calcareous dolomite. Intraclasts range in size from 0.3 to 0.8 inch (0.7-2.0 cm) in diameter and are composed of carbonate mud. Beds weather to ledges and slopes.

Yellowish gray (5Y8/1) biomicrite is relatively rare and composed of limestone with gastropod, pelecypod, and ostracode shells and shell fragments. Insoluble residues range from 0.8 to 17.0 percent mud or mud and fine sand. Light brownish-gray (5YR6/1) oncolitic micrite occurs where Lake Flagstaff lapped against paleo-highs of the Indianola. The oncolites are 0.2 to 3 inches (0.5-7.6 cm) in diameter and supported in a matrix of limestone or dolomitic limestone. Insoluble residue consists of mud and fine quartz sand. Beds are massive and weather to form ledges.

Sandstones and pebbly sandstones are generally grayish orange (10YR7/4) or light gray (N7) and fresh samples are commonly pinkish gray (5YR8/1). The poorly sorted, fine to coarse sand forms massive beds approximately 10 feet (3 m) thick with a tabular geometry. Two pebbly sandstone layers occur at the base of the sandstone units. Compositionally, the Flagstaff sandstones are quartz arenites, sublitharenites, and lithic arenites. Lithoclasts consist of micrite and mudstone. The Sevier orogenic belt and the Juab and Sanpete Valley anticlines provided clastic sediments to the Flagstaff basin (Godo, 1979; Stanley and Collinson, 1979).

Western sections show a marked increase in clastic material, implying proximity to the lake margin. Eastern sections are nearly devoid of sandstone. Flagstaff strata in the Wasatch Plateau range in thickness from 200 to 1,500 feet (61-457 m), average 800 to 1,000 feet (244-305 m), with a general increase in thickness to the west and southwest (Spieker, 1946). Godo (1979) measured two complete sections in or near the Hells Kitchen Canyon SE quadrangle of 820 and 940 feet (250 and 287 m) at Timber and South Maple Canyons respectively.

Marcantel and Weiss (1968, p. 46) used changes in rock assemblages to establish the placement of the upper Flagstaff boundary. The contact between it and the Colton Formation is established where (1) the clastic nature of the rocks increases significantly and persists, (2) the fossil content of the rocks shows a marked and persistent decrease, (3) the abundance of the carbonate units decreases strikingly, and (4) the rocks change from brown or gray to red, green, and pastel colors. Additionally, the change from cliffs and ledges associated with the Flagstaff to the gentle mudstone slopes of the Colton is helpful. An additional criterion is the presence of mica-bearing, feldspathic sandstones in the Colton (Stanley and Collinson, 1979). Detailed petrography by Godo (1979) reveals that Colton sandstones (fine and very fine sand) are finer grained than Flagstaff sandstones (medium to fine sand).

The freshwater molluscan fauna found in the Flagstaff Limestone of the Wasatch Plateau led Spieker (1946) to consider the formation Paleocene in age. Gill (1950) discovered Eocene mollusks in the upper part and LaRocque (1951, 1960) divided the formation into three units: a lower unit of late Paleocene age, a middle unit of Paleocene and/or early Eocene age, and an upper unit of early Eocene age. On the east front of the Gunnison Plateau in South Maple Canyon, a mammalian fossil, *Vulpavus australis*, was recovered in the uppermost Flagstaff (Rich and Collinson, 1973). This species suggests an early Eocene age for the upper Flagstaff of the Gunnison Plateau. Using LaRocque's (1960, 1956) descriptions, the author identified *Gyralus aequalis* (White), *Physa pleromatis* (White), *Viviparus paludinaeformis* (Hall), and *Elliptio mendax* (White) from the Hells Kitchen Canyon SE area. They are typical of the early Tertiary mollusks of central Utah and do not indicate a definitive age. The Flagstaff Limestone in this quadrangle probably ranges from Paleocene to early Eocene in age.

Colton Formation—The Colton sediments prograded from the east or southeast and record the partial infilling of the Lake Flagstaff basin. The formation is dominantly clastic with sandstone and shales of floodplain and lacustrine origin (Spieker, 1949). Thin limestone beds are present but rare. The Colton Formation strata of central Utah are believed to be Eocene in age.

The Colton Formation is found over much of the Hells Kitchen Canyon SE quadrangle. A complete section of 540 feet (165 m) was measured at the head of South Maple Canyon. The broadest and best exposures are in the southeast corner of the quadrangle, where the Colton dips gently to the southeast, and in the southern portion of the Chriss/Mellor graben. No attitudes were obtained in the graben, but enclosing formations dip from 20 to 40 degrees in various directions. Good exposures are rare in the north because of heavy vegetation. Gently rolling hills and shallow dissected canyons mark the formation where it flanks the Divide graben. Horizontal Colton beds cap the plateau north of Timber Canyon. In the northwest corner the Colton forms slopes between the more resistant Green River and Flagstaff strata.

Fine-grained clastic rocks dominate the Colton Formation in the quadrangle and sandstones and limestones are rare. Pale yellowish-green (10GY7/2) and variegated (pinkish gray, 5YR8/1; white, N9; light brown, 5YR6/4; and grayish red purple 5R4/2) mudstones are most common. The rock contains silt and clay-sized particles. Quartz, calcite, and dolomite are most abundant with lesser amounts of muscovite, plagioclase, kaolinite, and illite. The mudstones weather to slopes.

Grayish-red (5R4/2), pale-green (5GY7/2), and variegated (light brown, 5YR6/4; greenish gray, 5G8/1; pale red purple, 5RP6/2; and pale reddish brown, 10R5/4) claystone also weathers to slopes. The mineralogy is similar to that of the mudstones. Colton sandstones weather yellowish gray (5Y7/2) or light brown (5YR6/4). Fresh samples are yellowish gray (5Y7/2), very pale orange (10YR8/2), or pale red (10R6/2). Nearly all the samples are of fine-grained, subangular, well-sorted sand; the mineral composition is dominated by quartz with subordinate muscovite, biotite, feldspar, chert, and hematite. Matrix percent ranges from 0 to 20. Calcareous cement is most common but silica-cemented samples do occur. Bedding differs from unit to unit. Convex-down channel sandstone lenses contain trough crossbeds and grade upward into massive or medium-bedded planar units. Thin sheet-like planar units are massive or thin bedded. Although the sandstones are friable, they are more resistant than the surrounding claystone and mudstone and weather to ledges.

In decreasing abundance, the most common sandstone types are feldspathic wacke, lithic wacke, feldspathic arenite, and subfeldspathic arenite (Volkert, 1980). Sedimentary structures include trough and herringbone cross-stratification, burrows, rain-drop imprints, and dish structures. Pale olive (10Y6/2) micrites are rare. The rock is composed of thin-bedded slope- and ledge-forming limestone.

Three major facies were recognized in the Colton of the Gunnison Plateau (Volkert, 1980): (1) fresh water lake-carbonate flat, (2) saline lake, and (3) alluvial plain. The saline lake did not extend into the Hells Kitchen Canyon SE area. Green calcareous claystone or variegated claystone of fresh water lake-carbonate flat facies were deposited in a shallow fresh water lake and in lakes or lagoons located on the carbonate mudflats adjacent to the main lake. Thin carbonate beds were also deposited in this environment. Although some material filled Lake Flagstaff along the edge of the Sevier orogenic belt, volumes of mica-bearing, feldspathic sandstones indicate a shift in major source areas from the Sevier orogenic belt in the west to Laramide uplifts in the east (Stanley and Collinson, 1979; Volkert, 1980).

The alluvial facies consist of green or variegated mudstone and claystone interbedded with channel sandstone and sandstone of sheet-like geometry representing deposition in a deltaic or deltaic plain environment. Mudstones are interpreted as floodplain deposits. Fining-upward channel sandstones suggest meandering streams dissected the floodplain with occasional crevasse splay or proximal channel overbank deposits. The sediment dispersal pattern of the Colton indicates an eastern or southeastern source (Stanley and Collinson, 1979). The mineralogy implies both plutonic and sedimentary source terrains.

The Colton-Green River boundary is more distinct than the Flagstaff-Colton contact. The Colton grades into and intertongues with the Green River Formation (Spieker, 1949). Criteria for recognition of the Colton-Green River boundary are, "(1) an increase in the liminess of the shale, (2) a return to thicker, more persistent carbonate units, and (3) a change in color from the reds of the upper Colton to the pale greens of the lower Green River beds" (Marcantel and Weiss, 1968, p. 48). The Colton Formation is thought to be of early Eocene age (Spieker, 1946).

Green River Formation—Lacustrine conditions returned to eastern and central Utah with the deepening of the Uinta Basin and the expansion of Lake Uinta over much of the state. The Gunnison Plateau divide (Divide graben) contains exposures of the Green River Formation. It is poorly exposed in the upper reaches of the Dry Canyon graben (northeast corner) while slope-forming beds crop out in the southeast part of the quadrangle. Beds are horizontal or dip gently east. Green River fault blocks are common in the Chriss/Mellor graben, especially toward the north. The center portion of the monocline bounding the quadrangle to the west is Green River Formation dipping westward from 18-40 degrees.

In Hells Kitchen Canyon SE quadrangle three Green River lithofacies can be distinguished: (1) a mudstone facies, (2) a carbonate facies, and (3) a clastic/carbonate facies (figure 4). The first consists of greenish-gray mudstone, intramicrite, flat-pebble conglomerate and micrite; it is well represented in Rough Canyon. Mudstone dominates the mudstone facies and weathers light greenish gray (5G8/1) and yellowish gray (5Y8/1). The fresh surfaces range from yellowish gray (5Y8/1) to pale olive (10Y6/2). In decreasing abundance, quartz, calcite, and dolomite comprise the rock. Accessory minerals include illite and orthoclase feldspar. Mudstone beds are massive, generally 10 to 20 feet (3 to 61 m) thick between the thin micrite layers. The rock weathers to laterally continuous slopes.

Yellowish gray (5Y8/1) and light greenish gray (5G8/1) intramicrites contain clay intraclasts up to 0.3 inches (0.8 cm) in diameter. The carbonate is limestone or dolomitic limestone. The insoluble residue of these rocks consists entirely of mud. Beds are massive, ledge forming, and are generally several feet thick.

A single massive bed of yellowish-gray (10YR8/6) flat-pebble conglomerate occurs near the top of the mudstone facies. Clasts are composed of dolomite with interspersed terrigenous mud. Rounded pebbles range from 0.2 to 1.6 inches (0.5-4.1 cm) in length and 0.1 to 0.2 inch (0.3-0.5 cm) in width. The long axes of the clasts are nearly horizontal. The rock forms slopes upon weathering. Light greenish-gray (5GY8/1) micrite is composed of dolomitic limestone.

The carbonate facies consists of micrite, tuff, sandy micrite, and fine conglomerate. Grayish-yellow (5Y8/4) and moderate orange-pink (5YR8/4) micrites weather yellowish gray (5Y8/1) and grayish yellow (5Y8/4). Dolomites are most common, followed by calcareous dolomites and limestones. Insoluble residues consist of mud. Units are thin bedded or massive and weather to ledges of blocky slabs or slopes. Beds range in thickness from 0.6 to 4.6 feet (0.2-1.4 m) and average 2.6 feet (0.8 m).

Tuff weathers from pinkish gray (5YR8/1) and yellowish gray (5Y8/1) to grayish orange (10YR 7/4) and very pale orange (10YR8/2). Two aphanitic samples were collected. X-ray diffraction reveals potassium feldspar, quartz, and dolomite. Both samples contain euhedral pyrite with hematite halos. One sample is nearly 50 percent dolomite and reflects deposition in a lacustrine environment. The tuffs are thin bedded, planar, and weather to ledges.

Thin beds (under 1.1 ft or 0.3 m) of sandy micrite weather from a fresh color of pale yellowish orange (10YR8/6) to grayish orange (10YR7/4). Composition varies from dolomite to limestone. Insoluble residues consist of loose, medium, quartz sand with minor feldspar and black chert. Units are thin bedded or massive and weather to ledges.

Grayish orange (10YR7/4) fine conglomerate consists of grain-supported carbonate clasts ranging from 0.1 to 0.6 inch (0.3-1.5 cm) in diameter. Clasts are moderately sorted, rounded, and composed of dolomite. No preferred orientation was observed. Beds are massive and weather to slopes or ledges.

Nearly equal amounts of sandstone and micrite comprise the clastic/carbonate facies exposed near the mouth of Timber Canyon. Minor sandy micrite, micrite, intramicrite, and oomicrite are also present. Sandstones of the clastic/carbonate facies weather to grayish orange (10YR7/4) and pale yellowish brown (10YR8/2) to grayish orange (10YR7/4). The sand is moderately sorted with fine to medium or medium to coarse sand being common. Beds are massive or thin bedded. A discontinuous channel lies near the center of the section. Sedimentary structures include mudcracks, ripples, and trough crossbeds.

The sandstones are sublitharenites and lithic arenites (Pettijohn and others, 1972); monocrystalline quartz and carbonate rock fragments comprise most of the rock. Very pale orange (10YR8/2) and pale yellowish orange (10YR8/6) micrites range from dolomite to limestone. Mud dominates the insoluble residue with minor fine sand consisting of quartz, black chert, feldspar, and iron oxide. Thin beds are common with rare massive beds.

Sandy micrites are pale yellowish orange (10YR8/6) or yellowish gray (5Y7/2) in color and are composed of limestone. One sample contains 45 percent fine quartz sand. Sandy micrites are thin bedded or massive and slope forming.

Moderate orange pink (5YR8/4) oomicrite forms a single bed 0.3 foot thick (0.09 m) of ledge-forming dolomite. A three-foot (1 m) section of very pale orange (10YR8/2) intramicrite forms the base of the section. Dolomitic mud supports clay and carbonate intraclasts. The intramicrites are massive or thin bedded and ledge forming.

Facies changes in the Green River of the Hells Kitchen Canyon SE quadrangle are shown in figure 4. The mudstone facies is seen to thin southwestward from nearly 950 feet (289 m) near South Baldy Peak (Millen, 1982) to approximately 140 feet (43 m) in Rough Canyon. West of Rough Canyon the mudstone facies may interfinger and grade into the clastic/carbonate facies or pinch out. Erosion has removed much of the carbonate facies, but pebbly conglomerates of the Crazy Hollow Formation cap the carbonate facies in the Divide graben, providing an approximate thickness of 220 feet (67 m). The carbonate facies is believed to interfinger and grade laterally into the clastic/carbonate facies. The clastic/carbonate facies is found only along the west margin of the quadrangle and may be equivalent to the Tawny facies of Zeller (1949). In the first major drainage south of the mouth of Hells Kitchen Canyon the clastic/carbonate facies lies directly on Indianola conglomerate.

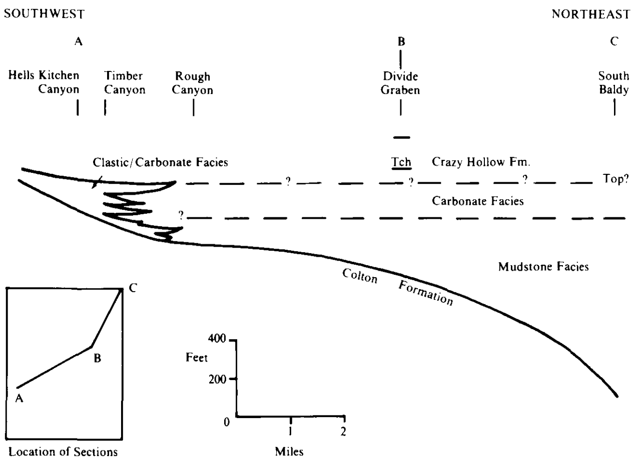

Figure 4. Facies changes in the Green River Formation across the Hells Kitchen Canyon SE quadrangle.

A complete section of Green River strata is not exposed in the Hells Kitchen Canyon SE quadrangle. The incomplete section in Rough Canyon is 206 feet (63 m) thick. The beds of the clastic/carbonate facies near the mouth of Timber Canyon have a combined thickness of 339 feet (103 m). In the north portion of the Divide graben the Green River is more than 900 feet thick. In the southern portion of the Divide graben the mudstone facies is approximately 270 feet (82 m) thick, the carbonate facies is approximately 220 feet (67 m).

In central Sanpete Valley Sheliga (1980) determined the age of the Green River Formation to be Eocene, deposited in a 4-5 million year span as indicated by K-Ar dates ranging from 43.1 to 46.4 million years. Fossils are rare in the Hells Kitchen Canyon SE quadrangle; four specimens of *Australorbis* sp. were tentatively identified following LaRocque (1956).

Crazy Hollow Formation—Down-faulted Crazy Hollow pebbly conglomerate is exposed on the crest of the Divide graben and red sandstones are exposed near the highest point of the quadrangle. At both locations the beds appear to dip concordantly with the underlying Green River Formation (about 3 degrees west). A small area of Crazy Hollow outcrop caps a fault block which extends to the north from the northeasternmost portion of the Chriss/Mellor graben.

The Crazy Hollow is comprised of sandstone and pebbly conglomerate in the quadrangle area. Light-brown (5YR6/4) pebbly conglomerate is grain or matrix supported. Well-sorted and rounded pebbles range in size from 0.1 to 0.4 inches (0.3-1.0 m). Grayish sandstone, similar to that described below, comprises the matrix. Pebbles of black chert, white orthoquartzite, and gray limestone and dolomite are weakly cemented by silica or calcite. Pebbly conglomerate occurs as channel lag or at the base of large-scale crossbeds. In general the rock is friable and weathers to slopes or ledges. Rare massive beds weather to a honeycomb pattern.

Light olive-gray (5Y6/1) pepper-and-salt sandstone consists of moderately sorted, sub- to well-rounded, fine to medium grains. Monocrystalline quartz, gray and black chert, and carbonate rock fragments are common with lesser polycrystalline quartz and feldspar. The matrix is less than 5 percent and the cement is calcareous. The bedding is massive or consists of large-scale crossbeds. The sandstone forms slopes or small ledges.

Pale reddish-brown (10R5/4) or grayish-red (5R4/2) sandstone occurs near the top of the Divide graben. The rocks are similar to those found overlying the grayish sandstone just east of the quadrangle. The sand is fine grained, well sorted, and rounded. Calcareous cement appears to be the host of the red color. Bedding was not observed due to poor exposures, but the rock is slope forming. The channel geometry and the large-scale crossbeds of the Crazy Hollow Formation reflect the establishment of fluvial systems in the quadrangle and the waning of Green River lacustrine deposition.

No bedrock units overlie the Crazy Hollow Formation in the quadrangle. Elsewhere the formation is overlain by the Moroni, Bald Knoll, Gray Guloh, or Axtel Formations (Babisak, 1949; Fograsher, 1956; Gilliland, 1951; and McGookey, 1960). The formation shows considerable variation in thickness in central Utah ranging to maximum 1,000 feet (305 m), but quadrangle exposures are poor and incomplete. Approximately 40 feet (13 m) of pebbly conglomerate are down-faulted at one site on the plateau's crest.

Spieker (1949) used stratigraphic relations to suggest an Eocene or late Eocene age for the Crazy Hollow Formation. Near Salina, K-Ar dates on biotite show the Crazy Hollow and formation of Aurora to have been deposited in the late Eocene (Willis, 1985). Age determinations of rocks collected from the Goldens Ranch Formation of the region, which overlies the Crazy Hollow in the Chriss Canyon-Skinner Peaks area, show that unit to be early Oligocene in age (Armstrong, 1970; Marvin, 1984, unpublished data). No datable material (paleontologic or radiogenic) was found in the Crazy Hollow in the quadrangle, but a late Eocene age is assigned based on Willis' observations to the south and the early Oligocene age of the overlying Goldens Ranch Formation to the north.

QUATERNARY SYSTEM

Lake Bonneville sediments—In the Hells Kitchen Canyon SE area Lake Bonneville sediments are exposed in SENW Sec. 12, T. 18 S., R. 1 W. Local farmers have used the sediment to replace topsoil removed by flooding of the Sevier Bridge Reservoir. These pits provide small areas of good exposure where elsewhere the sediments have been plowed to cropland. These sediments form a low ridge which parallels the Sevier Valley. The Gunnison-Fayette canal bounds the deposit to the west. Sediment west of the canal is believed to have been removed by Sevier River lateral cutting. Alluvial fans bound the Lake Bonneville sediments to the east. The nature of the contact is unknown. The Lake Bonneville sediments are slightly higher than the toes of the neighboring fans, which implies super-position of the lake over the edges of the fans.

The Lake Bonneville deposits are light brown (5YR6/4) and consist of fine sand, very fine sand, silt, and mud. The sand is dominated by quartz with lesser amounts of feldspar, hornblende, and biotite. Strata are very thinly bedded or laminated. Structureless layers are rare. The total thickness of the exposed unconsolidated and cohesive sediment is 15 feet (5 m). C. G. Oviatt (1984, pers. comm.) indicates the deposit is an underflow fan, mostly deposited subaqueously by the turbid and possibly relatively cold water of tributary rivers entering the lake and flowing along the lake bottom as density currents.

Mass movement deposits—Mass movement deposits of two distinct ages occur in this quadrangle: late Pleistocene and Holocene. A late Pleistocene mass movement covers about one square mile in the southeast corner of the quadrangle. The lack of typical landslip forms, as characterized by Schroder (1971), implies a relatively old geomorphic age. The surface of the mass is hummocky and dissected, and no remnants of the crown, scar, or toe of the mass movement were found. Mudstones of the Colton Formation and probably the mudstone facies of the Green River Formation were moved. Pebble- to boulder-sized bedrock fragments were rafted from both the Colton and Green River Formations. The lack of mass-movement features hinders the determination of the exact type of mass movement. A large (about 10 inches more than at present) increase in annual precipitation during the Pleistocene glaciation (Schumm, 1965) created conditions favoring mass movement.

Seventeen displaced masses of Holocene-age mass movements were mapped and described (appendix). The fresh appearance of these geomorphic features implies a very young age. Shallow landslides (debris slides of Varnes, 1958) involving soft cohesive mud are most common. Size is generally on the order of hundreds of feet (length and width), and sliding was the dominant form of movement. In some cases coherent slide blocks underwent rotation. Earthflows extend from the toes of three slides. All of the younger landslides are composed of mudstones or soils developed on the Colton Formation. Many of the Holocene mass movements are believed to have been caused by high precipitation in 1983 and the spring of 1984. A single rockslide was mapped in the carbonate facies of the Green River Formation.

Alluvial fan deposits—Four alluvial fans of differing relative ages bound the quadrangle to the south and northwest. The oldest fan (Qaf_4) has a limited terrace form and rises 165 feet (50 m) above the younger fan deposits (Qaf_2 and Qaf_1). A Pleistocene age is based on a greater vegetation density, outcrop area (very little of the fan has escaped erosion), and the fan's higher elevation. Poorly stratified and sorted material ranges in size from mud to large boulders. Gravel is more abundant than sand. The maximum size of clasts decreases westward with large cobbles occurring near Utah State 28. The clasts include sandstone and orthoquartzite cobbles from the Indianola, micrites from the Flagstaff, and nondescript siltstones, mudstones, and sandstones. Utah State 28 cuts through the fan in the western portion of Sec. 36, T. 17 S., R. 1 W.

Sediments of Qaf_3 cover the bedrock of the monocline bounding the plateau's western margin. Fresh and inferred fault scarps form the boundary with younger fan deposits to the southwest. Clast size and composition is similar to Qaf_4. Alluvial fan (Qaf_3) deposits are up to 200 feet (61 m) higher than the younger deposits (Qaf_1 and Qaf_2).

Qaf_2 consists of coalesced alluvial fans. The semi-circular geometry usually associated with the topography of alluvial fans (Rachocki, 1981) has been modified with the present topography sloping gently to the southwest. Maximum clast size decreases to the southwest from boulders near the mountain front to mud and sand west of Utah State 28. Clast composition reflects the bedrock of the local drainage basin. An isolated area of Qaf_2 occurs in Timber Canyon, SWNE Sec. 12, T. 17 S., R. 1 W. The sediment of Qaf_2 appears to underlie or be laterally equivalent to the Lake Bonneville sediments, implying a Pleistocene age for both Qaf_3 and Qaf_2. At least three alluvial fans have coalesced to form the youngest fan deposits (Qaf_1). The deposits have been built on top of the Qaf_2 fans and show semi-circular geometry. The poorly stratified and poorly sorted material consists of mud to boulders and the composition reflects the local bedrock. The lower drainage and vegetation density, fresh appearance, and stratigraphic position (overlying Qaf_2) implies a younger (Holocene) age for Qaf_1.

Colluvium—Unconsolidated material of several formations has been gravitationally transported to the base of steep slopes and cliffs. Colluvium (Qc) flanks the lower slopes of the Divide graben in central and eastern Sec. 24, T. 17 S., R. 1 E. The material consists of clays belonging to the Colton and Green River Formations. Mud, sand, and cobble-sized debris were shed from steep slopes at the head of Hells Kitchen Canyon, SENE, Sec. 17 and SWNW Sec. 16, T. 17 S., R. 1 E. Strata of the lower Flagstaff and upper North Horn Formations acted as a source.

In several places steep cliffs of Indianola Group (undifferentiated) have gently sloping colluvium at their base. The colluvium consists of sand to boulder-sized Indianola materials. The largest such deposit is in W ½ Sec. 30 and N ½ Sec. 31, T. 17 S., R. 1 E.

Alluvium—Unconsolidated detritus of diverse composition and size is limited to canyon floors, a reservoir, and a lake in the quadrangle. The most common color of these deposits is light brown (5YR6/4). Size and composition of the detritus reflects the bedrock geology of the surrounding drainage basin. Alluvial deposits are generally poorly stratified with units being subdivided by changes in clast size. Typically the alluvium is poorly sorted, structureless mud to boulder-sized debris. Graded units and units composed only of pebbles and cobbles are rare. Units are generally one to three feet thick. Clasts of Indianola orthoquartzite, Flagstaff Limestone, Colton mudstone, and Green River limestone are recognizable. Some units are slightly cemented by calcite but remain friable. Alluvium floors portions of Timber, Hells Kitchen, Axhandle, and Mellor Canyons. Alluvium of the Sevier River is found at the margin of the Sevier Bridge Reservoir. The thickness of this alluvium is unknown.

STRUCTURE

GENERAL STATEMENT

The structure of the Hells Kitchen Canyon SE quadrangle is perhaps the most complex in the Gunnison Plateau. High-angle normal faulting produces three grabens, the plateau's southwestern margin, and an additional graben perpendicular to the regional strike. The faulting has offset gently dipping strata of the western limbs of the Gunnison Plateau synclines and an anticline to the west (see cross sections, plate 2). A faulted monocline borders the western margin of the quadrangle.

The quadrangle is located on the western limb of south-plunging synclines in the Gunnison Plateau. An anticline involving the Indianola Group (undifferentiated) is centered along the axis of the Chriss/Mellor graben. The east limb of the anticline is the west limb of the syncline involving the Indianola. The west limb of the anticline is a west-dipping monocline which bounds the Chriss/Mellor graben to the west. In the monocline the Indianola beds dip to the west and southwest from 2 to 31 degrees. The anticline is well expressed by a line from S ½ Sec 25, T. 17 S., R. 1 W. to the S ½ Sec 29, T. 17 S., R. 1 E. Just east of the Chriss/Mellor graben the Indianola dips 10 degrees ENE. Just west of the Chriss/Mellor graben the Indianola dips 11 degrees SW.

GRABENS

Chriss/Mellor graben—The Chriss/Mellor graben extends 12 miles (19 km) from south of Mellor Canyon to just north of Chriss Canyon. The width varies from 0.75 to 1.5 miles (1.2 km-2.4 km), averaging a mile (1.6 km). A series of NNW- to NNE-trending high-angle normal faults define the graben. The eastern boundary fault is here designated the Escarpment fault. The fault trends NNW from Sec. 8, T. 18 S., R. 1 E. to Sec. 18, T. 17 S., R. 1 E., then turns to the NNE and continues into the Chriss Canyon quadrangle. Displacement along the Escarpment fault decreases southward from approximately 2,400 feet (732 m) at Timber and Hells Kitchen Canyons to 2,100 feet (640 m) at Mellor Canyon.

The western boundary fault is made of two segments which are subparallel to the Escarpment fault. From the center of the graben Sec. 30, T. 17 S., R. 1 E. and continuing 8 miles (13 km) to the north, the fault is continuous and shows no lateral offset. To the south of Sec. 30 the west graben boundary might be better described as a fault zone. No fewer than 5 high-angle normal faults, with an average length of one mile (1.6 km), form the graben boundary. The faults are offset laterally up to 1,300 feet (396 m) (E ½ Sec. 25, T. 17 S., R. 1 W.) or form a series of connected branches (NE Sec. 6, T. 18 S., R. 1 E.). One mile (1.6 km) north of Mellor Canyon a gap of over just half a mile (.9 km) occurs where the western boundary fault is discontinuous (SWSW Sec. 5 and NW Sec. 8, T. 18 S., R. 1 E.). Displacement of the western boundary faults decreases to the south. In Timber Canyon, Indianola beds abut the carbonate facies of the Green River, indicating a vertical displacement of 1,700 feet (518 m). The relationships at Hells Kitchen Canyon are more complex, with Flagstaff, Indianola, and Green River all faulted against the Indianola. A rough estimate of displacement in this area ranges between 200 and 1000 feet (61 and 305 m).

Several horsts of Indianola conglomerate lie inside the Chriss/Mellor graben, and the largest horst is just north of Rough Canyon. The mile-long (1.6 km), gray block of Indianola is locally referred to as the "Battleship." High-angle normal faults are relatively abundant within and along the western margin of the Chriss/Mellor graben. Major drainages follow faults in Timber, the north and south branches of Hells Kitchen, and Rough Canyons. The faults are commonly two miles (3.2 km) in length. At least 8 faults cross-cut the western boundary fault. No faults cross-cut the Escarpment fault.

Divide graben—The Divide graben extends over 7 miles (11 km) from the east-central part of the map area to just north of the head of Timber Canyon (plate 1). Its width varies from 1 to 1 ¼ miles (1.6-2.0 km). The graben's positive topographic relief is due to a cap of resistent rocks of the carbonate facies of the Green River Formation. Two high-angle normal faults define the graben and trend northeast from Sec. 25 to Sec 23, T. 17 S., R. 1 E., then continue to the NNE. Both faults show similar displacement with the northern part downdropped at least 750 feet (229 m) and the southern part downdropped 600 feet (183 m). The eastern boundary is poorly exposed for much of its length because of soft mudstone slump of the lower Green River and Colton beds on the more moist east side where snow lodges in abundance. Exposures of the western boundary fault can be seen near the head of Timber and Hells Kitchen Canyons.

The internal structure of the Divide graben is much simpler than in the Chriss/Mellor graben. A set of four *en echelon* faults trend to the northwest just south and southeast of the head of Hells Kitchen Canyon. Normal faults of small (less than 150 ft or 46 m) displacement have moved several Green River blocks down the mountain to the southwest. These blocks are believed to be the most recent in a series of movements which have involved the entire hillside. The small movement and slight rotation seen in masses of the carbonate facies of the Green River suggest the area may consist of toreva blocks sliding on the mudstone facies of the Green River.

Dry Canyon graben and other faults related to grabens—The east-west-trending normal fault of Secs. 35 and 36, T. 16 S., R. 1 E. defines the southwest part of the Dry Canyon graben. Movement across the fault is down approximately 600 feet (183 m) on the north. The fault continues three miles (4.8 km) to the east where it is well exposed on the east Gunnison front. The graben is further described in Spieker (1949, p. 74). Flat Canyon is a broad, flat-bottomed linear depression that begins near Timber Canyon and ends four miles (6 km) to the north just south of Chriss Creek. Its width is approximately one mile (1.6 km). The high-angle normal fault which parallels the southwest front of the Gunnison Plateau bounds Flat Canyon on the east. The fault is buried by alluvium and with the lack of outcrop in the canyon no estimate of the displacement can be given. The hills west of Flat Canyon are mostly Tertiary-Quaternary rubbly deposits so the displacement of the depression cannot be specified. Across from Chriss Canyon a normal fault 1.5 miles (2.4 km) long bounds the west margin. The depression may be an asymmetric graben or half-graben (Zoback and Anderson, 1983) with the east fault showing considerable displacement relative to the western margin.

The major high-angle normal fault bounding the southwest margin of the Gunnison Plateau, here designated the Valley fault, suggests that Sevier Valley is a graben or at least a half-graben. Total movement on the fault is unknown but a minimum estimate is 1,400 feet (427 m). Holocene movement of about three feet (0.9 m) is indicated by relatively fresh fault scarps between Mellor and Rough Canyons (plate 1, Anderson and Miller, 1979). McKee and Arabasz (1982) consider the Valley fault to be the southern terminus of the Wasatch fault zone.

OTHER STRUCTURAL FEATURES

A west-dipping monocline forms the western margin of the Gunnison Plateau from Fayette Wash to Buck Canyon, north of Little Salt Creek, a continuous length of over 18 miles (29 km). The monocline is here designated the West Gunnison monocline. In the Hells Kitchen Canyon SE quadrangle the West Gunnison monocline is cut by the western boundary fault of the Chriss/Mellor graben to the east and the Valley fault to the west; Indianola through Green River strata are involved.

North of the large Indianola fault block at the mouth of Hells Kitchen Canyon (NE Sec. 24 and SE Sec. 13), the West Gunnison monocline is divided into two segments by a NE- to NW-trending normal fault. To the east the West Gunnison monocline is capped by west-dipping (17-35 degrees) Flagstaff Limestone. Timber Canyon has dissected the monocline exposing west-dipping (2 degrees) bleached Indianola conglomerate. To the west the monocline is composed of Green River and Colton beds. The Green River increases in dip to the west from 18 to 25 degrees. Near the mouth of Hells Kitchen Canyon the West Gunnison monocline is composed of a single fault block of Indianola. The western portion of the block shows westward increase of west dip from 15 to 31 degrees.

At Hells Kitchen Canyon and continuing 1.5 miles (2.4 km) to the south the monocline is capped by Green River strata. Dips are 26-40 degrees to the west and southwest. South and southeast a horst of west-dipping (11 degrees) Indianola comprises the West Gunnison monocline. The horst is over two miles (3.2 km) in length and trends to the northwest. The second small drainage northwest of Rough Canyon contains a west-dipping (85 degrees) outcrop of Green River which appears to sit in angular unconformity on the underlying Indianola. From Rough to Mellor Canyon, the West Gunnison monocline consists almost entirely of Flagstaff Limestone. Dips are to the southwest from 15 to 43 degrees. Two small patches of Colton Formation dip 52 degrees west just north of the mouth of Mellor Canyon.

STRUCTURAL EVOLUTION

Figure 5 shows six schematic diagrams representing chronologic events aligned along cross-section D-D′. Although parameters such as formation thickness, bedding attitude, magnitude of deformation, and amount of stratigraphic displacement vary from place to place, section D-D′ (see figures 1 and 5) is typical of the western part of the quadrangle. From Cenomanian/Turonian to early Campanian time, coarse clastic debris was transported eastward from a western highland source (Sevier orogenic belt). The material was deposited in alluvial fans which sloped to the east from 3-6 degrees. Figure 5a shows the Indianola conglomerate at the end of this phase.

Deformation began in the Maastrichtian Age (latest Cretaceous). Indianola beds were gently folded into shallow synclines and anticlines prior to major thrusting (figure 5b) as the active part of the Sevier orogenic belt migrated eastward into central Utah (the thrusting becomes younger and higher to the east). At least two thrust faults are thought to have cut the area (figure 5c), and stratigraphic displacement on the pre-Escarpment fault is thought to have been on the order of 1,000 feet (305 m). The displacement on the pre-Valley thrust fault is unknown. North Horn sediments were deposited from Maastrichtian to early Paleocene time (figure 5d) as quiescent lacustrine deposition. A relatively deep basin developed east of the pre-Escarpment fault which received clastics from nearby structural highs. The North Horn is thinner between the faults and characterized by finer clastics. A few Indianola highs persisted through North Horn deposition and were later covered by Lake Flagstaff or Lake Uinta. The Colton, Green River, and Crazy Hollow Formations were deposited during the remainder of the Eocene.

A definitive age has not been determined for the onset of Basin and Range normal faulting in central Utah. Crazy Hollow beds are downfaulted in the quadrangle and faulting could have begun as early as the Oligocene Epoch. The work of McKee and Arabasz (1982) and Anderson and Miller (1979) shows faulting has continued into the Holocene. Fresh fault scarps along the Valley fault also indicate recent movement. Figure 5e gives the approximate location of normal faults just prior to the onset of Basin and Range extension faulting (Oligocene to Miocene time). The assumed present structural configuration is shown in figure 5f. The most recent movements occurred in the Holocene epoch.

GEOLOGIC HAZARDS

Three potential geologic hazards have been recognized in the quadrangle: earthquakes, flash flooding, and landslides.

EARTHQUAKES

Central Utah is part of the Intermountain seismic belt, a zone of shallow seismicity extending from Arizona to western Montana. In Utah the seismicity is concentrated in the transition between the Great Basin on the west and the Colorado Plateau and Middle Rocky Mountains on the east (Smith and Sbar, 1974). Cook and Smith (1967) have reviewed seismicity in Utah from 1850 to June 1965, and during that period only one damaging earthquake was recorded in lower Juab Valley. The earthquake occurred on July 7, 1963 near Levan and had a magnitude of 4.4. A second earthquake of the

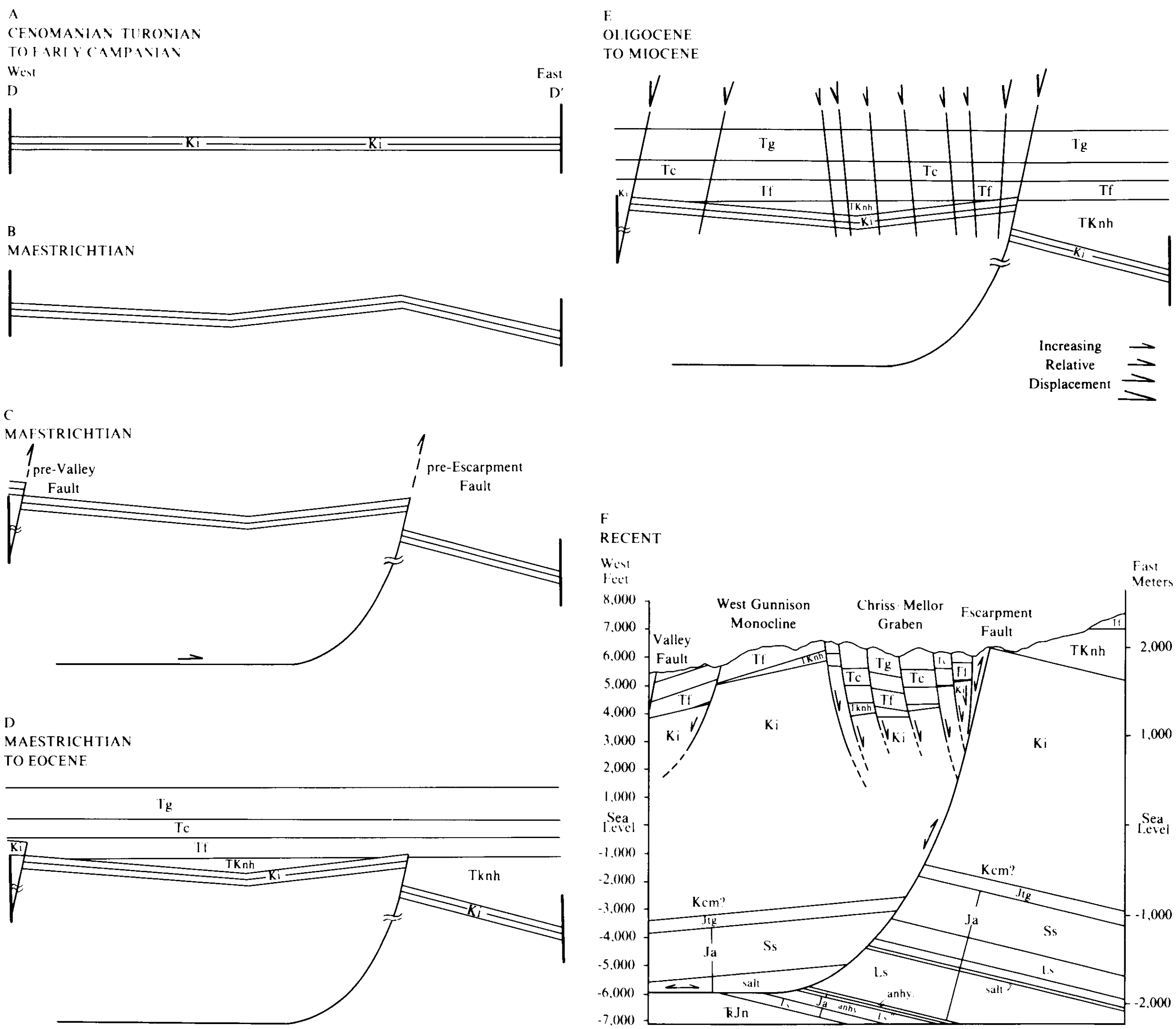

Figure 5. Stages in structural history of the west half of the Hells Kitchen Canyon SE quadrangle. Possible structural configuration suspected at depth along the west half of the quadrangle. Location of D-D′ shown on figure 1.

same magnitude occurred in Goshen Valley 25 miles (40 km) to the north-northwest on May 24, 1980 (Arabasz and others, 1980). Earthquake records and fresh fault scarps indicate the western portion of the quadrangle to be seismically active. Fortunately, the magnitude (less than or equal to 2.8) of recorded earthquakes in the quadrangle is low, and no damage to man-made structures has been experienced.

FLASH FLOODS

The high drainage density along the western half of the quadrangle is efficient in carrying surface water. Lag time between high precipitation (summer thunderstorms) and peak discharge is short and flooding may be hazardous to individuals, livestock, or equipment in the narrow canyons. Erosion associated with flash flooding has destroyed roads in several of the canyons.

LANDSLIDES

The abundance of ancient and recent landslides in the area suggests they are a potential future hazard. The late Pleistocene mass movement near the southeast corner of the map involves Flagstaff, Colton, and Green River deposits. This ancient slide was not reactivated by the unusually high precipitation in 1983 and 1984. Numerous smaller slides were created in the Colton Formation by the rain and snow melt of 1983 and 1984. The only damage caused by such a slide was the dislocation of an unimproved road in Sec. 15, T. 17 S., R. 1 E. Local ranchers rebuilt the road across restabilized slide material. Colton slides, such as the one in Timber Canyon, pose a potential danger of blocking drainages.

ECONOMIC GEOLOGY

SAND AND GRAVEL

Pratt and Callaghan (1970, p. 46) describe an unworked gravel deposit in the alluvial fans of the quadrangle (NENW Sec. 1, T. 18 S., R. 1 W.). This deposit is composed of 50 percent silty soil and 50 percent gravel occurring as sandstone, limestone, and quartzite and has been used locally to repair roads. A few boulders up to three feet (0.9 m) in diameter are present. Similar deposits are found near the mouth of Hells Kitchen Canyon.

The light brown, fine sand of the Lake Bonneville deposits is similar to that found just east of Fayette, which Gilliland (pers. comm.) and Pratt and Callaghan (1970) report to have been used as a commercial sand source for the manufacturing of cement blocks and concrete. The Bonneville sands of the quadrangle have not been used commercially but are used locally as fill.

DIMENSION STONE

The massive oolitic carbonates found in the Green River Formation of Sanpete Valley are absent in the study area. The oolitic units of the Flagstaff Limestone and the Green River Formation are less than one foot thick (0.3 m) or contain bedding or shale partings. Some of the argillaceous micrites of the Flagstaff and Green River are dense and homogeneous and may be suitable for dimension stone.

WATER RESOURCES

Three springs near the head of Hells Kitchen Canyon are reported in Pratt and Callaghan (1970) and discharges range from 0 to 10 gallons per minute (0.63 l/s). Additional springs of unknown discharge are located in NW Sec. 24, NE Sec. 22, and SW Sec. 16, T. 17 S., R. 1 E.; the first two are on faults. Many springs are used by ranchers as local water sources. Major permanent streams flow in Timber and South Maple Canyons with part of the water being used for irrigation, the remainder flowing into the Sevier Bridge Reservoir. Discharge from the other canyons disappears into the alluvial deposits of northern Sevier Valley. Ground water is usually encountered in the alluvium at depths of 40 to 425 feet (12 to 130 m) in the sand and gravel beds of the valley.

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REFERENCES CITED

Anderson, L.W., and Miller, D.G., 1979, Quaternary fault map of Utah: Fugro, Inc., Long Beach, CA., 35 p.

Arabasz, W. J., Smith, R.B., and Richins, W.D., 1980, Earthquake studies along the Wasatch Front, Utah: network monitoring, seismicity, and seismic hazards: Bulletin of the Seismological Society of America, v. 70, p. 1479-1499.

Armstrong, R.L., 1970, Geochronology of Tertiary igneous rocks, eastern Basin and Range Province, western Utah, eastern Nevada, and vicinity, U.S.A: Geochimica et Cosmochimica Acta, v. 34, p. 203-232.

Babisak, J., 1949, The geology of the southeastern portion of the Gunnison Plateau, Utah: unpublished M.S. thesis, Ohio State University, 97 p.

Banks, R.L., 1985, Petrologic study of the Cretaceous-Tertiary North Horn Formation in central Utah: unpublished report, Northern Illinois University, 11 p.

Birsa, D.S., 1973, The North Horn Formation, central Utah; sedimentary facies and petrography: unpublished M.S. thesis, Ohio State University, 189 p.

Cook, K.L., and Smith, R.B., 1967, Seismicity in Utah, 1850 through June 1965: Bulletin of the Seismological Society of America, v. 57, p. 689-718.

Dickinson, W.R., 1974, Plate tectonics and sedimentation *in* Dickinson, W.R., ed., Tectonics and Sedimentation: Society of Economic Paleontologists and Mineralogists Special Publication 22, 204 p.

Dickinson, W.R., and Snyder, W.S., 1978, Plate tectonics of the Laramide orogeny, *in* Mathews, V., III, ed., Laramide Folding Associated with Basement Block Faulting in the Western United States: Geological Society of America Memoir 151, p. 355-366.

Dutton, C.E., 1880, Geology of the High Plateaus of Utah: U.S. Geographical and Geological Survey, Rocky Mountain Region Report.

Fograsher, A.C., 1956, The stratigraphy of the Green River and Crazy Hollow Formations of part of the Cedar Hills, central Utah: unpublished M.S. thesis, Ohio State University, 88 p.

Fouch, T.D., Lawton, T.F., Nichols, D.J., Cashion, W.B., and Cobban, W.A., 1983, Patterns and timing of synorogenic sedimentation in upper Cretaceous rocks of central Utah and northeast Utah *in* Reynolds, M.W., and Dolly, E.D., eds., Mesozoic Paleography of the West-central United States, Rocky Mountain Paleogeography Symposium 2: Society of Economic Paleontologists and Mineralogists, 391 p.

Gazin. C.L., 1938, A Paleocene mammalian fauna from central Utah: Washington Academy of Science Journal, v. 28, no. 6, p. 271-277.

Gill, J.R., 1950, Flagstaff Limestone of Spring City-Manti area, Sanpete County, Utah: unpublished M.S. thesis, Ohio State University, 209 p.

Gilliland, W.N., 1951, Geology of the Gunnison quadrangle, Utah: University of Nebraska Studies, new series, no. 8, 101 p.

Goddard, E.N., Trask, P.D., De Ford, R.K., and others, 1975, Rock color chart: Geological Society of America, 10 p.

Godo, T.J., 1979, Stratigraphy and sedimentary petrology of the Flagstaff Limestone, Gunnison Plateau, central Utah: unpublished M.S. thesis, Ohio State University, 117 p.

Griesbach, F.R., and MacAlpine, S.R., 1973, Reconnaissance palynology and micropaleontology of the Late Cretaceous-early Tertiary North Horn Formation, central Utah (abs.): Geological Society of America Abstracts with Programs, v. 5, no. 6, p. 483.

Hardy, C.T., 1952, Eastern Sevier Valley, Sevier and Sanpete Counties, Utah with reference to formations of Jurassic age: Utah Geological and Mineral Survey Bulletin 43, 98 p.

Hardy, C.T., 1948, Stratigraphy and structure of a portion of the western margin of the Gunnison Plateau, Utah: unpublished M.S. thesis, Ohio State University, 81 p.

Hardy, C.T., and Zeller, H.D., 1953, Geology of the west-central part of the Gunnison Plateau: Geological Society of America Bulletin, v. 64, p. 1261-1278.

Kaufman, E.G., 1977, Geological and biological overview; western interior Cretaceous Basin: Mountain Geologist, v. 14, p. 75-99.

LaRocque, A.L., 1960, Molluscan faunas of the Flagstaff Formation of central Utah: Geological Society of America Memoir 78, 100 p.

———1956, Tertiary mollusks of central Utah: Intermountain Association of Petroleum Geologists Guidebook, 7th Annual Field Conference, p. 140-145.

———1951, Molluscan fauna of the Flagstaff Formation, central Utah: Geological Society of America Bulletin, v. 62, p. 1457-1458.

Marcantel, E.L., and Weiss, M.P., 1968, Colton Formation (Eocene) fluviatile and associated lacustrine beds, Gunnison Plateau, central Utah: Ohio Journal of Science, v. 68, no. 1, p. 40-49.

Mattox, S.R., 1986, The geology of Hells Kitchen Canyon SE quadrangle, Sanpete County, Utah: unpublished M.S. thesis, Northern Illinois University, 448 p.

McGookey, D.P., 1960, Early Tertiary stratigraphy of part of central Utah: American Association of Petroleum Geologists Bulletin, v. 44, 589-615.

McKee, M.E., and Arabasz, W.J., 1982, Micro-earthquake studies across the Basin and Range-Colorado Plateau transition in central Utah, p. 137-150 *in* Nielson, D.L., ed., Overthrust Belt of Utah, 1982, Symposium and Field Conference: Utah Geological Association Publication 10, 335 p.

McNeil, D.H., and Caldwell, W.G.E., 1981, Cretaceous rocks and their foraminifera in the Manitoba escarpment: Geological Association of Canada Special Paper 21, 439 p.

Millen, T.M., 1982, Stratigraphy and petrology of the Green River Formation (Eocene), Gunnison Plateau, central Utah: unpublished M.S. thesis, Northern Illinois University, 220 p.

Muessig, S.J., 1951, Geology of a part of Long Ridge, Utah: unpublished Ph.D. Dissertation, Ohio State University, 213 p.

Newman, K.R., 1974, Palynomorph zones in early Tertiary formations of the Piceance Creek and Uinta basin, Colorado and Utah *in* Guidebook to the Energy Resources of the Piceance Creek Basin, Colorado: Rocky Mountain Association of Geologists Guidebook 25th Annual Field Conference, p. 47-55.

Pettijohn, F.J., Potter, P.E., and Sevier, R., 1972, Sand and sandstone: Springer-Verlag, New York, 618 p.

Pratt, A.R., and Callaghan, E., 1970, Land and mineral resources of Sanpete County, Utah: Utah Geological and Mineral Survey Bulletin 85, 69 p.

Rachoski, A., 1981, Alluvial fans: New York, John Wiley & Sons, 161 p.

Reineck, H.E., and Singh, I.B., 1980, Depositional sedimentary environments with reference to terrigenous clastics, 2nd ed.: Springer-Verlag, N. Y., 549 p.

Rice, D.D., 1983, General characteristics of the Cretaceous western interior seaway or basin, *in* Rice, D.D., and Gautier, D.L., eds., Patterns of Sedimentation, Diagenesis, and Hydrocarbon Accumulation in Cretaceous Rocks of the Rocky Mountains, lecture notes for short course no. 11: Society of Economic Paleontologists and Mineralogists, p. 2-1 to 2-28.

Schumm, S.A., 1965, Quaternary paleohydrology in H.E. Wright, Jr., and Frey, D.G., eds., The Quaternary of the United States: Review Volume for VII Congress of the International Association for Quaternary Research, p. 783-794.

Schroder, J.F., 1971, Landslides of Utah: Utah Geological and Mineral Survey Bulletin 90, 51 p.

Sheliga, C. M., 1980, Sedimentology of the Eocene Green River Formation in Sevier and Sanpete Counties, central Utah: unpublished M.S. thesis, Ohio State University, 166 p.

Smith, R.B., and Sbar, M.L., 1974, Contemporary tectonics and seismicity of the western United States with emphasis on the Intermountain seismic belt: Geological Society of America Bulletin, v. 85, p. 1205-1218.

Spieker, E.M., 1949, The transition between the Colorado Plateau and the Great Basin in central Utah: Utah Geological Society Guidebook 4, 106 p.

Spieker, E.M., 1946, Late Mesozoic and Early Cenozoic history of central Utah: U.S. Geological Survey Professional Paper 205-D, p. 117-161.

Standlee, L.A., 1982, Structure and stratigraphy of Jurassic rocks in central Utah: their influence on tectonic development of the Cordilleran foreland thrust belt *in* Power, R.B., ed., Geologic Studies of the Cordilleran Thrust Belt; Rocky Mountain Association of Geologists, v. 1, p. 357-382.

Stanley, K.O., and Collinson, J.W., 1979, Depositional history of Paleocene-Lower Eocene Flagstaff Limestone and coeval rocks, central Utah: American Association of Petroleum Geologists Bulletin, v. 63, p. 311-323.

Varnes, D.J.,1958, Landslide types and processes *in* Eckel, E.B., ed., Landslides and Engineering Practice: Washington Highway Research Board Special Report 544, 123 p.

Vogel, J.W., 1957, The geology of the southernmost Juab Valley and adjacent highlands, Juab County, Utah: unpublished M.S. thesis, Ohio State University, 152 p.

Volkert, D.G., 1980, Stratigraphy and petrology of the Colton Formation (Eocene), Gunnison Plateau, central Utah: unpublished M.S. thesis, Northern Illinois University, 132 p.

Willis, G.C., 1985, Revisions to the geochronology and source areas of early Tertiary formations in the Salina area of Sevier Valley, central Utah: Geological Society of America, Abstracts with Programs, v. 15, no. 5, p. 272.

Zeller, H.D., 1949, The geology of the west-central portion of the Gunnison Plateau, Utah: unpublished M.S. thesis, Ohio State University, 93 p.

Zoback, M.L., and Anderson, R.E., 1983, Style of Basin-Range faulting as inferred from seismic reflection data in the Great Basin, Nevada and Utah: Geothermal Resources Council, Special Report No. 13, p. 363-381.

APPENDIX

MASS MOVEMENTS

LATE PLEISTOCENE MASS MOVEMENT

Location: portions of section 36, T. 17 S., R. 1 E., and 1, 2, 10, 11, 12, 14, and 15, T. 18 S., R. 1 E.
Type: probably debris-flow.
Dimensions: width, approximately 10,000 feet at the toe and crown; length, 1,000 to 2,000 feet; thickness, unknown.
Elevation: crown maximum 6,600 feet, crown minimum 6,200 feet; toe maximum 6,200 feet, toe minimum 6,000 feet.
Slope exposure: west to northwest.
Material: soft, unconsolidated mud.
Vegetation: sagebrush and grass.
Geologic setting: mudstones of Colton and possible lower member of the Green River Formations, rafted debris of sandstone, limestone, and Green River chert blocks up to 4 x 15 x 15 feet.

HOLOCENE MASS MOVEMENTS

1-slide/flow
Location: NE¼ NW¼ section 5, T. 18 S., R. 1 E.
Type: landslide and earthflow.
Dimensions: width, 200 feet; length, 50 feet; thickness, 9 feet.
Elevation: approximatey 6,080 feet.
Slope exposure: south.
Material: soft, unconsolidated mud.
Vegetation: junipers and grass. Process: sliding with rotation, some flowing at toe.
Effects: main scarp with 9 feet of downward rotation, numerous secondary scarps, trees tilted.
Geologic setting: Colton Formation.

2-rockslide Location: SW¼ SE¼ section 7, T. 17 S., R. 1 E.
Type: rockslide.
Dimensions: width, 300 feet; length, 500 feet; thickness, 15 feet.
Elevation: crown, 6,320 feet; toe, 6,080 feet.
Slope exposure: south.
Material: rock.
Vegetation: Juniper and sagebrush.
Process: sliding.
Effects: scarp, tilted trees.
Geologic setting: sliding parallel to bedding plane of upper member of Green River Formation.

3-slide
Location: NE¼ NE¼ section 22, T. 17 S., R. 1 E.
Type: landslide.
Dimensions: width, 300 feet; length, 400 feet; thickness, 6 feet.
Elevation: crown, 7,720 feet; toe, 7,600 feet.
Slope exposure: southwest.
Material: cohesive, soft mud.
Vegetation: grass.
Process: sliding with some rotation.
Effects: dislocated dirt road, scarps.
Geologic setting: Colton Formation. Slide located below a spring. Standing water present.

4-slide
Location: SW¼ NE¼ section 22, T. 17 S., R. 1 E.
Type: landslide.
Dimensions: width, 500 feet at toe; length, 300 feet; thickness, 3 feet.
Elevation: crown, 7,580 feet; toe, 7,520 feet.
Slope exposure: east.
Material: cohesive, soft mud.
Vegetation: grass.
Process: sliding.
Effects: single major scarp-producing crown.
Geologic setting: Colton Formation.

5-slide
Location: SW¼ NE¼ NE¼ section 22, T. 17 S. R. 1 E.
Type: landslide.
Dimensions: width, 350 feet at toe; length, 300 feet; thickness, 5 feet.
Elevation: crown, 7,680 feet; toe, 7,590 feet.
Slope exposure: west.

Material: cohesive, soft mud.
Vegetation: grass and cottonwood trees.
Process: sliding with some rotation, approximately 20 feet of fluid movement at base.
Effects: scarps and fissures, trees tilted.
Geologic setting: Colton Formation. Slide located below a spring. Standing water on slide. Water seeping from base of slide.

6-slide
Location: SE¼ SE¼ section 22, SW¼ SW¼ section 23, N½ NE¼ section 27, T. 17 S., R. 1 E.
Type: landslide.
Dimensions: width, 1,800 feet at toe; length, 1,600 feet; thickness, 2 feet.
Elevation: crown, 7,450 feet; toe, 7,200 feet.
Slope exposure: southeast.
Material: cohesive, soft mud.
Vegetation: grass.
Process: sliding.
Effects: single scarp at crown.
Geologic setting: Colton Formation.

7-slide
Location: SW¼ SW¼ section 2, T. 17 S., R. 1 E.
Type: landslide.
Dimensions: width, 250 feet at toe, length, 300 feet; thickness, 6 feet.
Elevation: crown, 7,670 feet; toe, 7,590 feet.
Slope exposure: east.
Material: cohesive, soft mud.
Vegetation: grass.
Process: sliding.
Effects: scarps.
Geologic setting: Colton Formation.

8-slide
Location: SE½ NE¼ section 24, T. 17 S., R. 1 E.
Type: landslide.
Dimensions: width, 900 feet at toe; length, 500 feet; thickness, approximately 15 feet.
Elevation: crown, 7,160 feet; toe, 7,080 feet.
Slope exposure: east.
Material: cohesive, soft mud.
Vegetation: scrub oak, grass.
Process: sliding with slight rotation.
Effects: tilting of trees, main scarp of 25 feet, fissures.
Geologic setting: Colton Formation. Slide located below a spring. Standing water on slide.

9-slide/flow
Location: SW½ NE¼ section 7, T. 17 S., R. 1 E.
Type: landslide and earthflow.
Dimensions: width, 600 feet at toe; length, 700 feet; thickness, 15 feet.
Elevation: crown, 6,100 feet; toe, 5,780 feet.
Slope exposure: northwest.
Material: cohesive, soft mud with minor bedrock.
Vegetation: scrub oak.
Process: sliding with some rotation, flow at base.
Effects: scarps up to 10 feet in height, fissures, trees down and tilted.
Geologic setting: Colton Formation.

10-slide
Location: NE¼ SW¼ section 12, T. 18 S., R. 1 E.
Type: landslide.
Dimensions: width, 500 feet at crown; 600 feet at toe; length, 300 feet.
Elevation: crown, 6,160 feet; toe, 6,080 feet.
Slope exposure: southwest.
Material: cohesive, soft mud.
Vegetation: scattered scrub oak.
Process: sliding.
Effects: scarps.
Geologic setting: Colton Formation.

STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES
UTAH GEOLOGICAL AND MINERAL SURVEY

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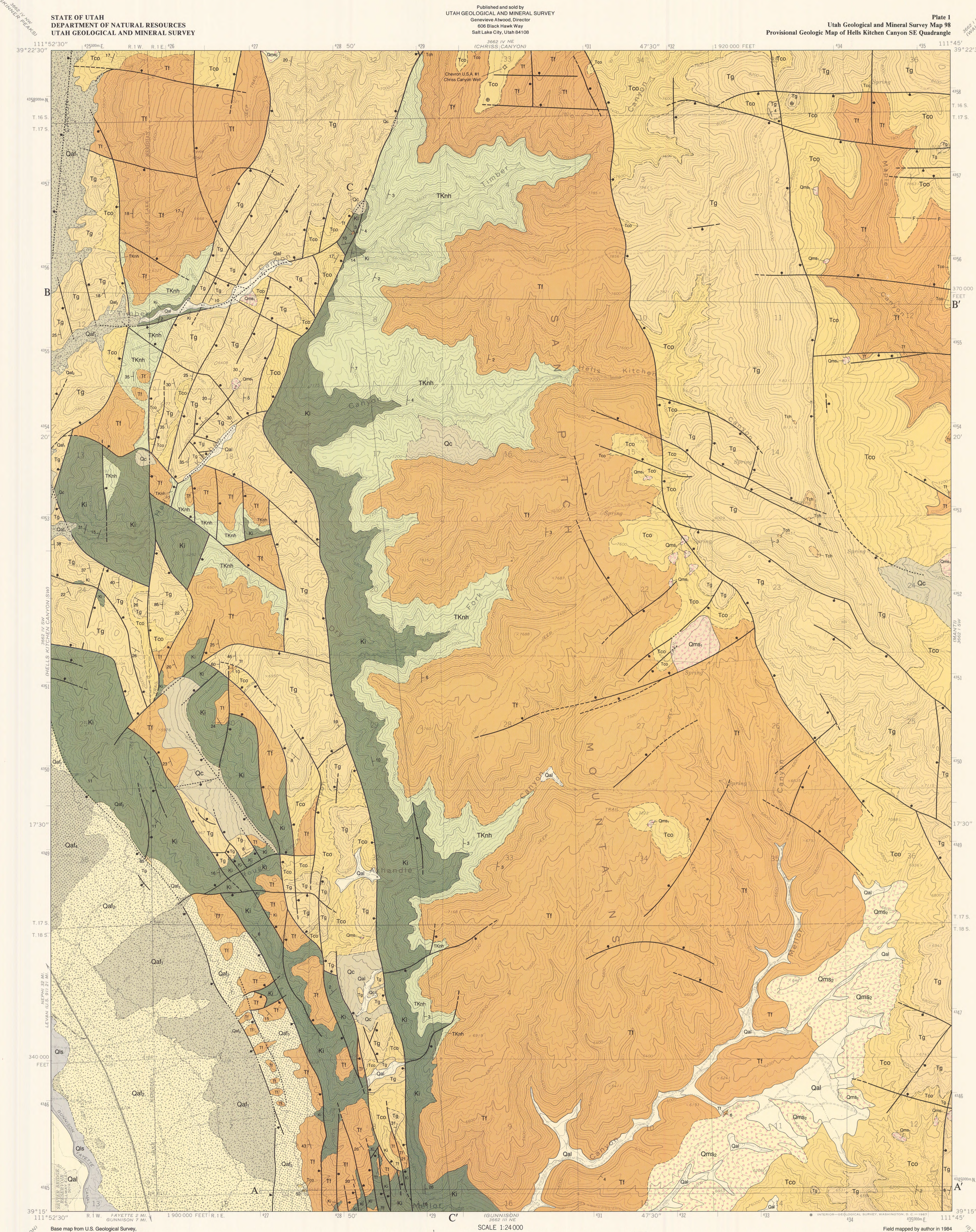
Salt Lake City, Utah 84108

Plate 1
Utah Geological and Mineral Survey Map 98
Provisional Geologic Map of Hells Kitchen Canyon SE Quadrangle

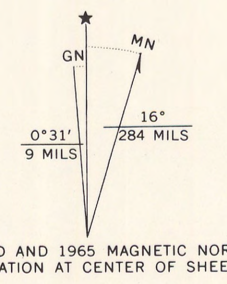


Base map from U.S. Geological Survey, Hells Kitchen Canyon SE Quadrangle, 1965

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

Field mapped by author in 1984
Dr. Malcolm P. Weiss, Thesis Advisor/Chairman, NIU
J. W. Parker, Cartographer



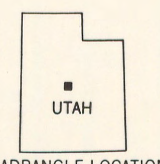
UTM GRID AND 1965 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

PROVISIONAL GEOLOGIC MAP OF THE HELLS KITCHEN CANYON SE QUADRANGLE, SANPETE COUNTY, UTAH

by

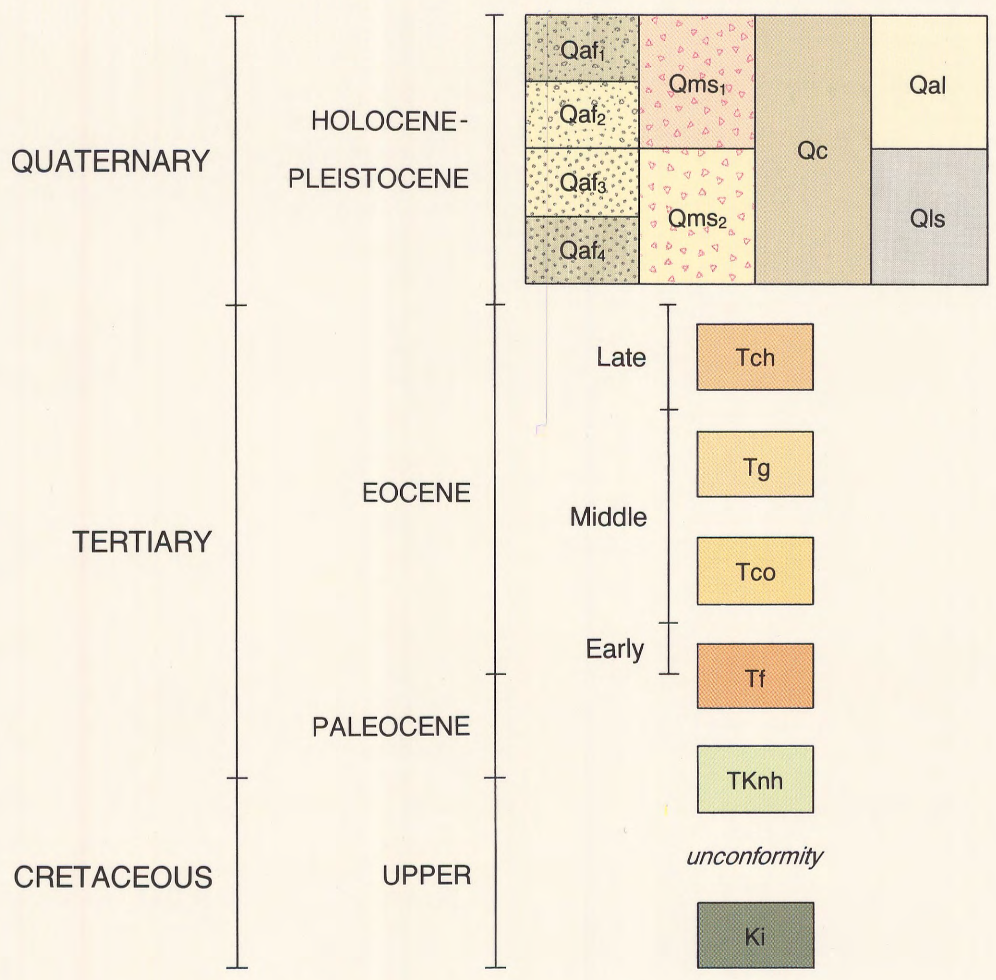
Stephen R. Mattox

1987

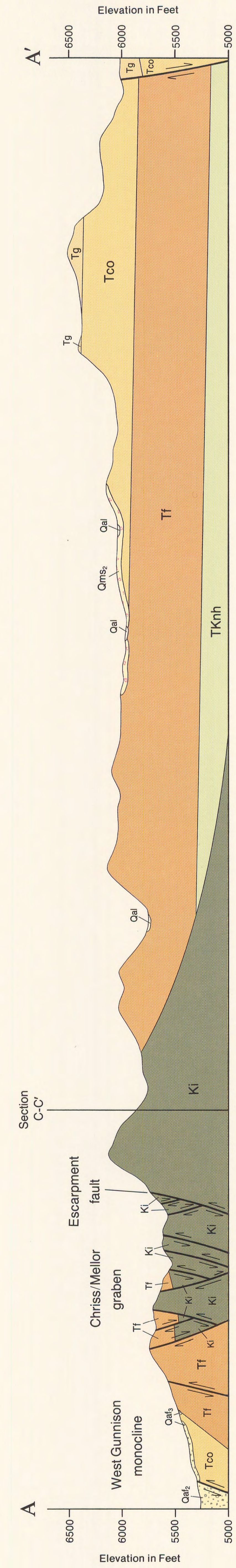


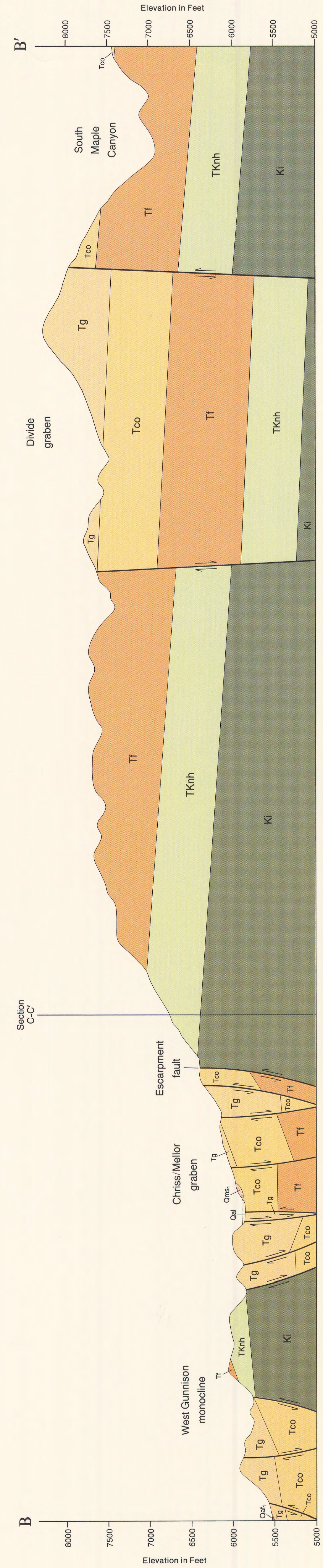
QUADRANGLE LOCATION

CORRELATION OF MAP UNITS

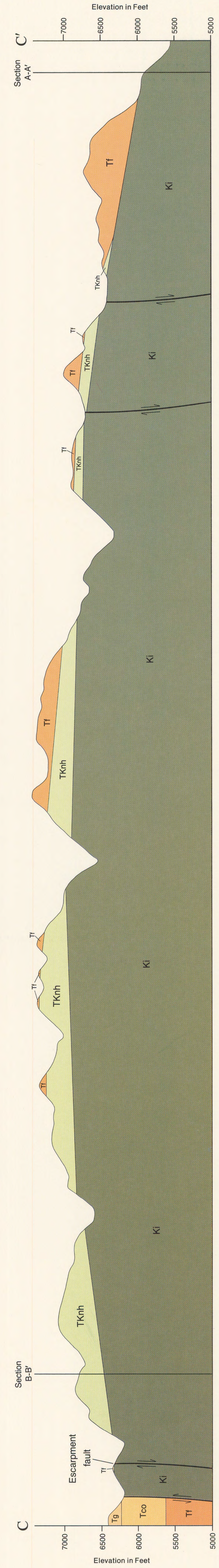


SYSTEM	SERIES	FORMATION		SYMBOL	THICKNESS feet (meters)	LITHOLOGY
QUATERNARY	PLEISTOCENE/HOLOCENE	Surficial deposits		Q	0-300 (0-90)	
		Crazy Hollow Formation		Tch	60 (18)	
TERTIARY	EOCENE	Green River Formation	Upper Member	Tg	200-600 (60-185)	
			Lower Member	Tg	400-900 (120-275)	
		Colton Formation		Tco	280-440 (85-135)	
	PALEOCENE	Flagstaff Formation		Tf	820-940 (250-287)	
CRETACEOUS	MAASTRICHTIAN	North Horn Formation		TKnh	West 0-125 (0-38) East 0-830 (0-253)	West East
	CENOMANIAN/TURONIAN EARLY CAMPANIAN	Indianola Group		Ki	8760 (2670)	





Note: 2x vertical exaggeration on cross sections



MAP SYMBOLS

CONTACT
Dashed where inferred or poorly exposed

HIGH-ANGLE NORMAL FAULT
Dashed where inferred, dotted where concealed; bar and ball on downthrown side

FRACTURE

20 Inclined — Horizontal
STRIKE AND DIP OF BEDS

Drilled well (dry hole)

DESCRIPTION OF MAP UNITS

Qal Alluvium—*Light brown mud, silt, sand, cobbles and boulders, poorly sorted and structureless, mostly in canyon floors.*

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

Qaf1 Youngest alluvial fan deposits—*Mud, silt, sand, cobbles, and boulders, in well-formed fans overlying Qaf_2.*

Qaf2 Young alluvial fan deposits—*Coalescing fans with the average clast size decreasing from the mountain front.*

Qaf3 Old alluvial fan deposits—*Mud to large boulders in fans up to 200 ft (61 m) higher than the younger Qaf_1 and Qaf_2.*

Qaf4 Oldest alluvial fan deposits—*Mud to large boulders with gravel more abundant than sand, lying up to 165 ft (50 m) above the younger Qaf_1 and Qaf_2.*

Qls Lake Bonneville sediments—*Light brown fine and very fine sand, silt, and mud, thinly bedded or laminated.*

Qms1 Younger mass movement deposits—*Earth flows and debris flows; pebbles to boulder-sized fragments covering relatively small areas.*

Qms2 Older mass movement deposits—*Debris flows consisting of material from the Colton and Green River Formations, appearing in larger hummocky and dissected masses.*

Tch Crazy Hollow Formation—*Grayish-orange cherty sandstone with scattered black chert pebbles; only thin remnants on quadrangle.*

Tg Green River Formation—*Mostly grayish-orange to yellowish-brown freshwater limestone and grayish orange sandstone in upper part and mostly greenish-gray mudstone in lower part.*

Tco Colton Formation—*Variegated mudstone, thin pale green limestone and yellowish-gray sandstone, generally less resistant and more prone to landsliding than units above and below.*

Tf Flagstaff Limestone—*Yellowish-gray to pale red argillaceous limestone, limestone, and sandy limestone, with a few sandstone beds to the west; ledges and cliffs more common than slopes.*

TKnh North Horn Formation—*Conglomerate, sandstone, and limestone, grayish to the east and reddish in western exposures.*

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