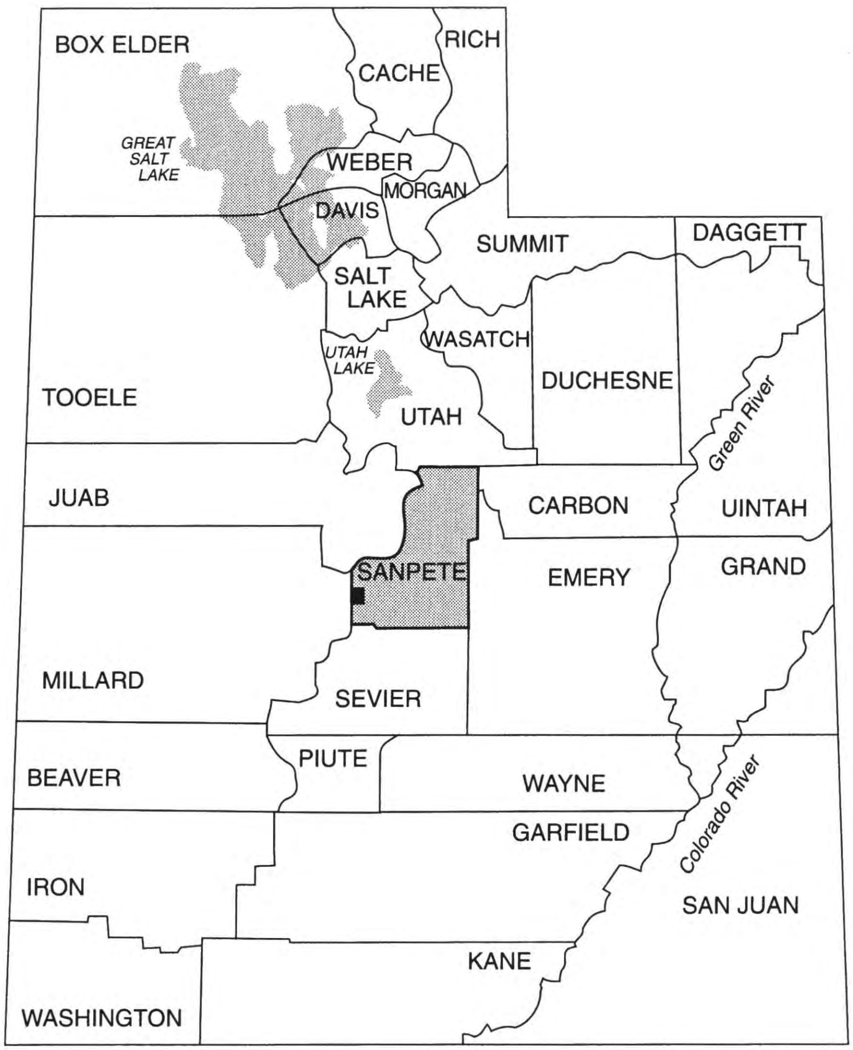
GEOLOGIC MAP OF THE HAYES CANYON QUADRANGLE, SANPETE COUNTY, UTAH

by
David H Petersen



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ABSTRACT

The Hayes Canyon quadrangle is in the transition zone between the Colorado Plateau and the Basin and Range Physiographic Provinces and includes the eastern part of the Valley Mountains and the western part of Sevier Valley. Exposed bedrock includes the upper 450 feet (135 m) of the Paleocene North Horn Formation; the Paleocene to Eocene Flagstaff Formation, which is divided into a lower member about 450 feet (135 m) thick, a middle member 175 to 300 feet (53-90 m) thick, and an upper member 250 to 300 feet (75-90 m) thick; the Eocene Colton Formation, which is 300 to 450 feet (90-135 m) thick; and the Eocene Green River Formation, which is at least 400 feet (120 m) thick. The Miocene to Pliocene Sevier River Formation unconformably overlies the Green River Formation in the area and, although not exposed in the quadrangle, probably is present beneath surficial deposits. Alluvial, fluvial, colluvial, and mass-movement deposits are locally present. Lacustrine and flood-plain sediments are found in the Sevier Valley.

Strata in the Valley Mountains strike nearly north-south and dip eastward 25 to 40 degrees near Sevier Valley, and 10 to 15 degrees near Japanese Valley. The increase in dip toward Sevier Valley reflects the Valley Mountains monocline, which decreases in magnitude toward the southern end of the quadrangle.

The quadrangle area is cut by many faults. They are steep, dipping about 80 degrees, and are of three types: (a) major north-south-trending normal faults with displacements up to 4,000 feet (1,219 m), (b) east-west-trending scissor faults with displacements ranging from a few tens of feet to about 500 feet (150 m), and (c) minor north-south-trending normal faults with displacements of a few tens of feet. Many gravity-induced slide blocks of the structurally weak North Horn and Flagstaff Formations are present along the edges of larger fault-bounded blocks.

Minor amounts of gravel, sand, and roadfill have been quarried and dimension stone and thin lenses of gypsum and coal are also present. There has been no drilling for oil or gas in the quadrangle. Ground water and surface water are also important resources.

Geologic hazards of concern include earthquakes, landslides, floods, shallow ground water, expansive clays, and debris flows. Several faults in the quadrangle cut Quaternary sediments and the southern part of the Wasatch fault is present a few miles east of the quadrangle.

INTRODUCTION

The Hayes Canyon 7.5-minute quadrangle is in the transition zone between the Colorado Plateau and the Basin and Range provinces (Stokes, 1977). The central part of the Valley Mountains is in the western part of the quadrangle and the western part of the Sevier Valley is in the eastern part of the quadrangle (figure 1). The mountains are predominantly Tertiary rocks that are faulted and tilted to the east. The valley is partially filled with Late Tertiary and Quaternary unconsolidated sediments.

Previous mapping in the area includes the Gunnison 15-minute quadrangle (Gilliland, 1951), the Manti 30x60-minute quadrangle (Witkind and others, 1987), and the Scipio 15-minute quadrangle, located west of the study area (Tucker, 1954). Four adjoining 7.5-minute quadrangles are also mapped: Hells Kitchen Canyon SE, to the northeast (Mattox, 1987); Gunnison, to the east (Mattox, 1992); Redmond, to the southeast (Witkind, 1981); and Redmond Canyon, to the south (Willis, 1991). Other important stratigraphic and structural studies include Spieker (1946, 1949), Armstrong (1968), Burchfiel and Hickcox (1972), Doelling (1972), Standlee (1982), Witkind and Page (1984), and Oviatt (1992).

STRATIGRAPHY

About 2,000 feet (600 m) of rock are exposed in the Hayes Canyon quadrangle (appendix). All the exposed rock is probably Tertiary, although some of the North Horn Formation may be Late Cretaceous. The North Horn and the lower part of the Flagstaff Formations are probably Paleocene, while the upper part of the Flagstaff, the Colton, and the Green River Formations are Eocene. Rocks of known Cretaceous age are not exposed in the Hayes Canyon quadrangle, but it is likely that the Cretaceous Cedar Mountain Formation, Indianola Group, and Price River Formation are present 1,000 to 2,000 feet (300-600 m) beneath the surface (unit Ku on cross sections A-A′ and B-B′) (Willis, 1991). The Eocene to Pliocene Crazy Hollow, Aurora, and Sevier River Formations, and volcanic and volcaniclastic strata probably underlie alluvial fill in Sevier Valley (Willis, 1986, 1991). These units are designated as undifferentiated Quaternary and Tertiary deposits (QTu) on the cross sections.

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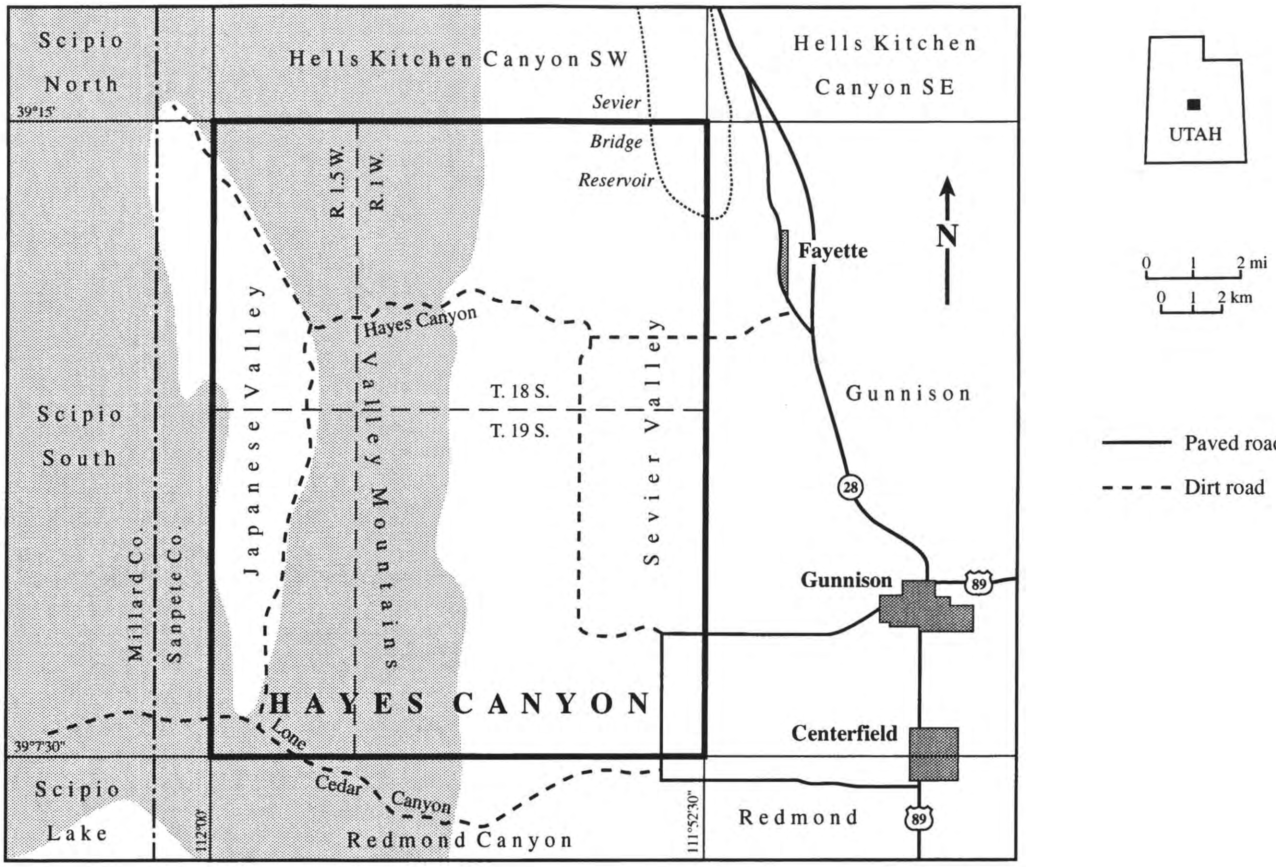


Figure 1. Index map of the Hayes Canyon quadrangle and adjacent areas.

Tertiary

North Horn Formation (TKnh)

The best exposures of the North Horn Formation are in Hayes Canyon and along the eastern side of Japanese Valley. Only the upper 450 feet (135 m) are exposed, though the formation is probably about 2,000 feet (600 m) thick in the area (Willis, 1991). Griesbach and MacAlpine (1973) and Newman (1974) indicated that the North Horn is Maastrichtian to early Paleocene in age. Spieker (1946) suggested a late Cretaceous to early Paleocene age for North Horn deposits on the Wasatch Plateau, east of Hayes Canyon quadrangle. Fouch and others (1982) assigned a Paleocene to Eocene age to North Horn deposits in Sanpete Valley, also located east of the quadrangle. Because only the upper part of the North Horn Formation is exposed in the quadrangle, outcrops are likely Paleocene, but could be as young as Eocene.

The formation is predominantly gray to tan, calcareous, ledge-forming sandstones, interbedded with gray to tan, predominantly sandy, slope-forming limestones and calcareous mudstones (appendix). Some of the limestones and mudstones are dolomitic. In Hayes Canyon, a few sandstone and limestone beds near the top of the sequence are reddish-brown to maroon.

Many of the sandstone intervals are lenticular, cross-bedded, and contain conglomerate lenses or have a conglomeratic base. Intervals commonly fine upward, grading into mudstone. Where the sandstone beds thicken, conglomerate increases and may compose the entire layer.

About 60 percent of the conglomerate clasts are dark-gray limestone and about 30 percent are white quartzite. The clasts range from gravel to small boulders, and are similar to Paleozoic rocks found to the west (Gilliland, 1951). The clasts may have been directly derived from the Paleozoic rocks, or may have been reworked from the Indianola Formation, which was locally exposed during North Horn Formation deposition.

The North Horn Formation becomes less sandy upward, and grades into the predominantly limestone units of the Flagstaff Formation. Although the contact between the two formations is gradational in the Hayes Canyon quadrangle, 4 miles (6.4 km) north of the quadrangle, in Red Canyon, the Flagstaff rests unconformably on the North Horn, recording a local erosional episode (Witkind and Page, 1984).

The North Horn Formation contains at least two oncolite beds; one, about 21 feet (6.4 m) thick, is near the top of the formation and extends over much of the quadrangle. The other oncolite bed is about 215 feet (64.5 m) from the top of the formation and is about 13 feet (4 m) thick. Three lenses of coal and carbonaceous shale are present in Hayes Canyon. The largest is about 10 feet (3 m) thick where exposed in a 20-foot-wide (6 m) road cut about 1.8 miles (2.9 km) west of the canyon mouth.

The gastropod, *Oreohelix* sp. (LaRocque, 1956), is common in the top 130 feet (40 m) of the formation. In a stream bed near the northwest corner of section 25, T. 18 S., R. 1½ W., poorly preserved leaf impressions, possibly *Platanus nobilis* (Newberry) and *Carya* sp?, are present in thin-bedded sandstone layers of a point-bar deposit. Poorly preserved wood fragments and impressions of reeds or mashed twigs are common throughout the area.

The point-bar deposits surrounded by sandy limestones and sandy mudstones probably formed in a meandering river and floodplain environment. Local interbedded non-clastic limestones typify a part-time lacustrine environment. Fossil remains and carbonaceous units indicate that deciduous trees and other plants grew on floodplains, in small swamps, and along stream banks.

Flagstaff Formation

I divided the Flagstaff Formation into informal lower, middle, and upper members in the Hayes Canyon quadrangle. Willis (1991), who mapped the adjacent Redmond Canyon quadrangle to the south, also divided the Flagstaff Formation into three informal members; however, because of the localized, lenticular nature of Flagstaff strata, Willis' (1991) members do not correspond with members I mapped in the Hayes Canyon quadrangle. The Flagstaff Formation is late Paleocene to early Eocene in age (Fouch and others, 1982).

Lower member (Tfl): The best exposures of the lower member of the Flagstaff Formation are in Hayes Canyon, where the member is about 450 feet (135 m) thick (figure 2). It is composed primarily of tan, gray, and olive, micritic limestone, some of which is dolomitic (appendix). Sedimentary structures within layers are generally absent. The limestones erode into alternating ledges and slopes and many break into chippy talus deposits. Slope-forming limestones are more thinly bedded than ledge-forming limestones. Thin calcareous sandstone layers, generally a few feet thick, are present at the base of the lower member. They thicken and are more abundant to the south.

The lower member of the Flagstaff Formation, especially the bottom half, is the most fossiliferous of the three members. Gastropods are common in most layers, and *Bulimulus* sp., *Oreohelix* sp., and "*Helix*" sp. were identified using LaRocque (1956). Oncolites cored by gastropods are common in a few layers. The lower member of the Flagstaff Formation probably was deposited in a near-shore to shallow lacustrine environment.

Middle member (Tfm): The middle member is the most lithologically variable Flagstaff member in the quadrangle. The best exposures are in Hayes Canyon and along Lone Cedar Road, south of the quadrangle (figure 2). It varies from 175 feet (53 m) to 300 feet (91 m) thick. It is thickest in the middle part of the quadrangle and thins to the north and south.

A 55-foot-thick (16 m), cliff-forming limestone at the top of the member is the most prominent bed in the quadrangle (figure 3). This layer contains sand, oolites up to 0.1 inch (0.25 cm) in diameter, and scattered limestone pebbles. The bottom half of the prominent layer is dark gray, changing upwards to pale grayish tan and typically has a pitted erosional surface. The upper half of the layer weathers mottled reddish tan to pink. It erodes more easily than the bottom half, and therefore is less commonly exposed. There are indications, such as bioturbation and recementation, that the upper half is a paleosol. Southward,

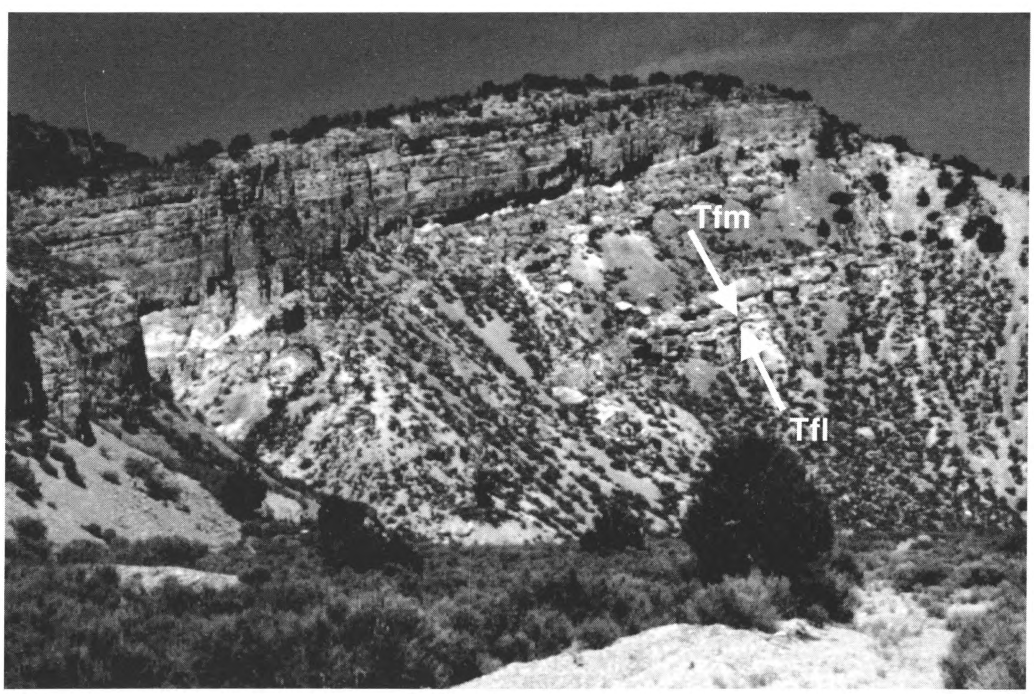


Figure 2. *Exposure of the lower and middle members of the Flagstaff Formation in Hayes Canyon. The contact is at the base of the lower-most resistant limestone unit (section 29, T. 18 S., R. 1 W.).*

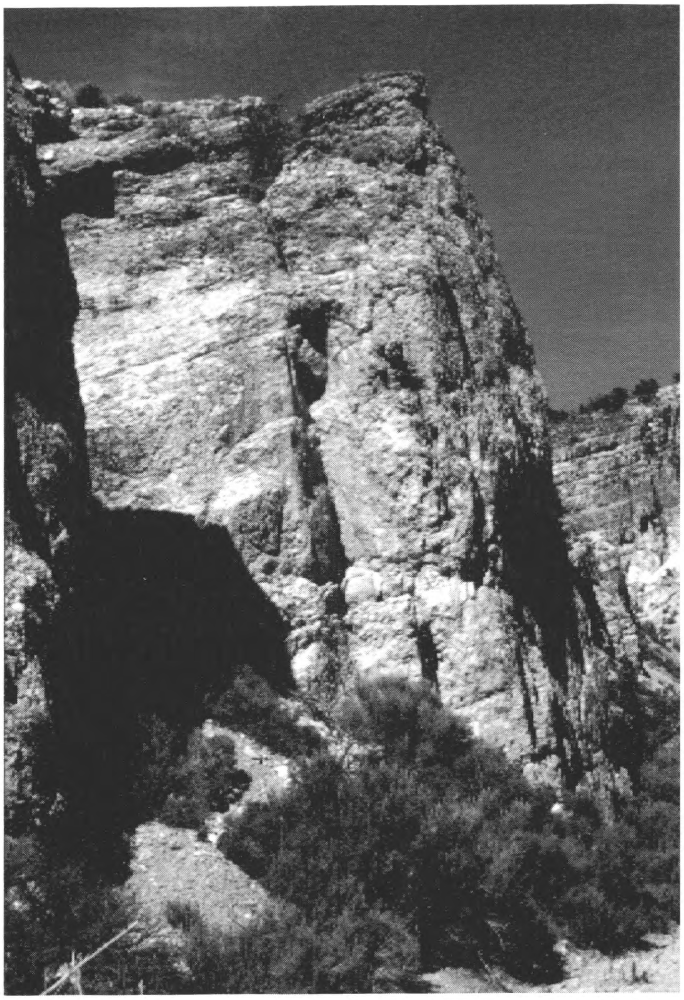


Figure 3. Cliff-forming interval in the middle member of the Flagstaff Formation (section 29, T. 18 S., R. 1 W.).

this prominent unit changes to very pale-gray, mostly chalky limestone that erodes into ledges with scalloped surfaces.

Below the prominent unit are chalky white and pale-gray to pale-pinkish-gray limestones. Many of these beds erode into ledges that have scalloped surfaces and undulating, irregular upper and lower contacts. Southward, the pinkish hue of some of the light-colored limestones intensifies. Included with the light-colored limestones in the Hayes Canyon area is a 12-foot-thick (4 m), resistant, pale-gray, sandy limestone layer with a pitted erosional surface. To the south, the resistant layer thickens and becomes darker gray.

The middle member of the Flagstaff Formation contains poorly preserved gastropods. It was probably deposited in a near-shore lacustrine setting with variable fluvial input.

Upper member (Tfu): The best exposures of the upper member are along the eastern flank of the Valley Mountains in the southern part of the quadrangle, north of Hayes Canyon, and in the northeastern part of Japanese Valley. The upper member is about 250 feet (75 m) thick in southern exposures and increases northward to about 300 feet (90 m).

Over most of the area, the upper member consists of lower and upper limestone intervals separated by a predominantly mudstone interval. The lower limestone interval is fairly homogenous, micritic, and forms a slope with resistant 4- to 5-foot-thick (1.2 - 1.5 m) ledges. It is heavily fractured and weathers into chippy fragments. Although it is predominately pale grayish tan, it also has hues of red, pink, pale yellow, and pale green on fresh fractures. Except for the pale yellow, these hues are less intense toward the north where the lower limestone interval is similar to the lower Flagstaff member. A pinkish-gray, very resistant dolomite that weathers pale brown caps the lower limestone interval. Although the dolomite is only 1 to 3 feet (0.3 - 0.9 m) thick, it is present in nearly all exposures.

The mudstone interval consists of grayish-blue, calcareous mudstone with purplish-red, dolomitic mudstone; pale-olive-green, calcareous mudstone; and a 1.5-foot-thick (0.5 m) selenite layer. The mudstones erode easily and range in thickness from 50 feet (15 m) in the south to 110 feet (33 m) near Hayes Canyon. The mudstones pinch out about 0.75 miles (1.2 km) north of Hayes Canyon.

In the upper limestone interval, pale-gray, locally shaly limestones are interbedded with numerous layers 1 to 3 feet thick (0.3 - 0.9 m) of pale-gray to grayish-green calcareous mudstone. Limestone beds range from about 8 feet (2.4 m) thick at the base of the section to about 10 inches (25 cm) thick near the top. All the limestones are micritic, porcelanous, and generally structureless. The lowest limestone bed contains lenses of mottled, translucent, brown, blue, and gray chert. In the north part of the quadrangle, the chert contains numerous elongate, rectangular voids that average 0.25 - 0.5 inches (0.62 - 1.25 cm) by 0.03 inches (0.07 cm). The voids appear to be casts of gypsum crystals that formed contemporaneously with the chert. Gypsum voids are also abundant in limestone just below the chert; these, however, have been filled with secondary calcite. The chert and limestone overlie gypsum-bearing mudstone. The upper limestone interval also contains a distinctive pale-orange-tan, 2-foot-thick (0.6 m), thin-bedded shale bed with mud cracks. The shale bed is about 13 feet (3.9 m) below the top of the upper limestone sequence and is exposed along the length of the eastern front of the Valley Mountains. The uppermost limestone beds are similar to parts of the lower Green River Formation and may represent interfingering between the Colton and Green River Formations.

Fossils are scarce in the upper Flagstaff member except in the pale-orange-tan shale of the upper limestone sequence. Ostracodes, *Goniobasis* sp., *Viviparus* sp., and *Australorbis* sp.? gastropods, and fish scales, vertebrae, jaw, and bone fragments are common in this unit. A small, poorly preserved, 3-inch (7.5-cm) long fish was also found. Worm burrows, reeds, coprolites, *Elliptio* sp. pelecypods, and *Chlorelopsis*, a type of clumped algae (identified by J.K. Rigby, personal communication, 1989) are less common.

The evaporitic nature of the mudstone and lower limestone intervals suggests that they were deposited in a high-salinity lacustrine setting with minor clastic input. The uppermost limestone sequence suggests a temporary resurgence of the lake where, at times, fish, worms, snails, ostracodes, and reeds flourished. Mudcracks indicate occasional subaerial conditions.

Colton Formation (Tc)

The Colton Formation is poorly exposed in a strike valley along the east side of the Valley Mountains where much of the unit is obscured by slope wash or disturbed by minor mudslides. The best exposure is near the mouth of Hayes Canyon. The Colton ranges in thickness from about 300 feet (90 m) in the north to about 450 feet (135 m) in the south. It is early Eocene in age (Spieker, 1946; Newman, 1974).

Mudstones, generally 10 to 60 feet (3-18 m) thick, make up the bulk of the formation. Most of the mudstones are reddish brown to dark reddish brown, with scattered thin, dark-brown, layers that may be paleosols, and thin, 1-foot- thick (0.3 m) lenses of micaceous siltstone. Calcareous, 3- to 15-foot-thick (0.9 - 4.5 m), greenish-gray mudstones are intermixed with the reddish-brown mudstones.

In the upper half of the formation, mudstones are locally interbedded with 1- to 3-foot-thick (0.3 - 0.9 m) beds of pale-tan to gray limestone and dolomite. A few very thin volcanic ash layers are also present in the upper half of the Colton Formation. The ashes are calcareous and poorly exposed. Most ash beds are 1 inch (0.25 cm) or less thick. However, one limonitic ash is about 12 inches (30 cm) thick.

The Colton Formation erodes to form a strike valley and is gradational with the overlying Green River Formation. Near the mouth of Tarr Canyon a very pale-tan to yellow, chalky limestone, similar to some Green River limestones, forms a 6-foot-thick (1.8 m) ledge in the upper part of the Colton Formation. The contact with the Green River Formation is mapped at the top of the highest reddish mudstone.

The Colton Formation is commonly described as a floodplain deposit (Marcantel and Weiss, 1968; Smith, 1986); however, in the Hayes Canyon quadrangle, sediments are more typical of a mudflat environment which was occasionally submerged by water. No fossils were found in the formation.

Green River Formation (Tg)

The Green River Formation crops out along the eastern front of the Valley Mountains (figure 4). The best exposures are near and north of Hayes Canyon, and south of Pickett Canyon, where a 400-foot (120 m) section is exposed. The top of the formation is not exposed, but it is likely that less than 100 feet (30 m) of additional Green River strata are buried beneath unconsolidated sediments. In the Valley Mountains, the upper part of the formation is cut out by an unconformity, which is exposed south of the quadrangle (Willis, 1991). In the Gunnison quadrangle, to the east where the unconformity is not present, the Green River Formation is 460 feet (140 m) thick (Mattox, 1992). It is early to middle Eocene in age (Fouch and others, 1982).

The formation consists of dark- to pale-grayish-green, calcareous, slope-forming mudstones with interbedded pale-tan to pale-gray, ledge-forming limestone and dolomite. Sandstone beds are rare. Mudstones dominate the sequence and range from 20 to 170 feet (6 to 50 m) thick. A few volcanic ash layers less than 1 inch (0.25 cm) thick are irregularly scattered throughout the mudstones. Most limestone and dolomite beds range from 1 to 13 feet (0.3-3.9 m) thick. The uppermost exposed limestone layer is thin bedded and at least 30 feet (9 m) thick. Most of the limestones are porcelanous and structureless. Thicker, massive limestone beds generally contain chert pods. Most of the chert is translucent and is mottled blue, tan, and red, but it ranges from white to dark brown. Some of the thick limestones have undulating upper and lower contacts and are ledge-forming with scalloped surfaces. The Green River Formation present in the quadrangle is interpreted to represent an offshore lacustrine environment with limited coarse clastic input. No fossils were found in the formation.

Quaternary - Tertiary

Undifferentiated Quaternary and Tertiary Deposits (QTu)

The Crazy Hollow, Aurora, and Sevier River Formations, volcanic and volcaniclastic strata, and older valley-fill deposits are not exposed in the study area, but probably are present beneath alluvial fill in Sevier Valley (cross sections A-A′ and B-B′). These units are exposed in areas to the south and southeast and are described in Willis (1986, 1991).

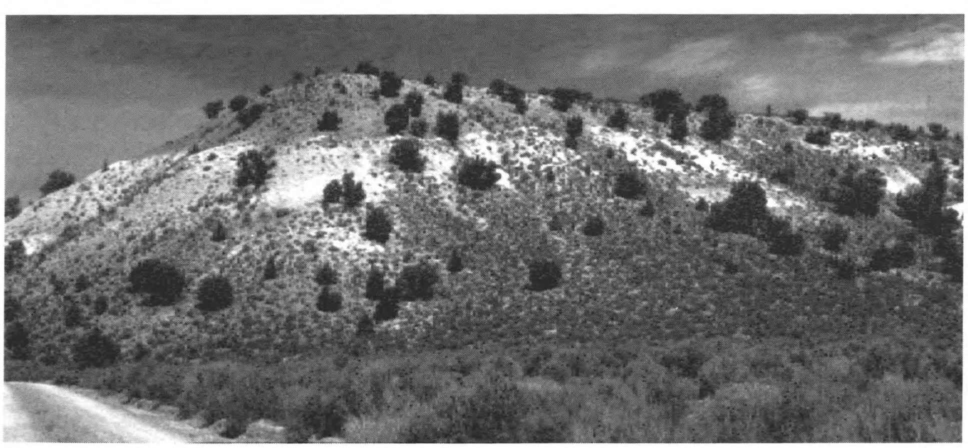


Figure 4. *Lower part of the Green River Formation capped by partially consolidated pediment-mantle deposits (section 28, T. 18 S., R. 1 W.).*

Quaternary

Alluvial Pediment-Mantle Deposits (Qap)

Surficial pediment-mantle deposits cut across bedrock units in much of the area between the Valley Mountains and the Sevier River floodplain. Thickness varies, but in some places deposits are at least 45 feet (13 m) thick. The deposits are easily eroded, forming slope wash that is deposited on surfaces cut into the Colton and Green River Formations (figure 4). There is a difference of approximately 5 degrees between the dip of the alluvial pediment-mantle deposits and the underlying formations.

The deposits are unsorted boulders, pebbles, sand, and clay. All clasts are partially rounded, appear to be derived from local formations, and fine toward Sevier Valley. Most boulders and gravel are either yellowish-brown, calcareous sandstone and conglomerate from the North Horn Formation, or gray or pinkish-red limestone from the middle member of the Flagstaff Formation.

Sediments are unconsolidated, with one exception. About 0.5 miles (0.8 km) north of the mouth of Hayes Canyon, a 2-foot-thick (0.6 m), well-sorted, subangular, well-cemented, pebble conglomerate lens is exposed at the base of unconsolidated pediment-mantle sediments. The lens is cemented with banded white travertine that fills numerous cracks in the conglomerate. The conglomerate lens is near a fault and cementation may be from an ancient spring.

Gilliland (1951) estimated the age of the alluvial pediment-mantle sediments to be late Pliocene or early Pleistocene. The sediments may be remnants of alluvial fans isolated by uplift due to fault movement.

Alluvial-Fan Deposits (Qaf and $Qaf_{1-3?}$)

Alluvial fans are present in Japanese Valley, in the central part of the quadrangle, and along the east front of the Valley Mountains. Two areas of Japanese Valley contains at least two, and possibly three, ages of alluvial-fans designated as Qaf_1, Qaf_2, and Qaf_3?; the lowest number indicating the youngest age. The older fans are isolated by uplift along faults and are deeply dissected. Young alluvial-fan deposits in the central part of the quadrangle also include small areas of older alluvial-fan deposits that are not mapped separately. Undifferentiated alluvial-fan deposits are designated Qaf and are shown only on the cross sections. Young fans (Qaf_1) are gradational with other Quaternary deposits and many fans have coalesced to form bajadas, especially along Sevier Valley.

Alluvial-fan sediments consist of poorly sorted, subangular boulders, gravel, sand, and mud; they fine outward from canyon mouths. In the northwest part of Japanese Valley, large debris flows with extensive hummocky topography make up a substantial part of recent fans.

Older Alluvial Deposits (Qa_2)

Downcutting has stranded deposits of moderately sorted, well-rounded boulders, gravel, sand, and mud on bedrock banks along the largest intermittent streams (figure 5). The deposits typically fine away from mountain fronts and are commonly gradational with other Quaternary deposits. Smaller deposits were not mapped separately. These deposits differ from alluvial-fan deposits in that alluvial-fan deposits are lobate and extend from mountain fronts; Qa_2 deposits are channel-shaped and are found along stream beds.

Younger Alluvial Deposits (Qa_1)

These actively accumulating deposits of moderately sorted, well-rounded boulders, gravel, sand, and mud are confined to intermittent stream channels. The alluvium becomes finer away from mountain fronts and is gradational with other Quaternary deposits.

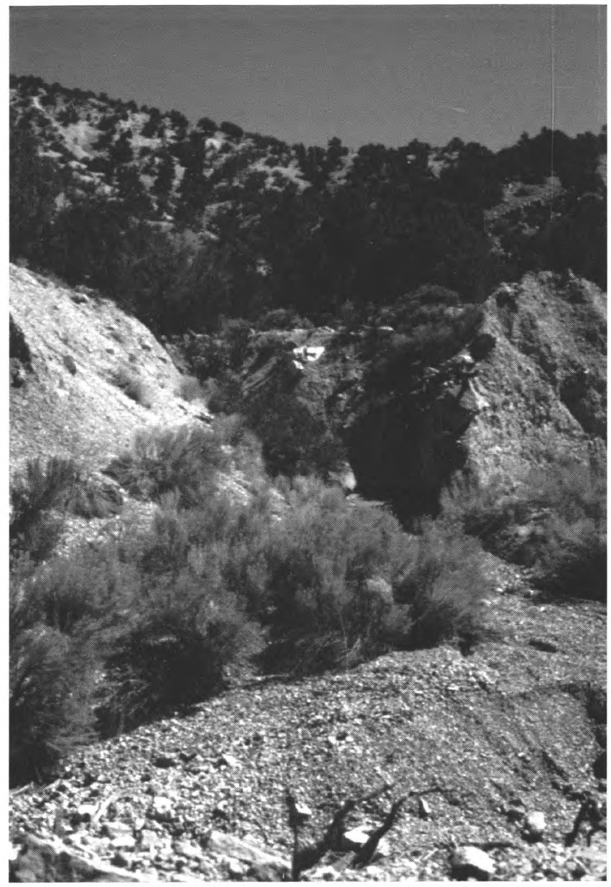


Figure 5. *Deeply dissected older alluvial deposits (Qa_2) in Hayes Canyon (section 25, T. 18 S., R. 1½ W.).*

Floodplain Deposits (Qal)

Floodplain sediments deposited by the Sevier River are present in the eastern part of the quadrangle. They are well sorted, consisting predominantly of fine sand, silt, and clay. Abandoned river channels contain well-sorted gravel, sand, and mud. The floodplain deposits grade into other surficial deposits.

Mixed Alluvial and Colluvial Deposits (Qac)

Thin blankets of unsorted boulders, gravel, sand, and mud have been deposited along mountain slopes and in small washes by alluvial and colluvial processes. These sediments are commonly angular, have been transported short distances, and are gradational with other Quaternary deposits.

Mass Movement - Landslides and Slump Blocks (Qms)

Landslides and slump blocks involving the North Horn Formation (Qms followed by TKnh in parentheses), and lower, middle, and upper members of the Flagstaff Formation (Qms followed by Tfl, Tfm, or Tfu in parentheses), are common throughout the quadrangle. Slump blocks are up to 3,000 feet (900 m) across and 100 feet (30 m) or more thick. Landslides and slumps are common along stream beds and major faults where slopes are oversteepened by erosion. Although strata in slump blocks generally remain intact; competent rocks within slides commonly fracture into large blocks, and incompetent rocks fracture into small rock chips. Small landslides are common within pre-existing major slides and slumps.

Mass Movement - Mudflow and Debris-Flow Deposits (Qmf)

Most mudflows and debris flows in the quadrangle occur within the North Horn and lower member of the Flagstaff Formations. However, two small flows near the mouth of Hayes Canyon involved the Colton and Green River Formations. Flows involve mudstone beds, have lobate edges, and form hummocky topography. Sediments are unconsolidated and unsorted and range from mostly muddy sediments to large angular broken blocks from resistant units. Some of the flows were active during the 1980s.

Lake Bonneville Sediments (Qls)

Lake Bonneville sediments are exposed in a series of small north-south-trending hills and terraces immediately west of the Sevier River floodplain (figure 6). The hills are between 5,040 and 5,080 feet (1,510 - 1,525 m) above sea level. The deposits become smaller and die out towards the south.

The Lake Bonneville sediments are composed of loosely consolidated, pale-tan, interbedded mud, silt, and very fine to fine sand. Thinly laminated silt and sand layers predominate, with silt increasing upwards. Some are cross-stratified. A few contain layers of limonitic sand and silt.

The tops and sides of many of the hills have been reworked by wind into small sand dunes less than 6 feet (1.8 m) high that are too small to map separately (figure 6). The dunes are generally composed of well-sorted sand and contain scattered, poorly rounded, gravel-sized residual pieces of chert that were probably derived from the Green River Formation. Many of the dunes are anchored by vegetation.

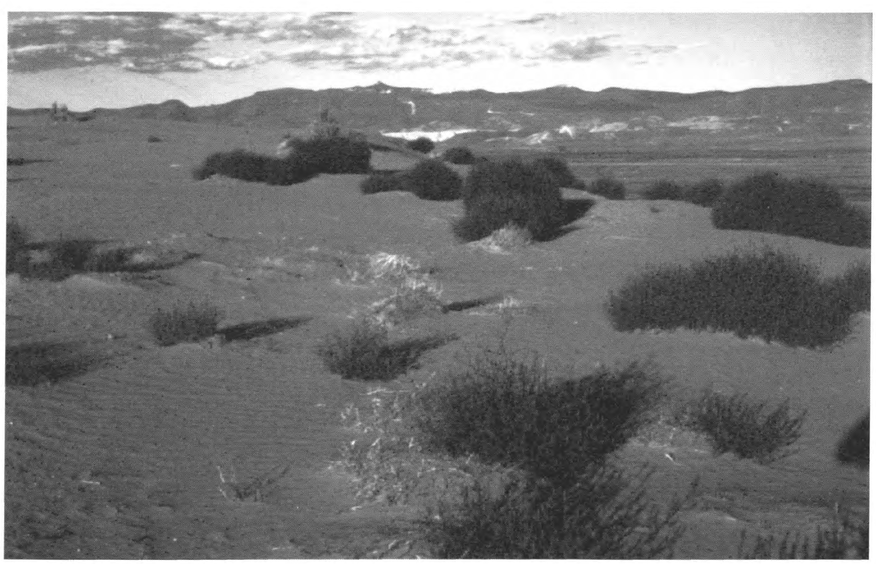


Figure 6. *Well-sorted sand deposited by Lake Bonneville and reworked by eolian activity in the northeast part of the quadrangle (section 22, T. 18 S., R. 1 W.).*

Mattox (1992) collected snail shells from similar Lake Bonneville sediments in the east portion of the Sevier Valley. Although the snail shells were radiocarbon dated at 13,290 ± 200 yrs B.P., Mattox believed that they were contaminated with younger carbonate and that the sediments are from the Lake Bonneville highstand, which existed from 15,500 to 14,500 years ago (Currey and others, 1983; Oviatt and others, 1992).

STRUCTURE

The Hayes Canyon quadrangle has high-angle faults typical of the Basin and Range Province, but also has near-horizontal strata, high relief, and elevations that are similar to the Colorado Plateau (Stokes, 1977). Rocks are dissected by three groups of faults, and are folded into an east-dipping monocline. Large slumps and landslides are common.

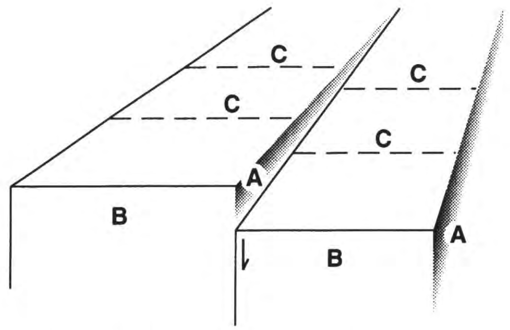
Major drainages are generally controlled by larger north-south- or east-west-trending faults. For example, Tarr and Pickett Canyons in the southern half of the quadrangle are controlled by east-west faults. Drainages in Japanese Valley and Sevier Valley are controlled by north-south faults.

Evidence of pre-basin-and-range (late Tertiary) deformation was not found in the study area. However, adjoining areas do contain evidence of earlier episodes of thrusting and folding (Standlee, 1982; Villien and Kligfield, 1986). Spieker (1949) and Gilliland (1951) showed that at least three main periods of deformation predate basin-and-range faulting. Subsurface rocks in the quadrangle may reflect these disturbances.

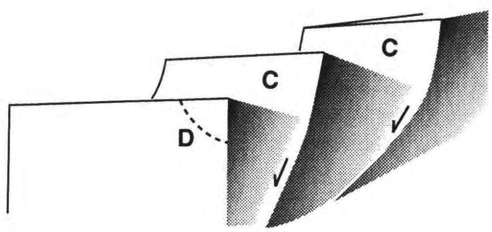
Uplift and extensional faulting in central Utah began in the late Tertiary (Hintze, 1988). The normal faulting and tilting of the Valley Mountains began after deposition of the Eocene Crazy Hollow Formation, which lies stratigraphically above the Green River Formation, probably in the Oligocene (Gilliland, 1951; Armstrong, 1968) or Miocene (Mattox, 1992). Miocene to Recent basin-and-range normal faulting and associated warping are probably mainly responsible for the structural elements exposed in the quadrangle (Gilliland, 1951; Willis, 1991).

Faults

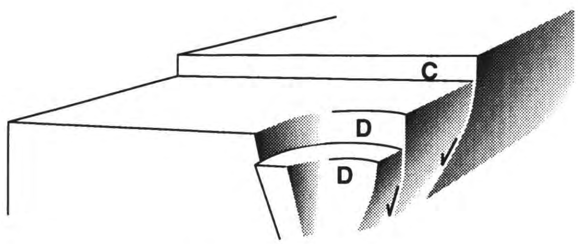
Numerous faults cut the Valley Mountains and Sevier Valley. They can be divided into three categories: (a) major north-south-trending normal faults, (b) east-west-trending scissor faults, and (c) minor north-south-trending normal faults (figure 7). Most are steep, with dips greater than 60 degrees, and typically about 80 degrees. A major north-south-trending normal fault may be present along the western edge of the Sevier Valley and is discussed in the Sevier Valley section.



Uplift activates east-west fractures or faults (A) along with major north-south faults (B).



Blocks, mostly on minor north-south faults (C), move and tilt, probably with continuous uplift.



Relatively small slide blocks (D) move and tilt. Those with lower Flagstaff and North Horn units may become rock slides or landslides.

Figure 7. *Schematic diagram showing probable history of fault and slump development in the Valley Mountains.*

The major north-south faults are along the western and eastern edges of Japanese Valley and in the mountainous region between Sevier and Japanese Valleys. Except along the west side of Japanese Valley, most north-south faults are down to the west. Fault displacements are typically a few hundred feet, but range up to 1,400 feet (420 m) along the east edge of Japanese Valley.

Six large, and a few small, east-west-trending, nearly vertical scissor faults intersect the north-south faults, dividing the range into roughly rectangular blocks. The east-west faults seem to have their greatest displacement near the east front of the Valley Mountains. Displacement on these faults varies from about 20 feet (6 m) to approximately 500 feet (150 m) near the mouth of Tarr Canyon. Four of the large faults are down to the north, and two are down to the south. The smaller faults follow a similar pattern.

Minor north-south-trending, down-to-the-west faults cut the rectangular blocks (figure 7). These minor faults are displaced an average of a few tens of feet and many are too small to be mapped at a 1:24,000 scale. Later landslide and slump block movement tended to develop near the north-south and east-west faults.

Fault History

At least two major episodes of faulting are recorded in the quadrangle, an earlier episode of contemporaneous north-south and east-west faulting, and a later, probably still active, episode of north-south faulting (figure 7).

Early faults: The major north-south and east-west faults of the earlier episode are probably contemporaneous, with some east-west fault movement continuing later. In most areas, east-west faults appear to cut north-south faults; however, locally, such as near Japanese Valley, north-south faults appear to cut east-west faults. Gilliland (1951) reported contemporaneous north-south and east-west faulting of a similar nature in the nearby Wasatch and Gunnison Plateaus. The minor north-south faults in the Hayes Canyon quadrangle mostly postdate the east-west faults.

Active faults: The Valley Mountains area is tectonically active as suggested by Quaternary offset along several of the major north-south-trending faults and tilted surficial deposits. Several faults along the north and east edges of Japanese Valley have scarps 3 to 12 feet (1-4 m) high that are of middle to late Pleistocene age (Hecker, 1993). Sediments of a similar age near Sevier Bridge Reservoir on the east side of the Valley Mountains are also offset up to 12 feet (4 m) by fault scarps, indicating the presence of a large range-front fault (section 15, T. 18 S., R. 1 W.).

An angular unconformity of about 5 degrees exists between the Green River Formation and Quaternary alluvial pediment-mantle deposits along the eastern edge of the Valley Mountains. The pediment-mantle deposits are further tilted a few degrees east, suggesting that tilting of the Valley Mountains continued after deposition of the mantle.

Valley Mountains Monocline

Bedrock in the Valley Mountains strikes nearly north-south, ranging between 10 degrees west and 10 degrees east of north, except locally near faults. Near Sevier Valley, most strata dip eastward 25 to 40 degrees, whereas near Japanese Valley most strata dip eastward 10 to 15 degrees. Witkind and Page (1984) named the flexure between these two valleys the Valley Mountains monocline. In the southern part of the quadrangle, the monocline becomes less well-defined. In most areas extensive faulting has disrupted and distorted the monocline, except in Red Canyon, about 4 miles (6.4 km) north of the Hayes Canyon quadrangle (Witkind and Page, 1984). The monocline may be partially due to block faulting and have some Quaternary deformation (Hecker, 1993).

Mattox (1987) described a west-dipping monocline along the east border of northern Sevier Valley in the Gunnison Plateau, which he named the West Gunnison monocline. Some workers have suggested that the Valley Mountains monocline and West Gunnison monocline form the limbs of a syncline that has an axis beneath Sevier Valley (Brown and Cook, 1982).

The Valley Mountains monocline may be the result of salt dissolution or thrusting and extensional faulting (Standlee, 1982; Witkind and Page, 1984; Willis, 1991; Witkind, 1994). According to Witkind and Page (1984) and Witkind (1994) salt was dissolved from Sevier Valley by the Sevier River, causing collapse of surrounding rocks and formation of the monocline. Although salt dissolution structures are common in the area (Witkind, 1994), it does not appear to be the major cause of the monocline and other mapped structures in the quadrangle for three reasons:

First, nearly all of the north-south faults in the Valley Mountains are down to the west, away from Sevier Valley. If salt collapse were responsible for the formation of the monocline one would expect most fault blocks to be down to the east toward Sevier Valley. The hypothesis also predicts a symmetrical series of down-to-the-west faults on the east side of Sevier Valley. This has not been observed.

Second, the amount of salt removal needed to cause the monocline would be enormous. Elevation differences between the flat-lying rocks at the crest of the Valley Mountains and the top of the bedrock beneath Sevier Valley is estimated at about 6,400 feet (1,900 m). The thickest known salt body in the area, 5,100 feet (1,530 m) thick, was discovered in the Argonaut Energy Corporation's No. 1 Federal well (Witkind and Page, 1984). However, a localized gravity low exists where the well was placed, suggesting that the well was drilled near the center of a salt diapir and did not penetrate a typical thickness of salt. Originally, the salt was probably bedded and averaged only a few hundred feet thick (Standlee, 1982).

Third, salt-bearing rocks may not be present beneath the quadrangle. No Jurassic salt-bearing rocks were encountered in the Placid Oil Company WXC USA 1-2 well, located about 4 miles (6.4 km) west of the study area, which was drilled to a depth of 18,266 feet (5,480 m) (Standlee, 1982; J.L. Baer, personal communication, 1990).

Intramontane Basins

Several graben or half-graben basins exist in two areas in the Valley Mountains. The basins trend north-south and are offset by the major east-west faults. In the first area, near the western edge of the quadrangle, grabens include Japanese Valley and a basin in Lone Cedar Canyon. Most of the floor of Japanese Valley, the largest topographic feature in this area, is covered by unconsolidated material. However, in the southern part of the valley, three "rock islands", predominately of the middle member of the Flagstaff Formation, rise above unconsolidated sediments. The rock islands typically have nearly horizontal dips with variable strikes but are heavily faulted with irregularly trending faults.

In the second area, a half graben developed in the middle of the mountainous region between the Sevier and Japanese Valleys. The graben contains several small basins; the largest are in the central and northern parts of the quadrangle. The largest basins contain rock islands similar to those in Japanese Valley.

Landslide Blocks

Many gravity-induced landslides and slumps are present on steep slopes near faults in the mountainous areas (figure 7). The landslides and slump blocks developed mostly in the structurally incompetent North Horn Formation and lower member of the Flagstaff Formation in weak mudstone and thin-bedded limestone that destabilized more competent overlying rocks as they eroded. As the landslides and slump blocks moved, they generally rotated backwards. Rocks within the landslides and slump blocks are highly fractured and jumbled. In larger landslides, which are up to 3,000 feet (900 m) long and across, smaller secondary landslides are common. Although some of the landslide blocks may have formed at the same time as the minor north-south faults, the well-defined edges of others suggest more recent development. Moussa (1968) described similar occurrences of landslide blocks in the Flagstaff Formation near Soldier Summit, Utah.

Sevier Valley Graben

The Sevier Valley is probably a large graben. Seismic data collected by the 1983 Brigham Young University summer field camp indicates the existence of a major, north-south-trending, down-to-the-east fault along the eastern front of the Valley Mountains. The fault is mostly covered by surficial deposits but is exposed in section 15, T. 18 S., R. 1 W. Bedrock east of the fault probably lies about 4,000 feet (1,200 m) below the valley surface (J. L. Baer, personal communication, 1990). Alternatively, Brown and Cook (1982) suggested that a fault does not exist along the east front of the mountains, but instead that the strata plunge steeply beneath Sevier Valley. Hecker (1993) showed this interpretation but indicated that the fold (Valley Mountains monocline) may be attributed in part to block faulting.

ECONOMIC RESOURCES

Gravel and Sand

Small amounts of gravel and sand have been excavated from stream beds and alluvial fans in three locations along the eastern edge of the Valley Mountains (Utah Department of Transportation, 1966). In addition, small amounts of chippy lower Flagstaff limestone talus have been removed from two locations along Hayes Canyon Road, presumably for use as road fill. The highest potential for other gravel and sand deposits is in the intermittent stream beds and alluvial fans between the Sevier River floodplain and the Valley Mountains. Economic sand deposits may also occur in Lake Bonneville sediments.

Dimension and Ornamental Stone

The Green River Formation has been quarried for building stone throughout Sanpete and Sevier Valleys. Although no stone is believed to have been quarried from the Hayes Canyon quadrangle, a possible site for dimension stone is located in the NW¼ section 21, T. 18 S., R. 1 W. Another possible quarrying site is located in upper Flagstaff Formation rocks in the NW¼NE¼ section 29, T. 18 S., R. 1 W. Some outcrops of Green River and upper Flagstaff chert may have use as ornamental stone.

Gypsum

A 1- to 1.5-foot-thick (0.3 - 0.45 m) layer of selenite is located near the bottom of the upper Flagstaff mudstone sequence. It crops out north of Hayes Canyon over a distance of about 0.5 miles (0.8 km). It has not been investigated for economic potential.

Coal

Three small lenses of carbonaceous shale and coal intermixed with calcareous mudstones in the North Horn Formation crop out in Hayes Canyon. Locally, lenses are more than 10 feet (3 m) thick. The shale and coal may contain humic acid and have potential as soil conditioners.

Water Resources

Water is the most important resource in the area and is mainly used for agriculture and to generate electricity. The Sevier River is the only permanent stream in the quadrangle with an average flow of 138,600 acre-feet (16,600 ha-m) per year. The river flows northward into Sevier Bridge Reservoir which, on the average, stores from 50,000 acre-feet (6,000 ha-m) of water in September to 125,000 acre-feet (15,000 ha-m) of water in April (Economic Research Service and others, 1976). The reservoir's storage capacity is about 236,000 acre-feet (28,000 ha-m) and ground-water storage in the area is estimated at 300,000 acre-feet (36,000 ha-m) (Young and Carpenter, 1965).

GEOLOGIC HAZARDS

Earthquakes

No historic moderate or large-magnitude earthquakes have been centered within the quadrangle's boundaries (Cook and Smith, 1967; Arabasz and others, 1979; Hecker, 1993). However, several moderate earthquakes occurred within 10 miles (17 km) of the quadrangle, with the largest measuring about 4.0 on the Richter scale. Mattox (1992) reported that residents in the Gunnison area felt a magnitude 4.9 (Richter scale) earthquake centered near Levan (about 20 miles [32 km] north of the quadrangle) on July 7, 1963.

Normal faults on the east side of the north and central parts of Japanese Valley and in the northeast part of the quadrangle in Sevier Valley cut sediments of middle to late Quaternary age, and may still be active (Hecker, 1993). One scarp, up to 12 feet (4 m) high, located along the northeast part ot the quadrangle in the Sevier Valley, indicates the presence of a large potentially active range-front fault. To date, no site-specific studies are known to have been done on these faults. Liquefaction poses a threat to structures near the Sevier River and the Sevier Bridge Reservoir where ground water is near the surface. Amplification of earthquake waves traveling through valley fill also poses a threat, especially since most structures in the area are built on unconsolidated sediments. The quadrangle is also near the Wasatch and Sevier faults, which are capable of generating large-magnitude earthquakes (Hecker, 1993).

Landslides

Except for small slides along roads or trails, no significant damage has occurred in the area due to landslides, but reactivation of old slides and the formation of new slides could threaten new or existing development in mountainous areas.

Flooding

During the high precipitation years of 1983-1984, the level of Sevier Bridge Reservoir rose sufficiently to flood roads in Sevier Valley and limit access to the quadrangle. Annually, flash flooding causes minor erosional damage to dirt roads, especially those located in or near canyons. There is potential for flash flooding near the mouths of larger canyons in the quadrangle.

Expansive Clay and Soil

Expansive clay in the Green River, Colton, and upper Flagstaff Formations, and expansive soil in valley-fill sediments in the Sevier and Japanese Valleys expands when wet and contracts when dry. These pose a hazard to human-made structures.

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APPENDIX

Composite Measured Section through Bedrock Units.

Measured by the author using a Jacob's staff and a Brunton compass during June 1989. Locations are noted beneath the name of each rock unit and are shown on the geologic map.

Pediment-mantle deposits

(Measured in the SE¼SE¼ section 20, T. 18 S., R. 1 W).

Unit	Description	Thickness feet (meters) Unit	Cumulative
100	Surficial cover, unconsolidated boulders, gravel, sand, and mud. Boulders appear to be predominately pieces of the North Horn and Flagstaff Formations. unconformity	44.5+ (13.4+)	2039.6 (611.9)

Green River Formation

(Measured in the NW¼NW¼ section 28; the NE¼NE¼ section 29; and the SE¼SE¼ section 20, T. 18 S., R. 1 W.)

Unit	Description	Thickness feet (meters) Unit	Cumulative
99	Limestone, dolomitic, muddy, pale-tan, weathers tan with rust banding, thin-bedded, 1 to 6 inch layers, irregular ledge-former.	30.0+ (9.0+)	1995.1 (598.5)
98	Limestone, dolomitic, pale-gray-green, weathers very pale gray green, breaks perpendicular to bedding plane, slope-former.	4.3 (1.3)	1965.1 (589.5)
97	Mudstone, calcareous, gray-green, weathers pale gray green, slope former.	30.0 (9.0)	1960.8 (588.2)
96	Limestone, pale-tan, weathers white, chalky, scattered chert, ledge-former	8.6 (2.6)	1930.8 (579.2)
95	Mudstone, dolomitic, dark-green-gray, weathers pale gray, some thin, white ash layers, slope-former.	171.2 (51.4)	1922.2 (576.7)
94	Limestone, micritic, pale-pink-tan, weathers very pale gray, ledge-former.	2.5 (0.8)	1751.0 (525.3)
93	Mudstone, dolomitic, pale-tan, weathers green gray, slope-former.	30.0 (9.0)	1748.5 (524.6)
92	Dolomite, micritic, pale-tan-gray, weathers very pale gray, chippy, ledge-former.	5.3 (1.6)	1718.5 (515.6)
91	Limestone, silicified, brown, weathers pale-gray-green with rusty coating, ledge-former.	0.5 (0.2)	1713.2 (514.0)
90	Mudstone, dolomitic, sandy, gray-green, limonite staining, slope-former.	4.3 (1.3)	1712.7 (513.8)
89	Limestone, sandy, tan, weathers pale brown, thin-bedded, ledge-former.	2.0 (0.6)	1708.4 (512.5)

Unit	Description	Thickness feet Unit	(meters) Cumulative
88	Dolomite, pale-tan, weathers pale-gray, porcelanous, slope-former.	8.6 (2.6)	1706.4 (511.9)
87	Mudstone, calcareous, yellow-tan, chippy, slope-former.	9.6 (2.9)	1697.8 (509.3)
86	Dolomite, pale-tan, weathers buff, breaks perpendicular to bedding planes, top of section breaks into thin, flat pieces parallel to bedding planes, ledge-former.	1.5 (0.5)	1688.2 (506.5)
85	Mudstone, calcareous, gray-green, weathers pale gray, slope-former.	4.3 (1.3)	1686.7 (506.0)
84	Limestone, micritic, pale-tan, weathers pale gray, shards, ledge-former.	4.3 (1.3)	1682.4 (504.7)
83	Chert, gray-blue to tan, pods of tan silicified limestone, ledge-former.	2.0 (0.6)	(1678.1 (503.4)
82	Limestone, slightly dolomitic, micritic,very light-gray, weathers very pale tan, shards, massive, ledge-former.	12.8 (3.8)	1676.1 (502.8)
81	Mudstone, dolomitic, green-gray, slope-former.	17.1 (5.1)	1663.3 (499.0)
	Total Green River Formation (incomplete)		348.9 (104.6)
	Colton Formation (Measured in the NE¼NE¼ section 29, T. 18 S., R. 1 W.)		
80	Mudstone (paleosol?), red-brown, slope-former.	8.6 (2.6)	1646.2 (493.9)
79	Dolomite, pale-tan, weathers pale gray, porcelanous, ledge-former.	3.2 (1.0)	1637.6 (491.3)
78	Mudstone, dolomitic, pale-tan-gray, weathers pale gray, slope-former.	2.0 (0.6)	1634.4 (490.3)
77	Limestone, pale-tan, very hard, marble like, calcite cleavage faces, ledge-former.	1.0 (0.3)	1632.4 (489.7)
76	Mudstone, dolomitic, pale-gray, weathers pale gray, slope-former.	12.8 (3.8)	1631.4 (489.4)
75	Limestone, micritic, pale-tan, weathers pale-gray, blocky, ledge-former.	1.5 (0.5)	1618.6 (485.6)
74	Mudstone, multicolored layers from pale-gray, pale-blue-gray, green-gray, pale-tan to dark-reddish-brown, probably a combination of ash falls and paleosols, gray beds are calcareous, slope-former.	12.8 (3.8)	1617.1 (485.1)
73	Volcanic ash, white, biotite altered to limonite, chalky, thickness varies, weak ledge-former.	1.0 (0.3)	1604.3 (481.3)

Unit	Description	Thickness feet Unit	(meters) Cumulative
72	Mudstone, reddish-brown, slope-former.	4.3 (1.2)	1603.3 (481.0)
71	Mudstone, slightly dolomitic, green-gray, weathers pale gray, slope-former.	3.2 (1.0)	1599.0 (479.7)
70	Limestone, dolomitic, pale-blue-gray, weathers pale gray, crumbly, slope-former.	1.0 (0.3)	1595.8 (478.7)
69	Mudstone, slightly dolomitic, green-gray, weathers pale gray, slope-former.	7.5 (2.3)	1594.8 (478.4)
68	Dolomite, micritic, tan-gray, weathers pale blue gray, breaks into irregular procelanous flakes perpendicular to bedding planes, ledge-former.	2.0 (0.6)	1587.3 (476.2)
67	Mudstone, calcareous, green-gray, weathers very pale gray, slope-former.	16.8 (5.0)	1585.3 (475.6)
66	Mudstone (paleosol?), red-brown, loosely consolidated, slope-former.	59.9 (18.0)	1568.5 (470.6)
65	Limestone, slightly dolomitic, micritic, tan, weathers rusty tan, thin-bedded, bedding thins upward from 6 inches to 1 inch, weak ledge-former.	2.0 (0.6)	1508.6 (452.6)
64	Mudstone, calareous, green-gray, weathers pale gray, slope-former.	5.8 (1.7)	1506.6 (452.0)
63	Mudstone, dark-red-brown, weathers red brown, slope-former.	51.4 (15.4)	1500.8 (450.2)
62	Mudstone, calcareous, green-gray, weathers pale gray, capped by pale-tan micritic limestone that weathers into pale-gray rounded knobs, slope-former.	2.5 (0.8)	1449.4 (434.8)
61	Mudstone, dark-brown, weathers reddish brown, slope-former.	41.5 (12.5)	1446.9 (434.1)
60	Mudstone, calcareous, green-gray, weathers pale gray, may be reworked volcanic ash layers, slope-former.	4.0 (1.2)	1405.4 (421.6)
59	Mudstone (paleosol?), red-brown to dark-brown, slope-former.	13.8 (4.1)	1401.4 (420.4)
58	Mudstone, calcareous, pale-green-gray, weathers pale gray, capped by 6 inches of pale-brown micritic limestone, slope-former.	8.3 (2.5)	1387.6 (416.3)
57	Mudstone (paleosol), dark-red-brown, weathers red brown, slope-former.	34.2 (10.3)	1379.3 (413.8)
	Total Colton Formation		301.1 (90.4)

Unit	Description	Thickness feet (meters) Unit	Cumulative
Upper Member of the Flagstaff Formation (Measured in the NW¼NE¼ section 29, T. 18 S., R. 1 W.)			
56	Limestone with interbedded calcareous mudstone, pale-gray, thin-bedded, most resistant units are less than 10 inches thick, slope-ledge-former.	12.9 (3.9)	1345.1 (403.5)
55	Shale, calcareous, pale-orange-tan, weathers red orange tan, contains large amounts of organic matter, ostracodes, snails and fish bones, weak ledge-former.	2.0 (0.6)	1332.2 (399.7)
54	Mudstone, calcareous, pale-gray, slope-former.	1.0 (0.3)	1330.2 (399.1)
53	Limestone, pale-gray, breaks into rounded boulder-sized pieces, ledge-former.	1.0 (0.3)	1329.2 (398.8)
52	Limestone with interbedded calcareous mudstone, pale-gray near bottom, breaks along bedding planes into thin irregular pieces, slope to ledge-former.	43.0 (12.9)	1328.2 (398.5)
51	Limestone, pale-gray, porcelanous, breaks at right angles to bedding planes, snail shell casts, ledge-former.	5.3 (1.6)	1285.2 (385.6)
50	Limestone, pale-gray, discontinuous pods of mottled translucent chert about 1 foot thick, scattered fish bone bits, ledge-former.	7.8 (2.3)	1279.9 (384.0)
49	Mudstone, calcareous, pale-olive-green, slope-former.	29.0 (8.7)	1272.1 (381.6)
48	Mudstone, dolomitic, purple-red, weathers rusty red to pale purple red, contains some gypsum, slope-former.	32.0 (9.6)	1243.1 (372.9)
47	Mudstone, calcareous, grayish-blue, weathers very pale gray, about 10 feet from the bottom is a 1.5-foot thick layer of gypsum, includes some gypsum-mudstone, marble-sized conglomerate, slope-former.	51.4 (15.4)	1211.1 (363.3)
46	Dolomite, pink-gray, weathers pale brown, fractures into blocky boulder-sized pieces, abundant juniper trees grow on this layer, ledge-former.	2.0 (0.6)	1159.7 (347.9)
45	Limestone, micritic, pale-gray-tan, weathers mottled tan with red, pink, yellow, and green highlights, heavily fractured, slope-former with scattered 4-5 foot ledges.	81.0 (24.3)	1157.7 (347.3)
	Total upper Member of the Flagstaff Formation		268.4 (80.5)
Middle Member of the Flagstaff Formation (Measured in the SE¼NW¼ section 29 and the NE¼NW¼ section 30, T. 18 S., R. 1 W.)			
44	Limestone, micritic, pale-gray-tan, weathers mottled red tan to pink tan, scattered dark-brown-gray limestone inclusions, porcelanous, fractures into very irregular platy shapes, scattered calcite snail casts, some oolites to 0.1 inch (0.25 cm) in diameter, some conglomerate, formed from pale-gray limestone, prominent cliff-former.	30.0 (9.0)	1076.7 (323.0)

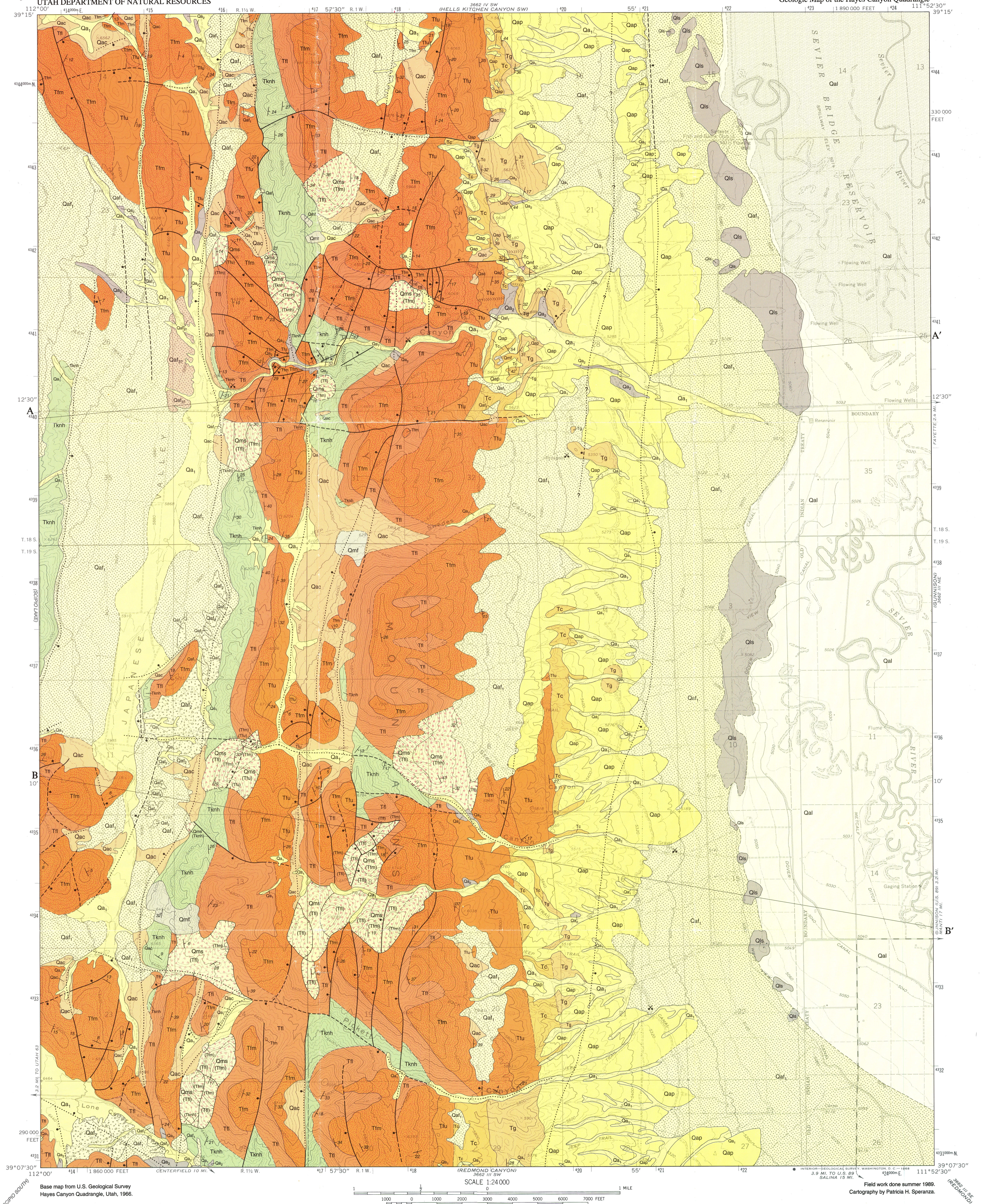
Unit	Description	Thickness feet Unit	(meters) Cumulative
43	Limestone, dark-gray, weathers pale gray with yellow-tan lenses, these are more fractured with calcite veins, same characteristics as unit 44, predominately a color change, prominent cliff-former.	25.0 (7.5)	1046.7 (314.0)
42	Limestone, very pale-gray, weathers white, chalky, may contain volcanic ash, slope-former.	24.7 (7.4)	1021.7 (306.5)
41	Limestone, pink-gray, weathers pale gray with pale-tan spots, extremely pitted surface, ledge-former with minor slopes.	12.8 (3.8)	997.0 (299.1)
40	Limestone, pink-gray, weathers very pale tan, abundant calcite snail casts, weak slope-former.	85.6 (25.7)	984.2 (295.3)
39	Limestone, pink-gray, weathers gray, snail outlines, weak slope-former.	12.8 (3.8)	898.6 (269.6)
	Total middle Member of the Flagstaff Formation		190.9 (57.3)
	Lower Member of the Flagstaff Formation (Measured in the SE¼NW¼ section 30, T. 18 S., R. 1 W.)		
38	Limestone, micritic, pale-olive-tan, weathers gray, weak ledge-former.	34.2 (10.3)	885.8 (265.7)
37	Limestone, slightly dolomitic, micritic, pale-tan-gray, weathers pale tan, ledge-former.	2.0 (0.6)	851.6 (255.5)
36	Limestone, tan-gray, weathers gray, weak slope-former.	62.2 (18.7)	849.6 (254.9)
35	Limestone, dolomitic, micritic, pale-tan-gray, weathers pale tan, very hard, ledge-former.	4.0 (1.2)	787.4 (236.2)
34	Limestone, micritic, pale-tan-gray, weathers pale gray, bits of shell, weak slope-former.	97.5 (29.3)	783.4 235.0)
33	Limestone, pale-tan-olive-gray, weathers pale gray with mottled pink, red, and tan spots, ledge-former.	5.8 (1.7)	685.9 (205.8)
32	Limestone, slightly dolomitic, micritic, very pale-gray, weathers pale gray, chippy slope-former.	17.1 (5.1)	680.1 (204.0)
31	Limestone, olive-brown, weathers pale tan gray, abundant snail shells, rare oncolites, weak slope-former.	21.4 (6.4)	663.0 (198.9)
30	Limestone, micritic, pale-gray, snails, ledgy steep slope-former.	72.8 (21.8)	641.6 (192.5)
29	Limestone, micritic, pale-pink-tan, massive, snails, ledge-former.	25.7 (7.7)	568.8 (170.6)
28	Limestone, micritic, pale-pink-tan, snails, massive, highly fractured with calcite veins, grades into unit 29, ledge-former.	34.2 (10.3)	543.1 (162.9)

Unit	Description	Thickness feet Unit (meters)	Cumulative
27	Limestone, micritic, pale-tan, medium bedded (4-5 feet), abundant weathered-out snails, ledge-former.	25.7 (7.7)	508.9 (152.7)
26	Limestone, pale-brown-gray, weathers pale tan, weathers into rounded fragments, slope-former.	7.3 (2.2)	483.2 (145.0)
25	Limestone, tan-gray, weathers pale gray, sometimes capped by thin sandy micritic limestone, abundant snails, slope-former.	17.1 (5.1)	475.9 (142.8)
	Total Lower Member of the Flagstaff Formation		427 (185.4)
	North Horn Formation (Measured in the NW¼SW¼ and SW¼NW¼ section 30, T. 18 S., R. 1 W.)		
24	Sandstone, calcareous, micritic, tan-gray, weathers yellow tan, ledge-former.	6.3 (1 .9)	458.8 (137.6)
23	Limestone, sandy, micritic, tan-gray, weathers pale gray, snails, weak slope-former.	74.8 (22.4)	452.5 (135.8)
22	Sandstone, calcareous, micritic, pale-gray, weathers tan, sand decreases upward, ledge-former.	10.6 (3.2)	377.7 (113.3)
21	Limestone, dark-brown, weathers pale yellow tan, numerous oncolites, slope-former with some resistant pods.	21.4 (6.4)	367.1 (110.1)
20	Limestone, pale-brown, weathers pale gray, sandy, weathered out snails, slope-former.	21.4 (6.4)	345.7 (103.7)
19	Sandstone, very calcareous, pale-brown, conglomerate pods, olive-tan chunks of micrite, abundant calcite crystals to 2 inches in length, bioturbation near top, ledge-former.	4.0 (1.2)	324.3 (97.3)
18	Limestone, micritic, olive-tan, resistant pods, weathers tan gray, sandy, ledgy slope-former.	39.5 (11.9)	320.3 (96.1)
17	Limestone, dolomitic, micritic, olive-tan, weathers yellow tan, abundant fine sand, breaks into small gravel-sized pieces, ledge-former.	5.3 (1.6)	280.8 (84.2)
16	Limestone, maroon, weathers mottled pink to red, many concentric circles colored red on outside, yellow inside, sandy, heavily fractured, ledge-former.	27.7 (8.3)	275.5 (82.7)
15	Sandstone, calcareous, pale-gray, weathers rust red, may be colored by above unit washing down, fine-grained, well-sorted, numerous calcite veins, some muddy sandstone lenses that weather red spotted with limonite, ledge-former.	5.3 (1.6)	247.8 (74.3)
14	Sandstone, calcareous, pale-gray, weathers red with some mottling of tan and yellow, muddy, weathered-out oncolites, slope-former.	12.6 (3.8)	242.5 (72.8)
13	Sandstone, calcareous, pale-gray, weathers rust red, some muddy lenses weather red spotted with limonite, fine-grained, well-sorted, numerous calcite veins, ledge-former.	5.3 (1.6)	229.9 (69.0)

Unit	Description	Thickness feet Unit	(meters) Cumulative
12	Sandstone, muddy, calcareous, pale-gray, weathers red with mottling of tan and yellow, slope-former.	11.8 (3.5)	224.6 (67.4)
11	Sandstone, calcareous, gray, weathers rust red, well-sorted, fine-grained, ledge-former.	4.0 (1.2)	212.8 (63.8)
10	Sandstone, muddy calcareous, pale-gray, weathers mottled tan, yellow, and red, fine-grained, slope-former.	38.5 (11.6)	208.8 (62.6)
9	Sandstone, calcareous, yellow-tan, weathers dark gray, well-sorted, conglomerate pods, cross-bedded, fines upward, lenses of mudstone that weather mottled red and tan, unit thins laterally, may be a point bar sequence, rare snail shells, ledge-former.	24.7 (7.4)	170.3 (51.1)
8	Conglomerate (8.2 feet) fining to sandstone, calcareous; conglomerate consists of gravel-sized clasts, 60 percent dark gray limestone, 30 percent white quartzite, some small pods of buff sandstone, weathers dark tan; sandstone fines upward to mudstone, weathers pale gray; a point bar sequence, ledge-former.	17.1 (5.1)	145.6 (43.7)
7	Limestone, micritic, mixed tan and red, massive, slope-former.	8.6 (2.6)	128.5 (38.6)
6	Limstone, micritic, pale-olive-gray, weathers pale tan, conglomerate or sandy base, fines upward, point bar sequence, ledge-former.	10.6 (3.2)	119.9 (36.0)
5	Mudstone, calcareous, gray, weathers pale gray, massive, slope-former.	53.4 (16.0)	109.3 (32.8)
4	Limestone, very sandy, olive-gray, weathers pale yellow tan, ledge-former.	4.3 (1.3)	55.9 (16.8)
3	Mudstone, calcareous, very carboniferous, very dark-gray, weathers dark gray, slope-former.	11.3 (3.4)	51.6 (15.5)
2	Limestone, micritic, muddy pale-tan-gray, weathers pale gray, slope-former.	33.0 (9.9)	4.0.3 (12.1)
1	Limestone, dark-brown-gray, weathers pale tan gray, weathers pale tan gray, abundant oncolites, ledge-former.	7.3 (2.2)	7.3 (2.2)
	Total North Horn Formation (incomplete)		458.8 (137.6)

UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES

Plate 1
Utah Geological Survey Miscellaneous Publication 97-3
Geologic Map of the Hayes Canyon Quadrangle



Base map from U.S. Geological Survey
Hayes Canyon Quadrangle, Utah, 1966.

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

1997 MAGNETIC DECLINATION
AT CENTER OF MAP

QUADRANGLE LOCATION

Field work done summer 1989.
Cartography by Patricia H. Speranza.

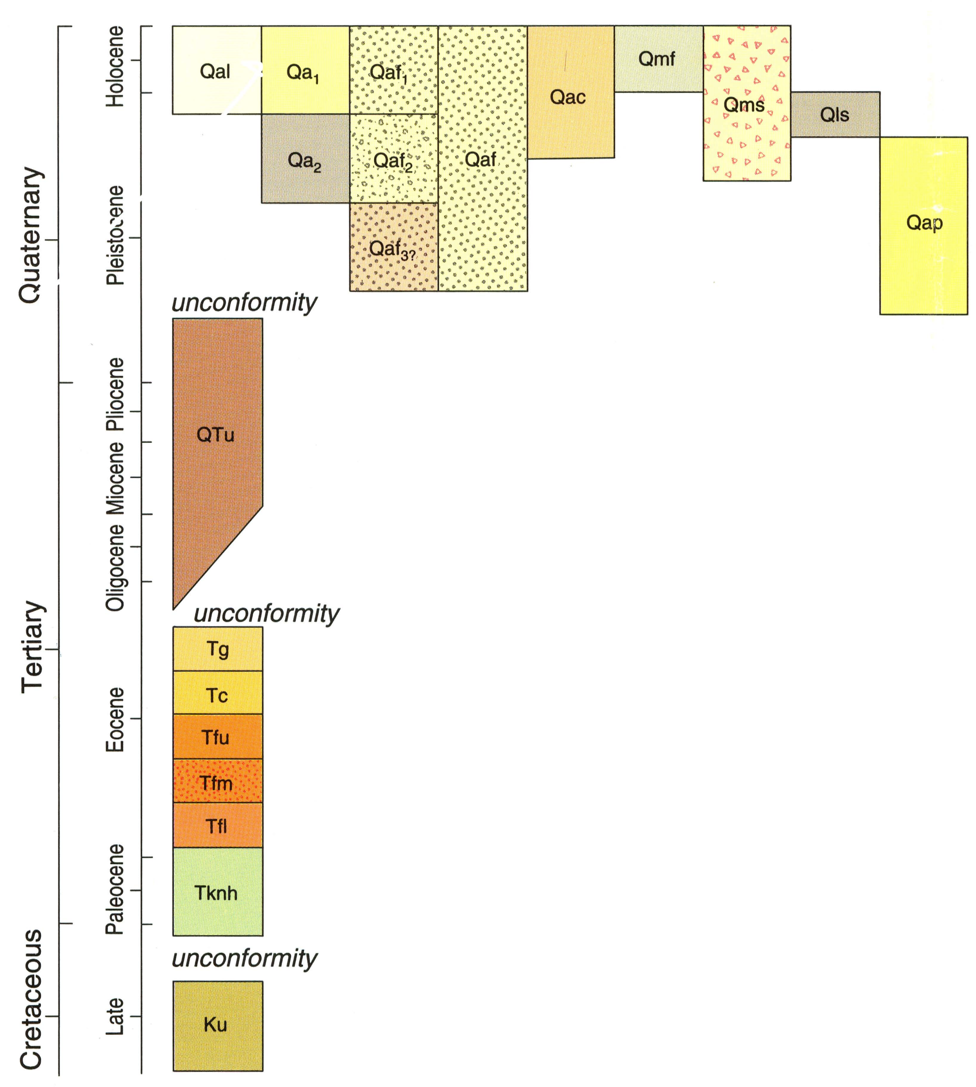
GEOLOGIC MAP OF THE HAYES CANYON QUADRANGLE, SANPETE COUNTY, UTAH

by

David H Petersen

1997

CORRELATION OF MAP UNITS



MAP SYMBOLS

Contact--dashed where approximately located

Fault--dashed where approximately located, dotted where concealed, queried where hypothetical; bar and ball on downthrown side; number indicates dip of fault plane

Strike and dip of bedding

Landslide or slump block scarp

Gravel or road-fill pit

Location of measured section traverses

SYSTEM	SERIES	FORMATION		SYMBOL	THICKNESS feet (meters)	LITHOLOGY	COMMENTS
Q		surficial deposits		Q	<200(61)		unconsolidated sediment
Tertiary	Eocene	Green River Formation		Tg	400+ (120+)		chert chert
		Colton Formation		Tc	300-450 (90-135)		volcanic ash beds volcanic ash beds volcanic ash beds
		Flagstaff Formation	Upper member	Tfu	250-300 (75-90)		snails, fish bones, ostracodes chert gypsum
			Middle member	Tfm	175-300 (50-90)		slightly oolitic
	—?—		Lower member	Tfl	450 (135)		snails
	Paleocene	North Horn Formation		Tknh	450+ (135+)		oncolites point bar deposits carbonaceous oncolites

DESCRIPTION OF MAP UNITS

Qu Undivided surficial deposits -- *Shown only on cross sections.*

Qal Floodplain deposits -- *Consisting mainly of fine-grained sediments; gradational with other Quaternary deposits.*

Qa_1 Younger alluvial deposits -- *Moderately sorted, clay- to small boulder-sized sediments; gradational with other Quaternary deposits; deposited in stream channels.*

Qa_2 Older alluvial deposits -- *Moderately sorted, clay- to small boulder-sized sediments; isolated by downcutting; gradational with other Quaternary deposits; deposited in stream channels.*

Qaf Undifferentiated alluvial-fan deposits -- *Shown only on the cross sections.*

Qaf_1 Younger alluvial-fan deposits -- *Poorly to moderately sorted boulders to clay; finer clasts predominate valleyward; sediments were derived locally; gradational with other Quaternary deposits.*

Qaf_2 Older alluvial-fan deposits -- *Dissected by Qaf_1 deposits and composed of poorly to moderately sorted boulders to clay.*

Qaf_3 Oldest alluvial-fan deposits -- *Dissected by Qaf_1 deposits; composed of poorly to moderately sorted boulders to clay which fine valleyward; appear to be higher and more dissected than Qaf_2 deposits.*

Qap Alluvial pediment-mantle deposits -- *Materials composed of boulders to clay; loosely consolidated with calcareous mud; sediments were derived from nearby rock formations, predominately the North Horn and Flagstaff Formations; lies unconformably on underlying formations; 0 to 44+ feet (0-13+ m) thick.*

Qac Mixed alluvial and colluvial deposits -- *Along mountainsides; poorly sorted boulder- to clay-sized clasts; gradational with other Quaternary deposits.*

Qmf Mass-movement - mudflow and debris-flow deposits -- *Very poorly sorted; locally contain blocks many feet across; derived from the North Horn and lower Flagstaff Formations; form hummocky topography.*

Qms Mass-movement - landslides and slump blocks -- *Large blocks of competent North Horn (Tknh) and Flagstaff Formation; lower member (Tfl), middle member (Tfm), upper member (Tfu), rocks that have slumped and rotated where slopes have been oversteepened, mainly along stream beds and major faults.*

Qls Lake Bonneville sediments -- *Alternating layers of loosely consolidated, pale-tan, fine sand and silt; thinly laminated with some cross-stratification; silt increases upward; the surface of many deposits are reworked by wind, forming eolian deposits up to 6 feet (2 m) thick.*

QTu Undifferentiated Quaternary and Tertiary deposits -- *May include late Eocene to Pliocene sedimentary, volcanic, and volcaniclastic strata, and Pliocene to Pleistocene unconsolidated valley-fill deposits; shown only on the cross sections.*

Tg Green River Formation -- *Predominantly calcareous to dolomitic, greenish-gray mudstone intermixed with thin, locally sandy, pale-tan, micritic limestone and dolomite, some of which contain thin, discontinuous beds of chert; local thin volcanic ash layers occur in mudstones; at least 400 feet (120 m) thick.*

Tc Colton Formation -- *Reddish-brown, with lesser amounts of greenish-gray, calcareous to dolomitic mudstone, intermixed with uncommon thin beds of pale-tan, dolomitic, micritic limestone, and volcanic ash layers; erodes to form a strike valley; 300 to 450 feet (90-135 m) thick.*

Tfu Upper member of the Flagstaff Formation -- *Pale-gray, pale-yellow, pink, and pale-green micritic limestone, changing upward to purplish-red dolomitic and greenish-gray calcareous mud-stone that locally contains gypsum, topped by pale-tan-gray micritic limestone that locally contains chert pods; 250 to 300 feet (75-90 m) thick.*

Tfm Middle member of the Flagstaff Formation -- *Pink-gray to white, soft limestone with minor gray, resistant limestone; capped by resistant, gray, sandy, micritic limestone changing upward to pink, tan, sandy, micritic limestone; both contain minor conglomerate and oolite grains; changes southward to very pale-gray limestone that erodes to a scalloped surface; 175 to 300 feet (50-90 m) thick; thins northward and southward.*

Tfl Lower member of the Flagstaff Formation -- *Pale-tan, pink-tan, gray and olive-tan, micritic, chippy, locally dolomitic limestone containing abundant gastropods, which become less common upwards; has thin sandstone layers at base which thicken southward; about 450 feet (135 m) thick. Gradational with the North Horn Formation.*

Tknh North Horn Formation -- *Intermixed, resistant, brown to gray conglomeratic and calcareous sandstone, and gray to tan, locally carbonaceous mudstone and oncolitic limestone; conglomerate contains abundant gray limestone and white quartzite pebbles; conglomerate and sandstone ledges pinch out laterally, contain cross-bedded sandstone, and have been bioturbated; about 450 feet (135 m) is exposed.*

Ku Undifferentiated Cretaceous deposits -- *Shown only on the cross sections.*