GEOLOGIC MAP OF THE ALTON QUADRANGLE, KANE COUNTY, UTAH

by

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Department of Science
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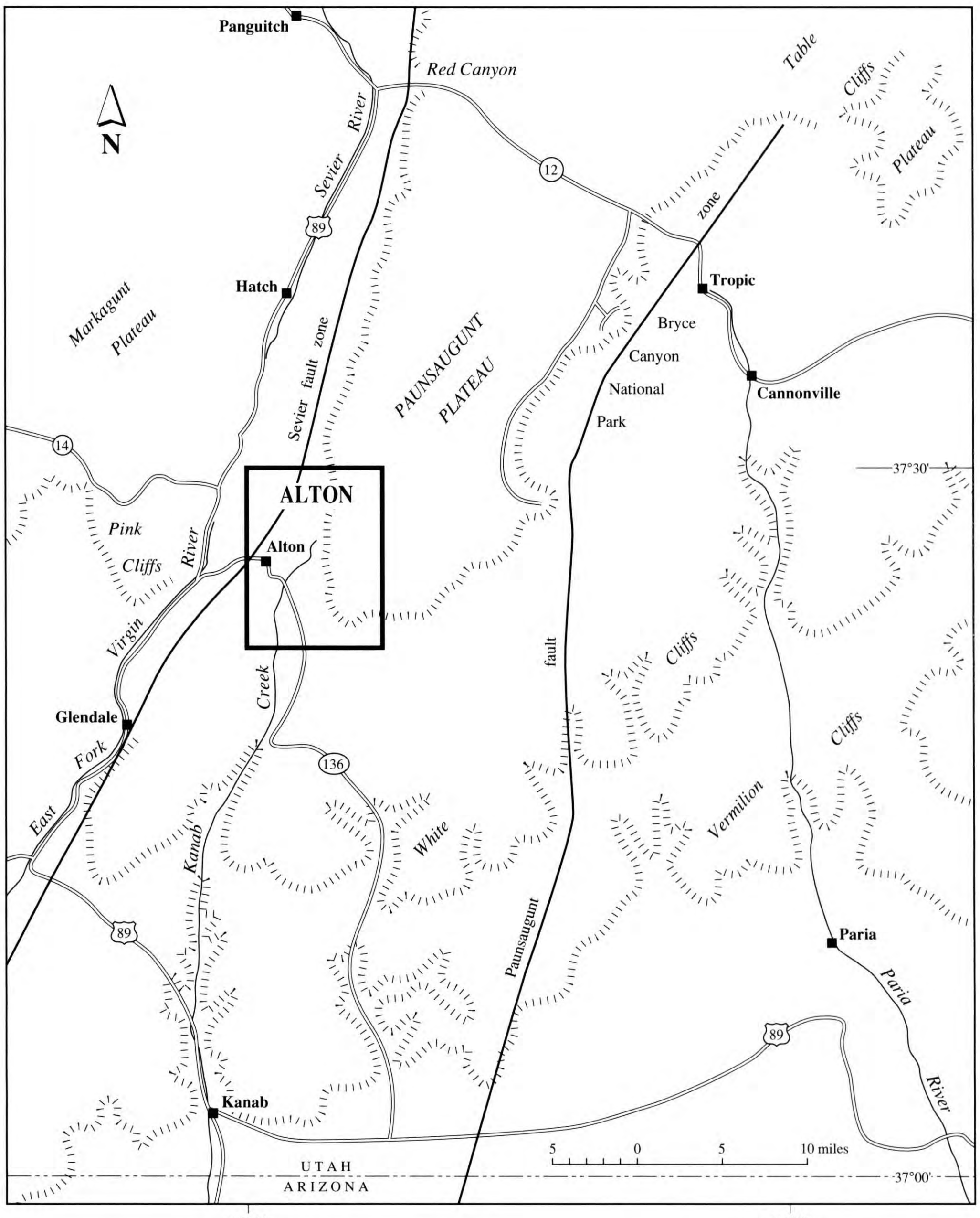
Laredo, Texas

(with mapping by E.G. Sable, U.S. Geological Survey)



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ABSTRACT

The Alton quadrangle is located in north-central Kane County and covers the southwestern part of the Paunsaugunt Plateau. The approximately 4,000-foot-thick (1,200 m) section of exposed sedimentary rock in the quadrangle ranges in age from Jurassic to Oligocene. Quaternary alluvium, mass-movement debris, pediment alluvium, and landslides cover these rocks. An igneous dike of Quaternary basalt is exposed near the center of the Alton quadrangle.

The Paunsaugunt Plateau is capped by the Tertiary Claron Formation. This unit displays spectacular pink and white cliffs that border the plateau rim, similar to those in Bryce Canyon National Park to the east. The thin and discontinuous Cretaceous and Paleocene Canaan Peak Formation is locally present at the base of and mapped with the Claron. From the plateau, long ridges of Upper Cretaceous clastic rocks of the Kaiparowits(?), Wahweap, and Straight Cliffs Formations descend westward. The drainages of Kanab Creek and Sink Valley are on the Tropic Shale. In the southwestern part of the Alton quadrangle are low hills of the moderately resistant Dakota Formation. In the extreme southwestern corner, approximately 50 feet (15 m) of the uppermost part of the Jurassic Winsor Member of the Carmel Formation are exposed along Kanab Creek. The Claron and overlying Brian Head Formations are present in the northwestern part of the Alton quadrangle where they form rugged hills west of the Sevier fault zone and Paunsaugunt Plateau.

Strata in the Alton quadrangle dip gently to the north and north-northeast, generally from less than 1 to 5 degrees. Three major unconformities are present within the strata: (1) at the top of the Jurassic Winsor Member of the Carmel Formation; (2) in the Smoky Hollow Member of the Straight Cliffs Formation, about 1,500 feet (460 m) below the top of the Upper Cretaceous strata; and (3) at the top of the Upper Cretaceous undivided Wahweap and Kaiparowits(?) Formations. The depositional history of the area appears to have been relatively unaffected by crustal movement until the time of the third unconformity and local near-vertical faulting near the end of the Cretaceous. The age of northward tilting of the area is post-Claron (post-Eocene). The post-Brian Head (post-Oligocene) Sevier fault zone cuts the northwest corner of the quadrangle, has a northeast trend, down-to-the-west displacement, and offsets strata as much as 2,000 feet (600 m) in Utah.

The topographically lower part of the quadrangle is occupied by the town of Alton and surrounding ranches. Of economic interest are two previously mined coal zones in the Dakota Formation and the limited amount of water resources. Several geologic hazards, mostly landslides, are present in the quadrangle, but the lack of development limits risks.

INTRODUCTION

The Alton quadrangle covers the southwestern part of the Paunsaugunt Plateau (figure 1), meaning "Land of the Beavers" plateau in Ute. Elevations in the quadrangle range from approximately 6,500 feet (1,980 m) to almost 9,300 feet (2,840 m) above sea level. The quadrangle includes the headwaters of Kanab Creek, the Alton Amphitheater (containing the town of Alton), Sink Valley, and the eastern portion of the divide between the Virgin River and the West Fork of the Sevier River. The Sunset Cliffs are along the eastern margin of the quadrangle and are the western Paunsaugunt Plateau's scenic counterpart of Bryce Canyon.

The cliffs bordering the Paunsaugunt Plateau dominate the scenery of the quadrangle. This nearly continuous rim of barren, near-vertical, towering cliffs allows the top of the plateau to be reached directly only by a few foot trails in the east-central portion of the quadrangle. To drive to the top of the plateau one must follow unpaved fair-weather roads south from Utah Highway 12; adequate maps and/or advice will be needed to follow the roads. The top of the plateau is administered by the U.S. Forest Service, Dixie National Forest.

The plateau portion of the Alton quadrangle is capped by the Tertiary Claron Formation, a thick, resistant, distinctive pink and white limestone sequence, referred to by some as the "Wasatch Formation." This high country is a land of Canadian-zone forested ridges and hills, and, usually, dry stream valleys. The highest portions of the ridges are prominently marked by white limestone.

West of the plateau rim, westward-projecting ridges of Upper Cretaceous sandstone and mudstone descend as a series of cliffs, ledges, and slopes. The country is moderately vegetated, with ponderosa pine high on the ridges giving way successively downward to pinyon pine, juniper, and Gambel oak, and then to sagebrush and rabbitbrush as the land descends to the irrigated hay fields and pastures around Alton.

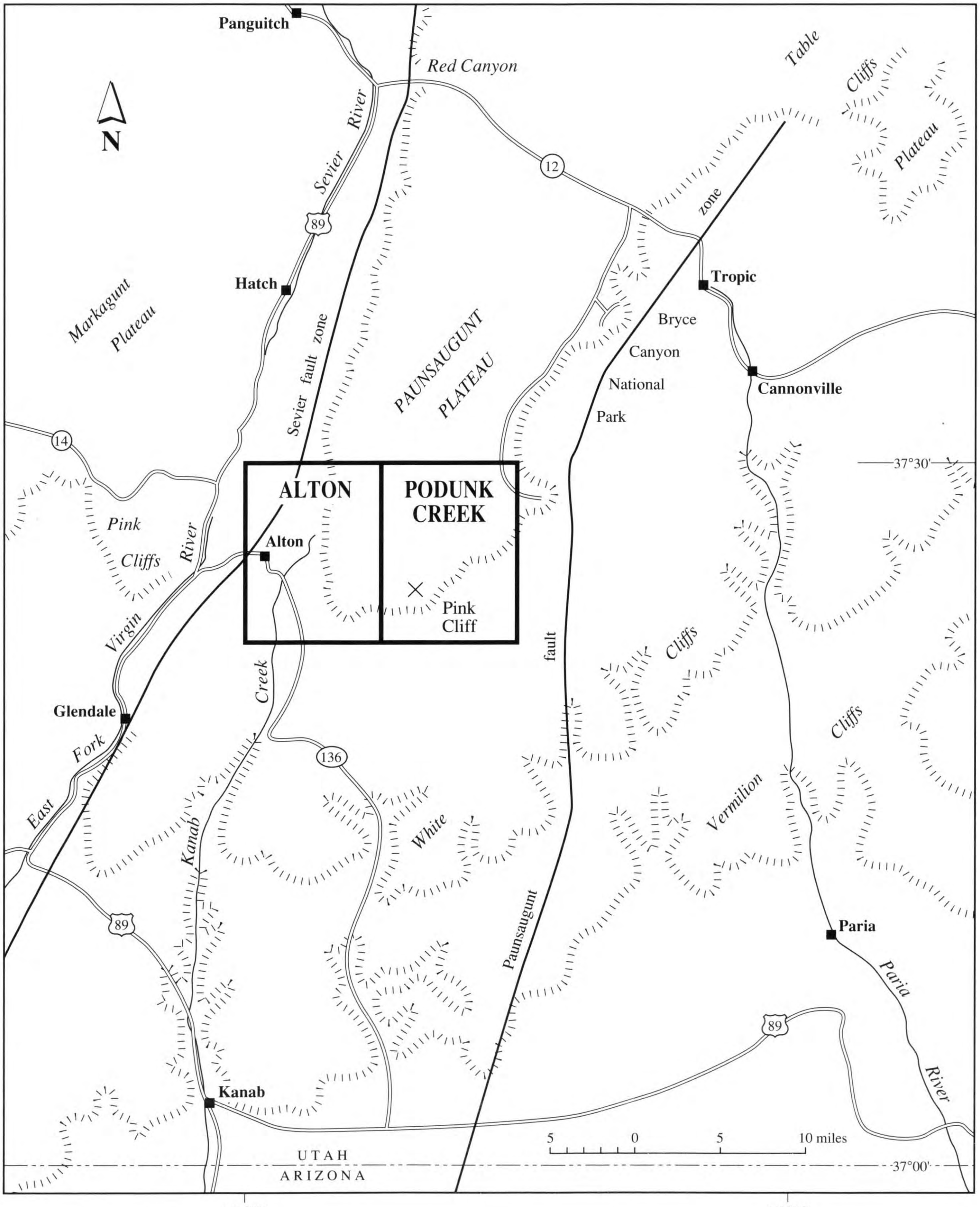

***Figure 1.** Index map of the Paunsaugunt Plateau region, showing the Alton and Podunk Creek quadrangles. The highest point (Pink Cliff) and only settlement in the study area (Alton) are indicated. The quadrangles were mapped together. The map is adapted from Gregory (1951, p. 3).*

The most prominent cliffs of the Claron Formation in the quadrangle are at the head of Kanab Creek. In their upper reaches, the tributaries of Kanab Creek flow through steep canyons cut into the Upper Cretaceous sandstone and mudstone. The roughly north-trending Sand Pass fault zone is located in these upper reaches below the Claron cliffs. In the central part of the Alton quadrangle, Kanab Creek flows on alluvium underlain by poorly resistant mudstone of the Tropic Shale (figure 2). Here the land opens into the broad Alton Amphitheater. Sink Valley similarly exists where streams flowing west from the plateau cut through the sandstone into the Tropic Shale.

The northwestern corner of the Alton Amphitheater is bordered by rugged hills. These hills mark the location of the northeast-trending Sevier fault zone. Erosion lowered the land surface southeast of the fault zone to a considerably lower position, forming the Alton Amphitheater. Although the hills northwest of the fault zone are in the down-dropped block, the rocks that occupy this area are more resistant than the upthrown block. This rugged upland is mostly underlain by the Claron Formation and is the eastern portion of the divide between the Virgin River and the West Fork of the Sevier River.

In the southwestern portion of the quadrangle, the Dakota Formation forms low hills. Here, coal beds have been mined in the past.

West of the quadrangle, across the valleys of the Virgin and Sevier Rivers, is the Markagunt Plateau, an area of geology and geography that is similar to that of the Paunsaugunt Plateau. A measured stratigraphic section of well-exposed Upper Cretaceous fluvial rocks on the eastern flank of the Markagunt Plateau, along U.S. Highway 89 north of Glendale, Utah, is included in the appendix of this report for comparison to rocks in the Alton quadrangle.

East of the quadrangle is the remainder of the southern Paunsaugunt Plateau. Farther east, across the major north trending Paunsaugunt fault zone, is a broad valley known as the Paria Amphitheater, which heads to the north in the Table Cliffs Plateau. East of this amphitheater is the Kaiparowits Plateau.

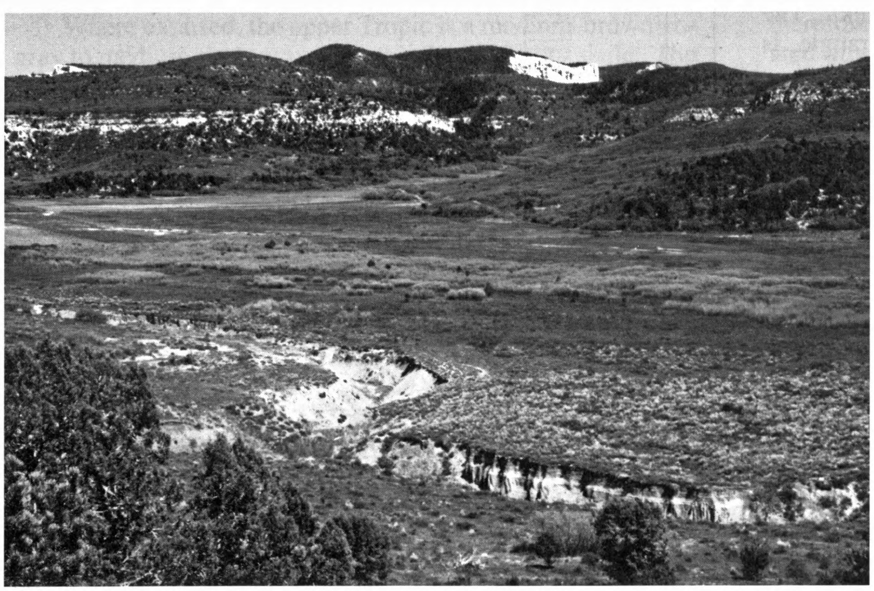

Figure 2. View to north up the valley of Kanab Creek from the Alton Amphitheater. Note stream cut in the Tropic Shale in the foreground, slopes and cliffs of the Straight Cliffs and Wahweap-Kaiparowits(?) Formations in the middle ground, and the cliffs of Claron Formation on the skyline. Lower white band at left is the Tibbet Canyon Member of the Straight Cliffs Formation.

The town of Alton can be reached by three miles of paved road (Utah Highway 136) eastward from U.S. Highway 89. The remainder of the roads in the Alton quadrangle were unpaved in 1991. The roads that lead into the canyons become rough tracks after a short distance and most are blocked by locked gates.

PREVIOUS WORK

Early geological investigations that included the Paunsaugunt Plateau are the nineteenth-century U.S. Government surveys led by Powell (1873), Gilbert (1875), and Dutton (1880). These studies established many of the salient physiographic and stratigraphic divisions now used in the southwestern Colorado Plateau.

The only previous work specifically on the geology of the Paunsaugunt Plateau is the classic study by Herbert E. Gregory (1951). His study of the Kaiparowits Plateau, east of the Paunsaugunt, provided the localities, descriptions, and stratigraphic nomenclature that established formations in the Upper Cretaceous section that are still used throughout the region (Gregory and Moore, 1931). I found important differences between Gregory's Upper Cretaceous stratigraphic divisions, as originally defined in the Kaiparowits Plateau, and his (1951) mapping of these units in the Paunsaugunt Plateau. The units I used to map this quadrangle were delimited with the aid of Peterson's (1969b) paper defining the members of the Straight Cliffs Formation; they are comparable to the original descriptions of Gregory and Moore (1931) from the Kaiparowits Plateau.

Cashion's (1961) geologic map of the southern Markagunt Plateau extends into the southwestern Paunsaugunt Plateau. In 1963, a comprehensive stratigraphic study and geologic-mapping program was begun in the Kaiparowits region, east of the Paunsaugunt Plateau, by the U.S. Geological Survey to evaluate the occurrence and distribution of coal resources. Important work refining the Jurassic and Cretaceous stratigraphy of the region was carried out, most notably by Peterson (1967, 1969a, 1969b) and Peterson and Waldrop (1965, 1967). Much of this work pertains directly to the stratigraphy of the Paunsaugunt Plateau.

Harry D. Goode (1973a, 1973b) mapped the geology of the Bald Knoll and Skutumpah Creek quadrangles to the south and southeast, respectively, of the Alton quadrangle. I mapped the geology of the Podunk Creek quadrangle, to the east, and Alton quadrangle concurrently (Tilton, 1991, 2001). Moore and others (1994) mapped the geology of the Asay Bench quadrangle to the northwest. The coal seams and geology of the Alton quadrangle were discussed and mapped at smaller scale by Doelling (1972). The quadrangle is shown on 1:100,000-scale geologic maps of Kane County (Doelling and Davis, 1989), and of the Kanab 30 x 60 minute quadrangle (Sable and Hereford, 1990). Shroder (1971) included a map of the landslides in part of the Alton quadrangle. This was an important guide in my mapping of the landslides. Most of the fieldwork for my dissertation (Tilton, 1991) was performed between 1972 and 1975, with additional fieldwork done in 1989, and fieldwork was done in 1992 for this report. Dr. E.G. Sable (U.S. Geological Survey, retired) provided mapping along and west of the Sevier fault zone from his work on the Kanab 30- by 60-minute quadrangle.

STRATIGRAPHY

The approximately 4,000-foot (1,200 m) section of exposed sedimentary rocks in the Alton quadrangle ranges in age from Jurassic to Oligocene (figure 3). An igneous dike of Quaternary basalt is exposed near the center of the Alton quadrangle. Quaternary alluvium, mass-wasting debris, pediment alluvium, and landslides cover much of the quadrangle. Three major unconformities are present in the strata: 1) on top of the Jurassic Winsor Member of the Carmel Formation; 2) in the Upper Cretaceous Smoky Hollow Member of the Straight Cliffs Formation, about 1,500 feet (460 m) below the top of Upper Cretaceous strata; and 3) at the top of the Upper Cretaceous undivided Wahweap and Kaiparowits(?) Formations.

Jurassic

Carmel Formation

Winsor Member (Jcw): The upper part of the Winsor Member of the Carmel Formation (Middle Jurassic) is exposed in the southwest corner of the Alton quadrangle. This exposure is located where Kanab Creek cuts to its lowest point in the Alton quadrangle. Here, up to about 50 feet (15 m) of cross-bedded, light-yellow, fine-grained sandstone forms steep-sided valley walls along Kanab Creek. The entire member, where exposed south of the quadrangle, is about 300 feet (90 m) thick.

Sandstone of the upper part of the Winsor Member is well sorted, with rounded grains, and occurs in thin beds. The contact with the overlying Dakota Formation is unconformable. Gray, lenticular, medium-grained, predominantly cross-bedded sandstone and coal of the Dakota lie on the eroded sandstone surface at the top of the Winsor. The Winsor Member of the Carmel Formation was probably deposited by wind, as evidenced by the cross-bedding and the well-sorted, subrounded quartz grains (Gregory, 1951).

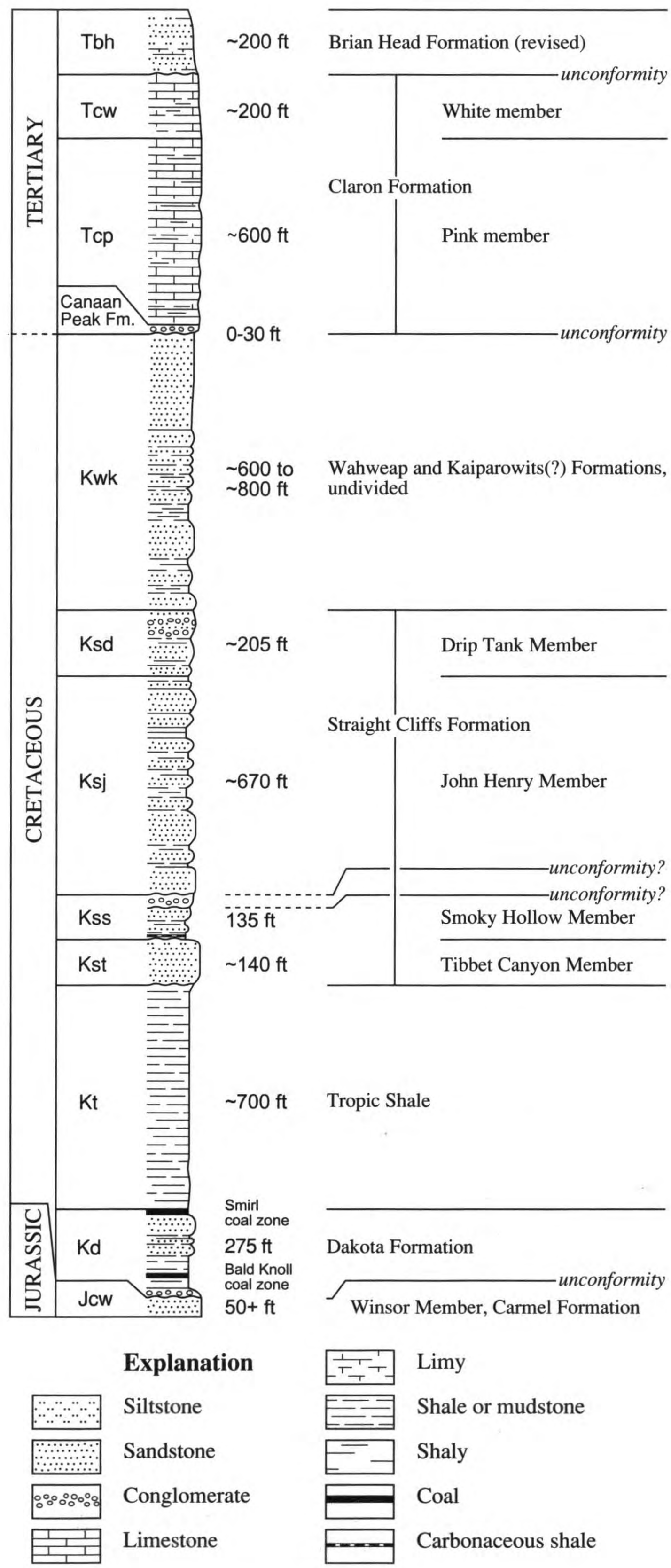

Figure 3. Generalized stratigraphic column of the Jurassic, Cretaceous, and Tertiary rocks exposed in the Alton quadrangle, Kane County, Utah.

Upper Cretaceous

Dakota Formation (Kd)

The Dakota Formation in the area is part of a widespread and discontinuous sheet of clastic and coal deposits in the Western Interior of the United States. The Dakota Formation crops out in the southwestern quarter of the Alton quadrangle and is about 275 feet (84 m) thick. Two significant coal zones are found in the unit: the lower one known as the Bald Knoll and the upper named the Smirl (Doelling, 1972).

The Dakota consists of interbedded yellowish-gray and brown sandstone, gray mudstone, black carbonaceous mudstone and coal, and some bentonite, with sandstone dominating the total thickness at almost a 2:1 ratio. The sandstones are resistant and, in part, conglomeratic. The sandstones in the lower Dakota are more lenticular and cross-bedded than those in the upper Dakota. Sandstones in the upper Dakota commonly contain abundant fossil oyster shells. The Dakota is characterized by its variety of textures, grain sizes, and bedding thicknesses and forms; and by streaks and thin beds of carbonaceous material.

The contact between the Dakota and the overlying Tropic Shale is placed at the top of the highest coal bed in the Dakota Formation. This coal bed has burned naturally over much of its outcrop in the Alton quadrangle. Consequently, the contact is commonly marked by the resulting baked shale ("clinker") in the base of the Tropic. Local residents have excavated clinker for aggregate, creating many exposures of this contact.

The Dakota was deposited during transgression of the Cretaceous Western Interior Seaway (Lawrence, 1965). The upper Dakota formed in the back swamps, littoral zone, and nearshore marine zone as the coastal area moved progressively westward over the region. The channel sands and associated overbank muds in the lower Dakota were deposited by meandering streams, flowing eastward, that fed into the coastal swamps. The lower Dakota is Aptian and the Lower-Upper Cretaceous boundary is probably in the upper Dakota (Lawrence, 1965, p. 86).

Tropic Shale (Kt)

The Tropic Shale was named by Gregory and Moore (1931) for exposures near Tropic, Utah. This unit is about 700 feet (215 m) thick in the Alton quadrangle. The Tropic tends to form vegetated gentle slopes and broad flats with poor exposures. It is best exposed in the sides of dissected stream valleys and their tributary gullies.

Where exposed, the upper Tropic is a medium-brownish-gray to medium-dark-gray, very thin-bedded, silty shale. The top of the Tropic interfingers with basal sandstones of the overlying Tibbet Canyon Member of the Straight Cliffs Formation.

The upper contact of the Tropic is mapped at the base of the lowest thick (about 2-3 feet [0.6-0.9 m]) sandstone bed in the Tibbet Canyon. This contact is commonly covered by the weathering products of the lower Straight Cliffs Formation and by landslide deposits. Locally, seeps at the base of the Tibbet Canyon support verdant vegetation on flats developed on the underlying Tropic Shale.

The mapped boundaries of the Tropic Shale used in this quadrangle were established by Lawrence (1965), and are the same as those mapped by Goode (1973a, 1973b) to the south in the Bald Knoll and Skutumpah Creek quadrangles and by Tilton (1991, 2001) in the adjoining Podunk Creek quadrangle. On the earlier map of Gregory (1951) the boundaries were inconsistently placed.

In the Tropic Shale, fossil oyster and gastropod shells are locally abundant and ammonite shells are common, whereas vertebrate material is rare. Fossils and regional sedimentological relations indicate that the Tropic Shale was deposited in an open-marine, neritic (offshore) environment during the maximum westward transgression of the Western Interior Seaway that covered the Paunsaugunt Plateau area in the Late Cretaceous (late Cenomanian)(Lawrence, 1965). In the quadrangle, a relatively thick transitional sequence of increasingly sandier beds are interlayered with the mudstone of the uppermost Tropic Shale. This sandy interval and sandstone in the base of the Tibbet Canyon Member of the Straight Cliffs Formation, intertonguing with dark-gray Tropic mudstone, are a zone that marks the initial sand influx onto offshore marine facies.

Straight Cliffs Formation

This formation was originally named the Straight Cliffs Sandstone by Gregory and Moore (1931) for rocks in the cliffs of this name in the Kaiparowits Plateau along the southwest side of Escalante Valley. There the formation is a prominent steep-sided cliff of resistant, thick sandstone as much as 1,000 feet (305 m) high. Because substantial amounts of mudstone and coal are present in the Straight Cliffs in the western and southern parts of the Kaiparowits Plateau, and in areas farther west, the unit name was changed to the Straight Cliffs Formation by Peterson and Waldrop (1965).

This formation is about 1,200 feet (365 m) thick in the Alton quadrangle, where the Straight Cliffs Formation forms the lower two-thirds of the ridges radiating out from the southern Paunsaugunt Plateau. The strata consist of sandstone and mudstone; sandstone makes up approximately 75 percent of the section. Except for a few inches of coal near the base of the unit, no coal was found in the Straight Cliffs Formation in the Alton quadrangle.

Gregory (1951), after measuring several stratigraphic sections in the Paunsaugunt Plateau area, indicated that he could not separate the Straight Cliffs Formation from the Wahweap Formation. "In measured sections the sandstone, shale, and conglomerate components of the Straight Cliffs have no systematic relations" (Gregory, 1951, p. 38). He therefore mapped this stratigraphic interval as "Undifferentiated Straight Cliffs Wahweap sandstones."

Peterson (1969b) divided the sandstone, mudstone, and coal of the Straight Cliffs Formation in the southeastern Kaiparowits Plateau into four members. In ascending order, they are the Tibbet Canyon, Smoky Hollow, John Henry, and Drip Tank Members. These members have been recognized by virtually all subsequent workers in the region (for example Robison, 1966; Blakey, 1970; Bowers, 1975, 1983, 1991).

I recognized and mapped these members in the southern Paunsaugunt Plateau (Tilton, 1991, 2001) by using Peterson's (1969b) criteria. I recognized that: (1) a major unconformity is within the Straight Cliffs Formation, not at the top as previously reported (for example Gregory, 1951; Doelling and Davis, 1989); (2) the "calico bed" marking the top of the Smoky Hollow Member is probably bed 19 in Gregory's (1951, p. 62-65) Tenny Canyon section; and (3) the "white" sandstone Gregory (1951) placed in the base of the Kaiparowits (bed 38 in his Tenny Canyon section, p. 62-65) is in the Drip Tank Member of the Straight Cliffs Formation.

Geologic maps by Cashion (1961, 1967) to the west and by Goode (1973a, 1973b) to the south and southeast of the Alton quadrangle, and by Doelling (1972) and Doelling and

Davis (1989) on the south end of the Paunsaugunt Plateau show an abbreviated Straight Cliffs Formation that is essentially the lower two members of the Straight Cliffs. The upper two members were included in their Wahweap Formation.

Tibbet Canyon Member (Kst): The Tibbet Canyon Member commonly forms massive, orangish-gray-weathering sandstone cliffs that stand above the gentle gray-weathering slopes of the underlying Tropic Shale, and project outward from the mudstone slopes of the overlying Smoky Hollow Member. The Tibbet Canyon is one of two prominent markers in Upper Cretaceous strata in the region (see figure 2), the other is the Drip Tank Member at the top of the Straight Cliffs Formation.

Throughout the southern Paunsaugunt Plateau, the Tibbet Canyon consists mainly of grayish-yellow to grayish-orange, very fine- to medium-grained, horizontally stratified sandstone containing rare, scattered, small chert pebbles. In the Alton quadrangle it is about 120 to 160 feet (37-49 m) thick.

The basal Tibbet Canyon intertongues with gray mudstone in the top of the underlying Tropic Shale. The lower Tibbet Canyon is parallel laminated and, for the most part, intensely bioturbated. Burrows of *Ophiomorpha* (trace fossil) are abundant in the bioturbated zones. The middle Tibbet Canyon is mostly parallel laminated with zones of high- to low-angle cross-beds that contain evidence of bioturbation. In the uppermost Tibbet Canyon, beds with high-angle cross-stratification are common. The top few feet (<1 m) are made up of prominent, horizontally stratified beds that commonly weather out as slabs. Also common in the upper half to two-thirds of the member, especially in the upper 5 to 10 feet (2-3 m), are fossil oyster shells (*Crassostrea soleniscus*) and shell fragments associated with coarse quartz grains in beds 1 foot (0.3 m) or more thick.

The top of the Tibbet Canyon Member is conformably overlain by, and locally intertongues with, poorly resistant carbonaceous mudstone and thin coal in the base of the Smoky Hollow Member. This contact is sharply defined in outcrop by a persistent carbonaceous shale, or, more commonly, by the dark-gray color at the base of a weathering mudstone slope, above the resistant sandstone cliff. A bench has commonly formed on top of the Tibbet Canyon.

The Tibbet Canyon Member represents beach and bar sand deposits, and possibly coastal dunes, transitional in depositional environment between the offshore-marine muds of the underlying Tropic Shale and the swamp and stream deposits of the overlying Smoky Hollow Member. The depositional environment that existed in this area in Late Cretaceous time has been compared with modern day barrier-island complexes, such as those along the Gulf Coast of Texas (Peterson, 1969a; Moir, 1974).

The uppermost Tibbet Canyon contains abundant fossil oyster shells and represents deposition in the littoral environment in relatively quiet brackish waters on the landward side of the beach, before the eastward-encroaching back swamps and lagoons covered these sands.

The Tibbet Canyon sands were deposited during eastward withdrawal of the Cretaceous seaway from the area. Based on measured cross-bedding directions in the beach sands, deposition of the Tibbet Canyon included that from longshore drift moving southeast along a northwest- to southeast-trending shoreline (Tilton, 1991).

Smoky Hollow Member (Kss): The Smoky Hollow Member generally weathers to brush-covered slopes above the prominent cliffs of the Tibbet Canyon Member. The upper Smoky Hollow is generally indistinguishable from the overlying John Henry Member on these slopes. Locally, the distinctive brown, moderately resistant sandstone at the base of the John Henry forms ridges or cliffs, below which the light-gray, conglomeratic sandstone of the upper Smoky Hollow is exposed. The Smoky Hollow is about 135 feet (41 m) thick in the Alton quadrangle.

The three informal subdivisions recognized by Peterson (1969b) in his study of the Smoky Hollow in the Kaiparowits Plateau are also discernible in the Alton quadrangle. In ascending order, they are the coal zone, the barren zone, and the "calico bed." The coal zone is a few feet to 10 feet (<3 m) thick, and consists of dark-gray mudstone with a few inches (<10 cm) of carbonaceous shale to low-grade coal in the lowermost part; some beds contain abundant small fossil bivalve and gastropod shells and shell molds. The coal in this zone is equivalent to the thick coal zone of Peterson (1969b) in the Kaiparowits Plateau. The overlying barren zone, named in the Kaiparowits region for its lack of coal beds, consists of 25 to 80 feet (8-24 m) of very fine- to fine-grained, orangish-gray sandstone and medium- to dark-gray mudstone. The "calico bed," named by Peterson (1969b) for its distinctive color, is a 50- to 100-foot-thick (15-30 m), white to grayish-orange sandstone containing lenses of granule and pebble conglomerate (figure 4). This unit is predominantly a moderately sorted, very fine- to medium-grained sandstone, containing lenses of coarser grains and granules of quartz and chert, pebbles of light- and dark-gray

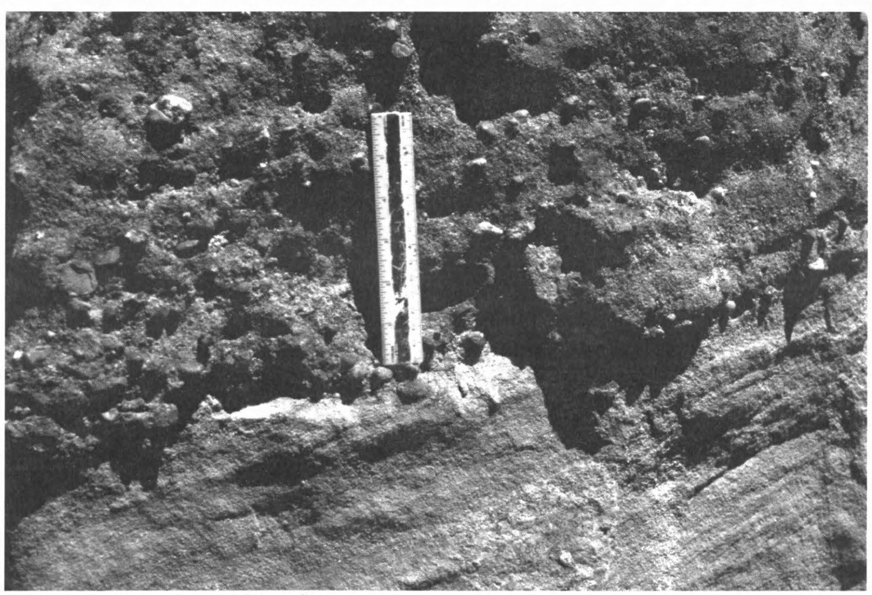

Figure 4. *Unconformable surface cut into top of sandstone in the barren zone unit of the Smoky Hollow Member, with the conglomeratic sandstone of the calico bed of the Smoky Hollow Member above it. Note six-inch (15-cm) ruler for scale.*

chert and gray and reddish-brown quartzite, and a few beds of gray mudstone.

The upper contact of the Smoky Hollow is placed at the top of the calico bed, where it is overlain by gray mudstone, or darker and more resistant, mostly non-conglomeratic sandstone of the John Henry Member. The mapped contact is based on several characteristics of the calico bed: (1) it tends to be poorly to moderately resistant and forms slopes covered with disaggregated pebbles (these slopes indicate the approximate position of the contact when covered); (2) it tends to be much lighter in color than the sandstones of the John Henry above it; (3) it generally exhibits dark-orange-brown ironstone clasts and concretions, and much orange-brown iron-oxide surface staining and cement; and (4) the calico bed is generally coarser grained than the sandstone in the basal John Henry. Also, the distinctive "caramel"-brown sandstone in the John Henry is moderately resistant and forms a ledge above the calico bed. This capping sandstone commonly contains imprints of leaves and carbonized plant fragments.

The John Henry Member lies unconformably on an erosion surface with little or no visible relief and with no discernible angular discordance between it and the underlying Smoky Hollow Member (Tilton, 1991). As pointed out by J.G. Eaton (written communication, 1997) a more significant unconformity, in terms of sequence stratigraphy, might be at the base of the calico bed rather than at the Smoky Hollow-John Henry contact (top of the calico bed). In most parts of the southern Paunsaugunt Plateau this contact is hidden by slope wash and vegetation; an approximate contact can usually be recognized by the occurrence of pebbles, from the underlying calico bed in the Smoky Hollow, weathering out on the slope.

Peterson (1969b) reported that the Smoky Hollow-John Henry contact corresponds to an unconformity and that it is the one clearly defined stratigraphic horizon in the Straight Cliffs Formation that can be traced throughout the region. This horizon, despite the poor exposures, can often be located using the consistent thickness of the Smoky Hollow throughout the Alton quadrangle (130 to 140 feet [40-43 m]). Where the base of the John Henry is exposed, the distinctive "caramel"-brown sandstone can be seen from a distance.

The Smoky Hollow is the basal unit of the thick Upper Cretaceous fluvial section in the southern Paunsaugunt Plateau. The lowest strata are paludal (swamp) and lagoonal mudstone, locally with thin, low-grade coal layers and carbonized plant material. These materials are interpreted to have been deposited in back swamps landward (west) of the marine sand beaches and east of the river systems flowing into the swamps. Fossil shells of small bivalves (*Corbula subtrigonalis*) and gastropods (*Turritella whitei* and *Cymbophora* sp.) are present in these rocks.

In a few locations, a basal sandstone lies above the contact with the underlying Tibbet Canyon Member, and is interpreted as fluvial deposition from distributary streams that apparently flowed through the back swamps and delivered sediment to the coast. Such a channel sandstone is displayed on the south side of the entrance to Reservoir Canyon.

Above the carbonaceous shale and gray mudstone in the lower Smoky Hollow are sandstone and mudstone deposited in stream channel and floodplain environments. These barren-zone deposits are part of the initial influx of stream sediments that were to continue to accumulate in the area throughout much of the Late Cretaceous.

The uppermost unit of the Smoky Hollow Member, the "calico bed," is a sequence of distinctive, stream-deposited, conglomeratic sandstone sheets of wide lateral extent that exhibit several cycles of channel cutting and filling without depositing associated overbank mudstones. This unit is interpreted to have been deposited by braided streams that were supplied large amounts of coarse clastic sediment from piedmont alluvial fans located on the steep flanks of highlands rising to the west. Although a few beds of mudstone are associated with the sandstone, rip-up clasts of mudstone are common in the sandstone in some horizons. Lateral movement of stream channels presumably reworked and carried away most of the finer sediment. The sandstone has high- to low-angle, trough cross-beds. Measurements of maximum dip of cross-bedding suggest stream-flow directions were to the northeast to east northeast (Tilton, 1991). Large, elongate, horizontally positioned, external molds of tree trunks and limbs are common in some horizons.

The upper contact of the Smoky Hollow is placed at the top of the calico bed, where it is overlain by gray mudstone, or darker and more resistant, mostly non-conglomeratic sandstone of the John Henry Member. The mapped contact is based on several characteristics of the calico bed: (1) it tends to be poorly to moderately resistant and forms slopes covered with disaggregated pebbles (these slopes indicate the approximate position of the contact when covered); (2) it tends to be much lighter in color than the sandstones of the John Henry above it; (3) it generally exhibits dark-orange-brown ironstone clasts and concretions, and much orange-brown iron-oxide surface staining and cement; and (4) the calico bed is generally coarser grained than the sandstone in the basal John Henry. Also, the distinctive "caramel"-brown sandstone in the John Henry is moderately resistant and forms a ledge above the calico bed. This capping sandstone commonly contains imprints of leaves and carbonized plant fragments.

John Henry Member (Ksj): The John Henry Member in the Alton quadrangle forms brush-covered slopes of poorly resistant mudstone broken by moderately resistant sandstone cliffs 20 to 50 feet (6-15 m) high. This unit is about 670 feet (200 m) thick in the Alton quadrangle. It is composed of stream-deposited, grayish orange, very fine- to fine-grained, low-angle-cross-stratified sandstone and medium- to dark-gray and grayish-red-purple mudstone. Sandstone is the dominant lithology, making up about 65 percent of the section. Neither coal nor carbonaceous mudstone were found in the John Henry in the Alton quadrangle.

Subdivisions of the John Henry in the Kaiparowits Plateau were established using coal beds (Peterson, 1969b) and are, therefore, not adaptable to the coal-barren rocks of this member in the southern Paunsaugunt Plateau. In the Alton quadrangle, neither marker beds nor stratigraphic breaks were found in this member.

On outcrop in the Alton quadrangle, the John Henry Member resembles the lower part of the overlying undivided Wahweap and Kaiparowits(?) unit more so than it does other members of the Straight Cliffs Formation. A difference between the two somewhat similar sequences is that sandstone is dominant in the John Henry, whereas in the lower part of the Wahweap-Kaiparowits(?) unit, sandstone and mudstone are essentially equally represented.

Finely disseminated carbonaceous plant debris and leaf imprints of angiosperm trees and bushes were found at scattered localities in the lower half of the John Henry. Other fossils in the John Henry are: petrified wood; fragments of fossil teeth and bone of reptiles and fish; gar scales; and shell molds of bivalves (*Cardium pauperculum*) and gastropods (*Physa* sp. and *Viviparus* sp.).

Leaf imprints were noted only in the John Henry Member in the Alton quadrangle and are most common in the base of the thicker sandstone beds. A cursory examination of some specimens of the John Henry flora showed that they have affinities with "*Populus*" *potomacensis*, *Populophyllum reniforme*, and *Sapindopsis magnifolia*. Affinities were discerned in the John Henry flora with the middle subzone II-B flora of the Potomac Group in Maryland and Virginia (Doyle and Hickey, 1976).

The upper contact of the John Henry is placed at the top of the highest sandstone or mudstone below the Drip Tank Member. A hard, dark-red-brown, thin (2 to 6 inch [5-15 cm]) clay ironstone bed persistently occurs in the top of the mudstone of the uppermost John Henry and was used as a guide in mapping this contact. Where covered, the contact was drawn at the base of the prominent white- to light-gray-colored slope material of the Drip Tank that contrasts with the darker underlying John Henry.

The John Henry Member in the area is entirely nonmarine and consists of alternating beds of stream-deposited, lenticular sandstone and mudstone. In meandering river systems, channels tend to migrate laterally in belts across a wide floodplain. In subsiding areas much of the sediment carried by streams is retained in the basin. With time, the accumulation of stream sediment leaves lenticular channel sands surrounded in long dimension by overbank muds, as found in the study area in the John Henry Member.

Thick sandstones of the John Henry tend to be parallel laminated in the middle portion and high-angle cross-bedded in the lower and upper portions, with current-ripple to ripple-drift lamination in the top few inches. Molds of tree trunks and branches are common in the thick sandstone beds. The thin sandstones tend to be parallel laminated to small-scale cross laminated, with the top few inches ripple-drift cross laminated. Thick sandstones exhibit characteristics of point-bar sands and the thin sandstones exhibit characteristics of lateral accretion within the interbedded deposits of overbank mud. Dip measurements of cross-bedding in the sandstones suggest north to east-northeast stream-flow directions (Tilton, 1991).

Drip Tank Member (Ksd): The Drip Tank Member forms distinctive, although not generally prominent, cliffs of light-gray sandstone that can be seen from a distance as a white band high on the ridges that radiate from the plateau. From a vantage point, such as a high ridge, in aerial photographs, or from a low-flying aircraft, the Drip Tank Member stands out in contrast to the remainder of the ridge in that it forms broad, bright, light-gray to white, sparsely vegetated saddles and passes. On the ground, the Drip Tank Member is characterized by areas of loose white sand with scattered, luxuriant manzanita bushes and large ponderosa pines. Locally, barite-cemented zones occur in the sandstone and "desert roses" can be found in these loose sandy saddles. Where capped by a resistant sandstone, the upper Drip Tank forms a cliff about 150 feet (46 m) high in the Alton quadrangle. The total thickness of the Drip Tank in the quadrangle is about 185 to 215 feet (56-66 m).

The Drip Tank Member is a stream-deposited, mainly white to light-gray, very fine- to fine-grained, cross-stratified, "salt and-pepper" sandstone. Although parallel lamination is common, the bulk of the unit is high-angle cross-stratified. Locally, large elongate molds of relatively large tree trunks are present in cross-stratified sandstone beds. The upper two-thirds of the member has two to four beds containing fine-grained to granule-sized quartz and small to large, rounded pebbles (up to 4 inches [10 cm] long) of mostly tan or black chert and gray quartzite. Fewer pebbles are dark-gray, silicified limestone; red, silicified, fossil horn coral; gray, fossil glass sponge; gray, indurated conglomerate; and aphanitic igneous rock. Throughout the member, and more abundant in the lower half to two-thirds, are zones of brownish-orange iron stain and/or scattered ironstone concretions. Some of the concretions appear to be permineralized (fossil) tree limb or root bark. A hard, dark-red-brown, thin, persistent ironstone bed is present at the contact between the Drip Tank and the underlying John Henry. One or two medium-gray and grayish-red-purple mudstone beds, about 10 to 30 feet (3-9 m) thick, occur in the lower half of the Drip Tank Member.

The upper contact with the undivided Wahweap and Kaiparowits(?) unit is conformable and is placed at the top of the distinctive, light-gray sandstone of the Drip Tank Member. Where interfingering occurs, the contact is placed at the top of the highest sandstone with typical Drip Tank lithology.

The Drip Tank's intermediate location in the stratigraphic column, the distinctive light-gray color, the presence of the only conglomerate lenses in this part of the section, and its tendency to weather into distinctive loose sandy saddles makes the Drip Tank one of two prominent and important guides in mapping the geology of the southern Paunsaugunt Plateau area; the other "marker" is the Tibbet Canyon Member of the Straight Cliffs Formation. It is, by far, the most useful horizon in discerning and tracing faults in Upper Cretaceous rocks below the rim of the plateau.

Conglomeratic sandstone characterizing the Drip Tank Member was deposited by streams flowing to the northeast and east (Tilton, 1991). The great lateral extent of sand bodies within this unit contrasts with the lenticularity of sand bodies in the underlying John Henry Member and the overlying Wahweap-Kaiparowits(?) unit. This is more indicative of braided streams than meandering streams. As during the deposition of the "calico bed" of the Smoky Hollow Member, large volumes of coarse clastic sediment spread across the area from piedmont fans that were on the margins of the rising highlands to the west.

Wahweap and Kaiparowits(?) Formations, undivided (Kwk)

The Wahweap and Kaiparowits Formations were established by Gregory and Moore (1931) in the Kaiparowits Plateau. During this study of the southern Paunsaugunt Plateau, mappable boundaries were not located within this interval between the Straight Cliffs and Claron Formations, and I don't think the Kaiparowits Formation is present here. However, as noted later, other researchers have questioned this conclusion. Therefore, the Wahweap and what may be the Kaiparowits Formation were mapped as an undivided unit in the Alton quadrangle.

This unit consists of mostly brush- and tree-covered slopes of poorly resistant mudstone and moderately resistant sandstone on the upper reaches of ridges directly below the Paunsaugunt Plateau rim. The only readily accessible outcrops of the Wahweap-Kaiparowits(?) in the Alton quadrangle are along roads on the Paunsaugunt Plateau. The outcrops are only of the uppermost part of the unit and are generally covered.

In the southeastern part of the Markagunt Plateau north of Glendale, I measured a stratigraphic section from the Tropic Shale up to the Claron Formation in which I identified two informal members of the Wahweap Formation but no Kaiparowits Formation lithologies. Although the measured section is west of the Alton quadrangle, it is included in this report as it is the most complete and accessible section in the area (see appendix).

The Wahweap-Kaiparowits(?) unit is about 600 to 800 feet (180-245 m) thick in the Alton quadrangle. The lower part consists of alternating prominent beds of mostly yellowish-gray to moderate-yellowish-brown, very fine- to fine-grained, horizontally stratified and low-angle cross-stratified sandstone and light- to medium-gray and grayish-red-purple mudstone. The upper part is almost entirely grayish-orange, very fine- to fine-grained, cross-stratified, thick-bedded sandstone, that contains some beds of medium- to coarse-grained sandstone and conglomerate lenses, with some thin mudstone beds in the lower portion of this upper part.

The ratio of sandstone to mudstone in the lower part is approximately 1:1. Individual beds are up to 100 feet (30 m) thick in measured sections, the predominant thickness being 20 to 25 feet (6-8 m) for sandstone beds and 30 to 40 feet (9-12 m) for the mudstone beds. The thicker mudstone beds commonly contain several interbeds of very fine-grained sandstone, generally less than one foot (<0.3 m) thick. Common features of sandstones in the lower part include: contorted or convoluted bedding; ripple lamination (in the upper portion of the lower part); mud-chip conglomerate; petrified wood, carbonized wood, and other preserved plant debris; ironstone-lined molds of tree roots and branches; casts and molds of bivalve and gastropod shells; and fossil bone and teeth fragments, most probably from crocodiles and dinosaurs. Internal and external molds in the sandstone are tentatively identified as bivalves of the genus "*Unio*" (up to 4 inches [10 cm] long), and gastropods of the genera *Viviparus*, *Campeloma*, and *Physa*.

In the upper part of the Wahweap-Kaiparowits(?) unit in the Alton quadrangle, a sandstone bed about 100 feet (30 m) thick is generally present. It is distinguished from sandstone of the lower part in that it contains: (1) some thin, lenticular beds of granule-sized grains, scattered chert pebbles, and lenses of chert pebbles; (2) salt-and-pepper grains in the uppermost portion of the sandstone bed; and (3) in containing large fragments (albeit few) of fossil dinosaur bones. A steep, sloping exposure of this bed is well displayed below the Sunset Cliffs at the head of Kanab Creek.

The upper portion of the upper sandstone bed in the Wahweap-Kaiparowits(?) is exposed on top of the plateau in the valley of Upper Kanab Creek in the Podunk Creek quadrangle. Locally, this upper sandstone bed resembles sandstone in the Kaiparowits Formation at its type locality east of the Paunsaugunt Plateau; it is massive, yet relatively poorly resistant, medium-gray "salt and-pepper" in color, and contains fossil dinosaur bones.

In the area of the Table Cliffs Plateau, Robison (1966, p. 26) reported that the upper Wahweap was conformable and gradational with the overlying Kaiparowits. He also reported that the Kaiparowits was absent west of the Table Cliffs Plateau, and the Claron unconformably overlies the Wahweap. Bowers (1991) reported the same relationship in Bryce Canyon National Park on the southern Paunsaugunt Plateau. Moir (1974) noted that palynomorphs indicate that the Kaiparowits Formation has no equivalent in the Markagunt Plateau (to the west) nor is the distinctive lithology of the Kaiparowits represented there. Nichols (1997) noted that palynology indicated the Kaiparowits(?) mapped by Sable and Hereford (1990) in the Markagunt Plateau is older than the type Kaiparowits (Santonian as opposed to Campanian), and might just as easily be termed Wahweap(?) Formation. Unlike the previous workers, Eaton and others (1993) suggested that the Kaiparowits Formation is present on the Paunsaugunt Plateau and that at least the uppermost sandstone exposed in the Podunk Creek quadrangle is part of the Kaiparowits. Thus, this uppermost sandstone of my undivided map unit may be the Kaiparowits Formation, gradational with the Kaiparowits Formation as exposed to the east of the Paunsaugunt Plateau, or be part of the Wahweap Formation.

The upper contact of my Wahweap-Kaiparowits(?) unit is placed at the top of the highest sandstone or mudstone below the basal conglomerate of the Canaan Peak Formation or, in its absence, at the base of limestone or limy sandstone of the Claron Formation. This contact is unconformable, with the overlying unit deposited in broad hollows that were eroded into the Wahweap-Kaiparowits(?) unit.

Rocks in the Wahweap and Kaiparowits(?) unit were deposited by streams. Measurements of the cross-bedding in the sandstones suggest they were deposited by meandering streams flowing in directions ranging from north to east (Tilton, 1991). Sandstones in the lower part of the unit are lenticular channel deposits that are surrounded in wide lateral extent by overbank mud. Most of the finer sediments were apparently reworked and carried out of the area during the deposition of the upper, thick sandstone bed.

Before deposition of the Tertiary Claron Formation, deposition in the Late Cretaceous was followed by at least one episode of erosion. This is attested to by the extensive erosion surface on the top of the Wahweap-Kaiparowits(?) unit throughout the southern Paunsaugunt Plateau. The upper sandstone of the unit appears to thicken northward, perhaps having been beveled by erosion as, or after, the land was slightly tilted. Other than the general lithologic division between the interbedded sandstone and mudstone of the lower part, and the upper sandstone, no stratigraphic breaks or persistent guides were evident in the Wahweap-Kaiparowits(?) strata.

Upper Cretaceous to Paleocene

Canaan Peak Formation

The Canaan Peak Formation was established by Bowers

(1972) for "mostly pebble-cobble conglomerates and conglomeratic sandstone, containing a few mudstone interbeds in the lower part" that unconformably overlie the Kaiparowits Formation in the Table Cliffs Plateau, northeast of the Paunsaugunt Plateau. Goldstrand (1990a, 1990b) extended Bowers' nomenclature to include the conglomerate and conglomeratic sandstone beneath the Claron Formation in the southern Paunsaugunt and Markagunt Plateaus. He reported that the unit was generally less than 35 feet (11 m) thick. The lower part of the formation is late Campanian or Maastrichtian, while the upper part is Paleocene; the unit represents reworking of older strata by streams, lake-shore, and soil-forming processes (Goldstrand, 1990a, 1990b, 1992).

This discontinuous, thin unit is a resistant, pebble to cobble conglomeratic sandstone, exhibiting low- and high-angle trough cross-bedding. Because it is thin, the Canaan Peak is mapped with the Claron. At the head of Tenny Canyon in the Podunk Creek quadrangle, 30 feet (9 m) of coarse conglomerate, containing clasts up to 15 inches (38 cm) long in a "salt-and-pepper" sand matrix, was measured below the Claron Formation. Also in the Podunk Creek quadrangle, 45 feet (14 m) of Canaan Peak conglomerate was measured near the Podunk Creek Guard Station (Tilton, 1991, 2001). The Canaan Peak Formation lies unconformably on the eroded top of the Wahweap-Kaiparowits(?) unit. Although portrayed by Goldstrand (1990a) as unconformably overlain by the Claron, the Canaan Peak appears to me to locally grade conformably into the Claron.

The Canaan Peak was deposited by high-energy streams following periods of erosion. This episodic action resulted in the reworking of older gravels within the deposit. Goldstrand (1990a, 1990b, 1992) reported that paleocurrent directions in the Canaan Peak braided-stream system changed upwards from east flowing to northeast flowing and suggested that this change was due to Laramide deformation in late Campanian time.

Tertiary - Paleocene(?) to Eocene

Claron Formation

The uppermost formation in the Paunsaugunt Plateau is the Claron Formation, which is also known by another name, the Wasatch Formation. Gregory (1951) used Wasatch Formation in his mapping of the Paunsaugunt Plateau, and through the years visitors to Bryce Canyon learned this name for the rock producing the scenic landscape there. Robison (1966), however, used the name Claron for this unit in mapping the northeastern Paunsaugunt Plateau, choosing the name for its historical precedence. The Utah Geological Survey currently uses the name Claron; Anderson and Rowley (1975) discussed the reasoning involved.

Where well exposed, the Claron is readily divisible into a lower pink member and a conformably overlying white member. Both of these units are mostly massive, fine-grained to crystalline limestone. The pink and white members vary both vertically and horizontally in resistance to weathering, forming a series of cliffs and steep slopes. These weathering differences, along with the prominent system of closely spaced joints in the Claron, produce spectacularly etched canyon walls and monuments. This is best displayed in the Alton quadrangle in the Sunset Cliffs, east of the headwaters of Kanab Creek. The third (uppermost) member, the variegated sandstone member (Tilton, 1991 after Bowers' 1972 usage for the Wasatch Formation), is now recognized as being the basal unit of the Brian Head Formation (revised) of Sable and Maldonado (1997).

Bowers (1972) reported Eocene, freshwater mollusc fossils were collected from the white member in the Table Cliffs Plateau (northeast of the Paunsaugunt), and assigned at least part of the pink member a probable Paleocene age. The Claron Formation is interpreted to have been deposited in freshwater lakes and by streams, with subaerial (paleosol) deposition contributing to the variety of limy sediments.

Pink member (Tcp): This member is characterized by thin- to massive-bedded, predominantly pink, dense, crystalline to fine grained, clastic limestone, and minor beds of limy sandstone and mudstone, with some conglomerate. No fossils were observed in these rocks by the author. The pink member in the Alton quadrangle is about 600 feet (185 m) thick.

White member (Tcw): The white member is mostly white to light gray, crystalline, thick-bedded, hard and dense limestone, with minor interbeds of calcareous, gray mudstone. The white member is about 200 feet (60 m) thick in the Alton quadrangle east of the Sevier fault zone and forms eroding ridges on the Paunsaugunt Plateau; it is an estimated 80 to 150 feet (25-45 m) thick west of the Sevier fault zone.

Eocene to Oligocene

Brian Head Formation (revised)(Tbh)

The Brian Head Formation on the Markagunt Plateau was revised and redefined by Sable and Maldonado (1997) to include rocks between the underlying white member of the Claron Formation (as mapped here) and the overlying ash-flow tuff of the Needles Range Group. Regionally, the revised Brian Head unconformably overlies the white member and, in places, the pink (also known as red) member of the Claron. The Brian Head has been eroded from most of the Paunsaugunt Plateau; it is not present east of the Sevier fault zone in the Alton quadrangle and is absent in the adjacent Podunk Creek quadrangle. At least the lower part of the Brian Head Formation (revised), as mapped in the Alton quadrangle and shown on the Kanab 30 x 60-minute geologic map (Sable and Hereford, 1990), is apparently equivalent to the sandy phase of the white member of the Claron Formation mapped in the Asay Bench quadrangle (Moore and others, 1994) to the north, and the variegated sandstone member of Bowers' (1972) Wasatch (now Claron) Formation. The upper part of the Brian Head in the Alton quadrangle contains volcaniclastic material and is tentatively correlated with the gray volcaniclastic member of Sable and Maldonado (1997).

In the Alton quadrangle, the Brian Head consists of poorly resistant, interbedded, pink and purplish-gray, very fine-grained, friable sandstone, conglomerate, siltstone, mudstone, and limy mudstone; and an upper unit of gray to white, fine- to medium grained sandstone and calcarenite, in part with a volcanically derived clay matrix. The Brian Head Formation is present in the rugged hills west of the Sevier fault zone, on the eastern margin of the Markagunt Plateau, where it is poorly exposed. It is an estimated 200 feet (60 m) thick.

The Brian Head (revised) is late Eocene to middle Oligocene in age and, like the Claron, was deposited in fluvial and lacustrine environments. In contrast to the Claron, the Brian Head contains more volcanic material and evidence of episodic soil formation (Sable and Maldonado, 1997).

Quaternary Units

Pediment Alluvium (Qap)

This unit consists of poorly sorted alluvial and locally colluvial silt, sand, and gravel (up to large cobbles) deposited on broad surfaces (pediments). This alluvium contains weathering products of the Canaan Peak and Claron Formations deposited mostly by flowing water during the Pleistocene and Holocene(?). These surfaces have been abandoned as streams have cut down to lower levels. The remaining pediments are being destroyed by erosion at their margins. The deposits are poorly exposed in vertical section; they appear to be about 10 feet (3 m) or more thick. Large pediments are present in the northwest corner of the Alton quadrangle, west of the Sevier fault zone; they are probably Pleistocene.

Landslide Deposits (Qms)

Landslides in the study area are gravity-transported hummocky deposits of mud and sand, commonly containing conspicuous blocks of sandstone. The bulk of the landslides involved the lower portion of the Straight Cliffs Formation sliding onto areas underlain by the Tropic Shale. Movement has also occurred within the Tropic Shale. The deposits generally sustain more plant growth (usually oaks) than the surrounding undisturbed land because of their ability to hold water; this makes them easy to identify but difficult to traverse. Other landslides originated in the Brian Head and Claron Formations and along the Sevier fault zone, with smaller slides in the John Henry Member of the Straight Cliffs Formation. A large, conspicuous sequence of progressively built landslides can be seen east of the Alton Amphitheater as a broad rolling apron below the lowest cliffs. Margins of individual landslide deposits are separated by dashed contact lines on plate 1. The thickness of landslide deposits varies from a cover of a few feet (<1 m) to an estimated 100 feet (30 m) or more.

Mass-Wasting Debris (Qm)

Mass-wasting debris (including talus, landslide debris, and colluvium) occurs on slopes below the cliffs bordering the plateau, and on ridges and hills away from the cliffs. This debris is predominantly resistant, dense, white and pink limestone, and cobbly gravel originating from the Claron and Canaan Peak Formations. Debris location determines the relative age, with older remnants of debris located away from the cliffs and Holocene debris bordering the cliffs. Discontinuous, thin patches of mass-wasting debris in this quadrangle actually extend downslope from the boundaries of thicker debris mapped on plate 1. The debris varies in thickness from a thin covering to an estimated 10 feet (3 m) or more.

Alluvium (Qa)

Alluvial deposits of unconsolidated clay, silt, sand, and gravel are present in and near existing drainages. This unit includes stream and fan alluvium, and terrace deposits. The alluvium is predominantly sand and gravel in the headwaters of streams coming off the plateau. Downstream from these areas, deposits are mostly mud where the streams cut through the Tropic Shale. Alluvial deposits vary in thickness from a thin covering to an estimated 10 feet (3 m) or more. These deposits are probably mostly Holocene.

IGNEOUS ROCKS

A dike of dense, black, fine-grained, porphyritic olivine basalt (Qb) is present northeast of Alton near Kanab Creek. It forms a northeast-trending ridge with a prominent wooded hill at its south end. Near-horizontal sets of columnar joints are prominently displayed (figure 5), as are abundant xenoliths of sedimentary rock. The limited amount of erosion that has occurred since emplacement suggests a Quaternary age. See Gregory (1951) for additional information. Best and others (1980) dated basalts (their samples #28, 36, 33) in the adjacent Long Valley Junction and Asay Bench quadrangles, as well as in the Skutumpah Creek quadrangle, south of the Podunk Creek quadrangle, at 0.56±0.06, 0.52±0.05, and 1.1±0.1 Ma (uncorrected), respectively.

Figure 5. *View to north along volcanic dike in northern Alton Amphitheater. Note the rough columnar jointing displayed by rocks at left. Note rock hammer at left for scale.*

STRUCTURE

The Paunsaugunt Plateau is east of the Sevier fault zone and west of the Paunsaugunt fault zone (figure 1). Both of these roughly north-trending fault zones have down-to-the-west, normal offset, yet Upper Cretaceous and Tertiary strata in the plateau dip gently and roughly north. Displacements along these two fault systems in Utah are about 1,000 to 2,000 feet (300-600 m) and 100 to 800 feet (30-245 m), respectively (Doelling and Davis, 1989). Between these two fault systems, the Paunsaugunt Plateau is a block that is tilted to the northeast. The Sand Pass fault zone (Eaton and others, 1993), with smaller, down-to-the-east normal offset, is located near the Claron Formation cliffs on part of the west side of the plateau. Therefore, a horst is present between the Sevier and Sand Pass fault zones, and at least part of the Paunsaugunt Plateau is in a graben between the Sand Pass and Paunsaugunt fault zones. The topographically high Paunsaugunt Plateau, therefore, likely owes its relief to erosional resistance and uplift rather than being a Basin-and-Range horst.

In the Alton quadrangle, Upper Cretaceous strata are inclined to the north and north-northeast, with dips generally from less than 1 to 3 degrees. These strata are cut by several generally north-trending (local) faults, including part of the Sand Pass fault zone, with relatively minor offset (<650 feet [<200 m]), and the Sevier fault zone. The Sand Pass fault zone is named for Sand Pass just north of the Alton quadrangle in the George Mtn. quadrangle (Eaton and others, 1993). Stratal dips vary considerably near faults in the Alton quadrangle. The local faults offset the Upper Cretaceous rocks below the plateau but do not appear to cut the Paleocene(?) and Eocene Claron Formation, while the Sevier fault zone offsets the Claron and Brian Head Formations. Therefore the local faults may be related to Laramide-style deformation rather than later Basin-and-Range extension. Dips on the Claron Formation in the adjacent Podunk Creek quadrangle are about 5 degrees to the north and north-northeast. A prominent north- to northwest-trending vertical joint set is displayed in Upper Cretaceous sandstone.

The Sevier fault zone trends roughly north-northeast through the northwest corner of the Alton quadrangle. To the north, the fault zone defines the western margin of the Paunsaugunt Plateau. Although the major down-dropped block is to the northwest, the more resistant Claron Formation forms the west margin of the Alton Amphitheater, which is underlain by the less-resistant Tropic Shale. Stratigraphic offset across the fault zone, from the top of Tropic Shale to base of Claron Formation, is here estimated at about 1,800 feet (550 m). The variety and pattern of differentially shifted fault blocks within the fault zone (plate 1) and striations along the fault planes in the zone reported in Anderson and Christenson (1989) suggest oblique slip.

Local faults trend roughly north-northwest and north, are generally several miles long, and are near vertical. These fault planes are relatively sharp with little or no fault breccia. These faults are seldom readily evident on the ground and are best located on aerial photographs. Other than the Sink Valley fault, these faults have readily apparent drag and offset. Offset shown on the Sink Valley fault on plate 1 is based on a low scarp in northern Sink Valley whose east side is up (see Goode, 1964). North-northwest-trending local faults in the southeast corner of the quadrangle, like those in the Podunk Creek quadrangle (Tilton, 1991, 2001), have displacements (stratigraphic offsets) of tens of feet to a few hundred feet (10 to <60 m).

Roughly north-trending faults include: the Sink Valley fault; three faults in upper Kanab Creek that are in the Sand Pass fault zone; and the Bald Knoll fault (Cashion, 1961) and an adjacent fault that might be in the Sand Pass fault zone. Three of the four north-trending faults, that are or might be in the Sand Pass fault zone, have down-to-the-east offset. The fault with down-to the-west offset is shorter than the others; it is only about a mile (1.5 km) long (see Doelling and Davis, 1989, plate 1). The Bald Knoll fault and the adjacent fault to the east have less than 650 feet (<200 m) of estimated stratigraphic offset and "die out" to the north. Two faults in the Sand Pass fault zone have an estimated 300 feet (90 m) or less of down-to-the-east stratigraphic offset, and the other has about 100 feet (30 m) of down-to-the-west offset.

Two scissor faults may be present in the local group of faults, but pivot points are obscured by surficial deposits. One fault may be present in upper Kanab Creek - the collinear western, down-to-the-east fault and the down-to-the-west fault to the north. The other possible scissor fault is a combination of a north-trending, down-to-the-east fault, just east of the Bald Knoll fault, and a north-northwest-trending, down-to-the-west fault in Tater Canyon. If these are actually scissor faults, they might indicate partial reactivation of Laramide structures during later Basin-and-Range extension.

GEOLOGIC HISTORY

The exposed Jurassic rocks in the quadrangle are limited to the eolian deposits of the Middle Jurassic Winsor Member of the Carmel Formation. A major unconformity marks the interval between Middle Jurassic and Upper Cretaceous rocks exposed in the quadrangle; regionally, older Jurassic units are beveled westward.

Most of the Cretaceous history in the Alton quadrangle is directly related to the interaction of two major geologic events: the Sevier orogeny and the movement of the Cretaceous Western Interior Seaway westward over, and then eastward out of the region. Eastward-directed thrusting began in the Early Cretaceous in the Sevier orogenic belt in southeastern Nevada and western Utah (Armstrong, 1968). An unconformity spans most of the Early Cretaceous in the Paunsaugunt Plateau. In the Late Cretaceous, as the orogenic highlands were eroded, clastic sediment moved eastward into the area. The Cretaceous Western Interior Seaway transgressed westward into the area by early Late Cretaceous (late Cenomanian) time. In the late Cenomanian, uplift and thrust faulting in the Sevier orogenic belt (highlands) and development of a foreland basin to the east affected depositional patterns in the area (Lawton, 1983). As part of the Sevier foreland basin, the mostly fluvial late Cretaceous rocks in the quadrangle reflect this deformation. In the latest Cretaceous and early Paleocene, Laramide-style deformation occurred in southern Utah (Goldstrand, 1994), and brought the relatively long period of fluvial deposition to an end. During this time, uplift of the region resulted in beveling of the top of Cretaceous sedimentary rocks, partitioning of the foreland basin into areas of internal drainage, and restriction of fluvial deposition to areas between uplifts (Lawton, 1983; Goldstrand, 1990b, 1992, 1994). The rocks were cut by steeply dipping, generally north-south-trending faults, and possibly underwent minor tilting.

Dates used in the following discussion of Cretaceous depositional events are from Eaton's (1991) study on the Kaiparowits Plateau rather than Nichols' (1997) work on the Markagunt Plateau. Until strata on the Paunsaugunt Plateau are dated, formation and member ages can only be estimated as younger than those on the Markagunt and older than those on the Kaiparowits, due to the time-transgressive eastward withdrawal of the seaway and eastward encroachment of clastic sediments. Details of the Upper Cretaceous depositional history and environments in the southern Paunsaugunt Plateau are presented by Tilton (1991).

The fluvial and swamp environments of the Dakota Formation in the Alton quadrangle were inundated by the westward marine transgression of the Cretaceous Western Interior Seaway in late Cenomanian time. In the late Cenomanian and continuing into the mid-Turonian, the marine Tropic Shale was deposited. Later in the Turonian, as the shoreline retreated eastward, the nearshore bar and beach sands of the Tibbet Canyon Member of the Straight Cliffs Formation were deposited on the Tropic Shale muds. Swamps and lagoons landward of the beach zone received fine sediment from the streams flowing into them, building up the deposits of the Smoky Hollow Member above the Tibbet Canyon. Deposition of the Smoky Hollow was interrupted and the resulting unconformity (calico bed) can be traced throughout the region.

Fluvial deposition resumed in late Coniacian and continued through the remainder of Cretaceous time, with an interruption near the end of the Campanian. This deposition produced the John Henry Member in late Coniacian and Santonian time, and the Drip Tank Member in early Campanian time (both members of the Straight Cliffs Formation). The overlying undivided Wahweap and Kaiparowits(?) unit was deposited in the Campanian, and the unconformably overlying Canaan Peak Formation during late Campanian and Maastrichtian (Cretaceous) and Paleocene (Tertiary) time. Resting unconformably on the Canaan Peak are the Paleocene(?) to Eocene (Tertiary) nonmarine limestones of the Claron Formation.

In late Cretaceous and early Tertiary time in the area, before deposition of the Claron Formation, Upper Cretaceous rocks were cut by generally north-south-trending, near-vertical faults, and uplifted and eroded during Laramide-style deformation. Erosion truncated the upper part of the Upper Cretaceous section such that strata of the upper portion of the Wahweap and Kaiparowits(?) unit beneath the unconformities vary locally. Goldstrand (1990a, 1990b) found that the conglomerates once considered basal Claron (Wasatch) are the discontinuous patches of Canaan Peak Formation.

Subsequent downwarping of the region in the early Tertiary created a large basin with intermittent lakes in which the mostly calcareous sediments of the Claron Formation were deposited. The depositional basin existed until at least the end of the Eocene, when erosion of the area resumed. Fluvial and lacustrine deposition of the Brian Head Formation (revised) occurred during the Oligocene, after Claron deposition. Volcaniclastic Brian Head strata record the onset of volcanic activity in Oligocene time.

Following deposition of the Claron and Brian Head Formations, the Paunsaugunt Plateau was tilted into a northward-dipping homocline and the rocks were cut by steeply dipping, generally north-south-trending, major, normal faults (Doelling and Davis, 1989). These major fault systems, which flank the Paunsaugunt Plateau, formed after the Eocene (Doelling and Davis, 1989), probably beginning in the Miocene (Stokes and Heylmun, 1965). Alternatively, the major fault systems flanking the Paunsaugunt Plateau, including the Sand Pass fault zone, further developed during this time or were reactivated when their Laramide reverse movement was overprinted by extensional (normal) faulting. The Colorado Plateau was uplifted in the last 5 to 10 million years (Lucchitta, 1989; Parsons and McCarthy, 1995). Basaltic magmatism occurred in the area in the Pleistocene. Erosion, working differentially on the various beds and structures in the area since the late Tertiary, has eroded the land into its present form.

ECONOMIC GEOLOGY

Coal Resources

The coal beds exposed in the Alton quadrangle are in the Smoky Hollow Member of the Straight Cliffs Formation and in the Dakota Formation. Coal in the Smoky Hollow locally reaches only a few inches in thickness. This coal is found within the few feet (~1 m) of carbonaceous shale that forms the basal unit of the member.

Coal in the Dakota Formation in the Alton quadrangle was mined in the past, so the two major zones have names: the upper is the Smirl coal zone and the lower is the Bald Knoll coal zone (Doelling, 1972). The Bald Knoll coal zone is about 200 feet (60 m) below the Smirl, which marks the top of the Dakota. Doelling (1972) reported that the Smirl coal zone is a 14- to 18-foot-thick (4-5 m) seam of coal without splits, while the Bald Knoll coal zone contains several coal seams separated by thin splits, with the thickest seam being 4.8 feet (1.5 m) thick. Five mines and two prospects have operated in the Alton quadrangle, all but one worked the Smirl coal zone (Doelling, 1972). The Smirl and Alton mines were the most important and the Smirl was the last to close. The mines produced between 35,000 and 50,000 short tons (32,000-45,000 metric tons) of coal from the late 1920s until 1969 when the last mine closed. The Smirl mine was located $1^1/2$ miles (2.4 km) south-southeast of Alton. Its last year of production (1969) yielded 1,597 short tons (1,449 metric tons) of coal (Doelling, 1972). The Smirl portal was sealed by the Utah Division of Oil, Gas and Mining in 1992. Large strip-minable reserves were drilled out in the Alton and adjoining quadrangles in the late 1970s and early 1980s, but development stopped because of environmental considerations (H.H. Doelling, written communication, 1997).

The coal has an apparent rank of sub-bituminous B, has an average heating value of about 9,560 Btu, an average sulfur content of about 1.0 percent, and an average ash content of 7.2 percent (Meiiji Resource Consultants, 1979). An analysis of coal by the U.S. Geological Survey from the lower part of the Smirl coal zone in the Alton quadrangle found 14 percent fusain and 31 percent inerts (E.G. Sable, written communication, 1989). Estimates published in Doelling (1972) indicate that coal reserves of just over 700,000,000 short tons (635 million metric tons) underlie the Alton quadrangle.

Aggregate

The Straight Cliffs Formation contains sheets of predominantly coarse-grained to granule-sized sandstone with abundant pebble lenses in the calico bed (upper unit of the Smoky Hollow Member) and in the middle to upper part of the Drip Tank Member. The pebbles are siliceous (mostly chert) and there is little fine matrix. Chert, however, is deleterious to good quality concrete (J.K. King, verbal communication, 1997). Saddles formed in the Drip Tank Member on some ridges contain loose, relatively clean, quartz sand. This sand might be useful in mixing with cement for concrete. Deposits of basalt rubble below the igneous dike in the south-central portion of the Alton quadrangle might provide a limited source of durable stone aggregate.

The coal beds in the Dakota Formation in the Alton quadrangle have burned naturally along much of the outcrop leaving clinker, collapse breccia, and baked mudstone. This resulting durable stone is utilized locally as aggregate and decorative stone. Pits are shown along the Smirl coal zone on the topographic base of plate 1.

Water Resources

The stream system on the Paunsaugunt Plateau is the north-flowing East Fork of the Sevier River and associated tributaries. The plateau is covered by thick snow during the winter, with melt water feeding the streams as late as June.

The streams below the plateau flow south and west from several canyons cut in the Upper Cretaceous sandstone and mudstone. Fed by melting snow, these streams will generally flow through the spring. Kanab Creek and Sink Valley Wash are only perennial in the vicinity of springs. With the arrival of summer rains, sometime in July, the streams will flow on the occasion of a rain storm in their drainage basin. Such summer flow is generally in the form of a flash flood and does not last long, however, and the streams are usually dry until the next spring.

Perched ground water in some sandstone layers above thick mudstone beds exists during the spring and into the early summer. Associated seeps support vegetation and some might be developed for a small water supply. The potential exists for ground water in sandstone aquifers in the subsurface Dakota Formation.

The town of Alton is supplied with drinking water from a pipeline connected to Birch Springs, located 2 miles (3.2 km) to the north in Birch Canyon. The spring water is of limited quantity and as of 1991 was only sufficient to support the existing population. A water well was drilled in Alton to a depth between 100 and 200 feet (30 to 60 m) to supplement the water taken from Birch Springs; however, the taste is much poorer than that of the spring water and the residents do not care to drink it. Sink Valley contains artesian wells that supply abundant water of good quality for irrigation and ranch use. Additional data on water resources are available in Goode (1964, 1966), Price (1980, 1981, 1982, 1983), Plantz (1983), Cordova (1981), and Doelling and Davis (1989).

Geologic Hazards

Numerous landslide deposits originate at the Straight Cliffs Tropic Shale contact and in the Tropic Shale in the quadrangle. At the contact, sandstone blocks of the Tibbet Canyon Member of the Straight Cliffs Formation have moved onto the underlying Tropic Shale. This process appears to be slow, but progressive, and is facilitated by the presence of perched ground water in the lower part of the Straight Cliffs Formation. Progressive landsliding has created a broad area of hummocky topography adjacent to many exposures of the lower Straight Cliffs. These hummocky areas tend to hold moisture that supports dense stands of scrub oak. Because seeps and hummocky areas are common at this contact, the potential for landsliding exists essentially wherever this contact is at, or near, the surface. Landslides are also present in the Brian Head and Claron Formations, and in the John Henry Member of the Straight Cliffs Formation. Hazards exist for structures that are built on and next to landslide deposits. Locally, other perched ground water in the thicker sandstone beds in the Straight Cliffs and Wahweap-Kaiparowits(?) Formations are indicated by boggy areas in the mudstone below; these areas should be considered in constructing roadways. For additional information on landsliding in the area, see Shroder (1971), Doelling and Davis (1989), and Harty (1991).

Much of the Tropic Shale contains expansive clays and is also subject to gulleying. The areas directly underlain by the Tropic are in the southwestern portion of the Alton quadrangle. Facilities and roads constructed on this shale should be designed and built to compensate for movement due to wetting and drying of these clays. Where streams flow on the Tropic Shale, steep-sided arroyos have been cut by erosion along main streams and lateral gullies. These arroyos cut deeply into the low areas between Kanab Creek and the flanking sandstone cliffs. Expansive clays are also present in other Cretaceous units and in the Brian Head Formation in the area and can be recognized by "popcorn" weathering surfaces. For additional information on expansive clays and gulleying in the area, see Doelling and Davis (1989) and Mulvey (1992).

The upper portion of the main drainages flowing westward from below the plateau rim and flowing southward into the Alton Amphitheater have channels bordered by coarse natural-levee deposits. This indicates that these valleys are subject to episodic flooding. For additional information on flooding in the area see Doelling and Davis (1989).

Sink Valley is a broad, low area where flowing (artesian) springs make a bog of much of the valley. The name is derived from stock animals sinking in the bogs (Goode, 1964). Avoid driving on the rich-green grassy areas below the sandstone cliffs flanking the valley, for vehicles can become hopelessly stuck in wet mud.

The physical beauty of the pink cliffs of the Claron Formation is related to their relatively rapid erosion. Any activity directly above, on, or below the bordering cliffs of the Paunsaugunt Plateau and Alton Amphitheater is at risk. Unpredictable rock falls warrant considerable caution for people, transportation, and construction on or below the cliffs, particularly the Claron cliffs.

Several faults are mapped in the Alton quadrangle. No indication of recent movement (surface rupture) of these faults was noted. Doelling and Davis (1989) reported that historical seismic activity has been recorded on the Sevier fault zone and nearby Kanab fault zone. Such earthquakes might cause landslides and rock falls in the quadrangle, and larger earthquakes along the Sevier fault zone might result in deformation (surface rupture) on this fault zone. Earthquakes could also affect areas of high ground water because earthquake shaking can cause water-saturated sandy and silty material to liquefy. Liquefaction can cause settlement and tilting of buildings and flow failure of slopes. Additional information on earthquake and volcanic hazards in the area is given in Anderson and Christenson (1989) and Hecker (1993).

SCENIC RESOURCES AND OUTSTANDING GEOLOGIC FEATURES

The Alton and Podunk Creek quadrangles display scenery similar to that of Bryce Canyon National Park. The western edge of the Paunsaugunt Plateau is bordered by abrupt cliffs of the pink and white Claron Formation. Some of these cliffs stand along the east margin of the Alton quadrangle, and several ridges of sandstone and shale trend westward down from the cliffs into the valley of Kanab Creek. Much of this area is managed by the U.S. Forest Service.

In the northwest portion of the Alton quadrangle are rugged hills developed in high country west of the Sevier fault zone. Nestled amidst this natural scene of cliffs, hills, and ridges, is the expanse of the Alton Amphitheater in which the small town of Alton is located.

The Alton quadrangle offers areas of relatively unspoiled nature in the Dixie National Forest that can be accessed by a limited system of unpaved roads. Roads access meadows within the wooded rolling country on top of the plateau. This is a fine area to camp, hike, and ride horseback in the summer and early autumn. For the adventurous, a clear view of the Sunset Cliffs and the Alton Amphitheater can be experienced from the head of Kanab Creek, just west of the plateau rim, and at Sand Pass, just north of the Alton quadrangle in the George Mtn. quadrangle. The view from Sand Pass is, by far, the most sublime I found in the southern Paunsaugunt Plateau.

The long ridges radiating out from the plateau are rarely visited. Some unmarked horse and foot trails in the lower country are on the map. These trails are seldom used and go through beautiful country of rocky canyons and across wooded ridges. The dry sandy saddles, common near the mid-length of the ridges, make excellent places to picnic and camp.

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APPENDIX

Stratigraphic Sections

Colors in the descriptions follow the nomenclature of the "Rock-color Chart" (Goddard and others, 1963) and the bedding classification generally follows that of McKee and Weir (1953).

1. GLENDALE SECTION. Measured up from base of prominent cliff at end of southeastward-trending spur on west side of Long Valley, northwest of Glendale, Utah, in the SE1/4SW1/4 section 14, T. 40 S., R. 7 W., Kane County, Utah (Glendale and Long Valley Junction quadrangles). Measurement was offset above unit 10 one-half mile north to ridge north of Madison Canyon, in NW1/4 same section; again offset above unit 29 three miles north to the northward-trending ridge north of the intersection of U.S. 89 and the road up Stout Canyon, in NW1/4 section 26, T. 39 S., R. 7 W.; and further offset above unit 76 one mile northeast to head of first canyon to the west going up Jump Up Canyon, in SW1/4 section 19, T. 39 S., R. 6 W. This relatively well-exposed complete Upper Cretaceous fluvial section is southwest of the Alton quadrangle. Measurement was by Jacob staff and tape by the author (Tilton, 1991).

Top of Section	Thickness (feet)
Claron Formation (incomplete):	
85. Limestone, moderate-red; massive	Unmeasured
84. Mudstone, moderate-red	50
83. Sandstone, light-bluish-gray, very fine- to medium-grained; much calcareous cement	9
82. Conglomerate, granule to pebble, mostly gray and black chert; top 1 ft mostly granules	6
81. Mudstone, medium-light-gray; includes a few thin sandstone beds	7
80. Conglomerate, pebble to cobble, mostly of tan, green, and black chert and white, pink, and purple quartzite, some calcareous pebbles; top 1 to 2 ft medium- to coarse-grained sandstone containing pebbles; possibly Canaan Peak Formation	7
Total measured Claron Formation	79
Wahweap Formation:	
"upper sandstone":	
79. Sandstone, same as unit 77; contains beds of medium to coarse grains with many dark grains; four lenticular mudstone beds (1-2 ft thick) at 10, 16, 190 and 220 ft above base; upper third contains several 1- to 2-ft-thick conglomerate lenses of small carbonate pebbles	290
78. Mudstone, medium-light-gray	5
77. Sandstone, grayish-orange to dark-yellowish-orange, very fine- to fine-grained; cross-bedded	50
Total "upper sandstone"	345

Note - Section above offset approximately one mile to the northeast, up first canyon to the west in Jump Up Canyon (SW1/4 section 19, T. 39 S., R. 6 W.). Probable error in unit placement is plus-or-minus 10 vertical feet in this offset. In 1991, a KOA Campground was located at the mouth of Jump Up Canyon.

"lower part":	
76. Mudstone, same as unit 40	32
75. Sandstone, same as unit 41	5
74. Mudstone, same as unit 40	22
73. Sandstone, same as unit 41	2
72. Mudstone, same as unit 40	5
71. Sandstone, same as unit 41	2
70. Mudstone, same as unit 40	10
69. Sandstone, same as unit 41; contains fossil bivalve and snail shells, and bone fragments in upper 2 ft	28
68. Mudstone, same as unit 40	7
67. Sandstone, same as unit 41; contains carbonized plant fragments	12
66. Mudstone, same as unit 40	3
65. Sandstone, same as unit 41; cross-bedded; includes some slumped bedding; contains mud-chip conglomerate lenses; weathers into spheroids up to 3 ft in diameter	26

64. Mudstone, same as unit 40 7
63. Sandstone, same as unit 41 4
62. Mudstone, same as unit 38 20
61. Sandstone, same as unit 41 12
60. Mudstone, same as unit 44; contains some thin (few inches) sandstone beds 40
59. Sandstone, same as unit 41 6
58. Mudstone, same as unit 44 9
57. Sandstone, same as unit 41 45
56. Mudstone, same as unit 40 4
55. Sandstone, same as unit 41; includes some slumped bedding 21
54. Mudstone, same as unit 44 12
53. Sandstone, same as unit 41 1
52. Mudstone, same as unit 40 2
51. Sandstone, same as unit 41 8
50. Mudstone, same as unit 40 5
49. Sandstone, same as unit 41 15
48. Mudstone, same as unit 40 13
47. Sandstone, same as unit 41; includes some slumped bedding 10
46. Mudstone, same as unit 40 15
45. Sandstone, same as unit 41; contains some mud-chip conglomerate lenses 7
44. Mudstone, medium-light-gray and grayish-red-purple 6
43. Sandstone, same as unit 41 1
42. Mudstone, medium-light-gray and pale-red-purple 9
41. Sandstone, grayish-orange, very fine- to fine-grained 5
40. Mudstone, medium-light-gray 3

Total "lower part" 434
Total Wahweap Formation 779

Note - Section offset approximately 3 miles to the north; NW1/4 section 26, T. 39 S., R. 7 W.; begins above light-gray conglomeratic sandstone north of intersection of U.S. Highway 89 and Stout Canyon road.

Straight Cliffs Formation:

Drip Tank Member:

39. Sandstone, grayish-orange, very fine- to fine-grained; cross bedded; contains scattered pebbles and pebble conglomerate lenses in 10 ft-thick zone 60 ft above base; upper 3 ft contains mud-chip conglomerate lenses; small ironstone concretions common throughout, some are fossil snail shells and wood fragments 80
38. Mudstone, medium-light-gray, pale-red-purple, and grayish red-purple 46
37. Sandstone, white to very light-gray, medium-gray; cross bedded; contains granules and pebbles scattered throughout, and pebble conglomerate lenses 72

Total Drip Tank Member 198

John Henry Member:

36. Mudstone, light-gray; contains two iron-oxide-cemented, resistant beds, 1 and 3 ft thick 14
35. Sandstone, same as unit 19; bedding is slumped near top 40
34. Mudstone, same as unit 12; contains small ironstone concretions 34
33. Sandstone, same as unit 19; contains a few thin, mud-chip conglomerate lenses 38
32. Mudstone, same as unit 12 7
31. Sandstone, same as unit 19 20
30. Mudstone, same as unit 12 14

Note - Section above offset approximately three miles north to the northward-trending ridge north of the intersection of U.S. 89 and the road up Stout Canyon, in NW1/4 section 26, T. 39 S., R. 7 W.

29. Sandstone, same as unit 19 35
28. Mudstone, same as unit 12 15
27. Sandstone, same as unit 19 13
26. Mudstone, same as unit 24 4
25. Sandstone, same as unit 19; includes some slumped bedding 48
24. Mudstone, medium-gray 20
23. Sandstone, same as unit 19 7
22. Mudstone, same as unit 12 10
21. Sandstone, same as unit 19 20
20. Mudstone, same as unit 12; contains a few thin beds (less than 1 ft thick) of very fine-grained sandstone 25
19. Sandstone, grayish-orange, very fine- to fine-grained; cross bedded 7
18. Mudstone, same as unit 12 8
17. Sandstone, same as unit 15 5

16. Mudstone, same as unit 12 11
15. Sandstone, pale-yellowish-brown, very fine- to fine-grained, with some thin beds that are medium-grained; cross-bedded 19
14. Mudstone, pale-red-purple 5
13. Sandstone, grayish-orange, very fine- to medium-grained, with some thin layers of coarse grains; cross-bedded; some finer grained beds ripple cross-laminated 61
12. Mudstone, medium-gray and pale-red-purple 6
11. Sandstone, grayish-orange, very fine- to medium-grained; cross-bedded; some ripple cross-lamination near top; contains seven thin (up to 0.5 ft thick) mudstone beds, medium-gray and pale-red-purple 44

Total John Henry Member 530

Note - Section above offset approximately $^1/_2$ mile to ridge north of Madison Canyon, NW$^1/_4$ section 14, T. 40 S., R. 7 W.

Smoky Hollow Member:

10. Sandstone, white to pale-yellowish-orange, very fine-grained to granule-sized; cross-bedded; contains lenses of chert and quartzite pebbles; some beds contain abundant iron oxide in bands; poorly resistant ["calico bed"?] 30
9. Mudstone, pale-red-purple 4
8. Sandstone, dark-yellowish-orange, very fine-grained to granule-sized; some thin beds of pebble conglomerate; abundant iron oxide in bands 2
7. Mudstone, medium-gray 2
6. Sandstone, grayish-orange to dark-yellowish-orange, very fine- to fine-grained 14
5. Mudstone, medium- to dark-gray 17
4. Sandstone and mudstone, interbedded (ratio about 1:1); sandstone, dark-yellow-gray, very fine-grained, fossil oyster shell fragments; mudstone, medium- to dark-gray with carbonaceous streaks in upper bed 20
3. Mudstone, carbonaceous 1
2. Mudstone, medium- to dark-gray 2

Total Smoky Hollow Member 92

Tibbet Canyon Member:

1. Sandstone, grayish-orange, weathers dark-yellowish-orange, very fine- to fine-grained; massive, forms conspicuous cliffs; laminated bedding with some cross-bedding in uppermost part; rare small chert pebbles; 1.5 ft thick medium-dark-gray mudstone bed 56 ft above base; 1 ft thick bed of fossil oyster shell fragments and medium- to coarse-grained sandstone 75 ft above base; 10 to 15 ft thick, coarse-grained sandstone bed 125 ft above base; abundant fossil oyster shells in top 6 ft 146

Total Tibbet Canyon Member 146

Total of four members of Straight Cliffs Formation 966

Tropic Shale:

Mudstone, medium-dark-gray; forms slope ....unmeasured

2. **KANAB CREEK SECTION.** Measured up from base of sandstone cliff at east side of mouth of Reservoir Canyon in the SE$^1/_4$NW$^1/_4$ section 33, T. 38 S., R. 5 W., approximately 4 miles northeast of Alton, Kane County, Utah (Alton quadrangle). Offset above unit to the north to end of north-trending ridge on east side of Reservoir Canyon, SE$^1/_4$SW$^1/_4$ section 28 (same T. and R.). Again offset above unit 14 to the north to ridge dividing the head of Reservoir Canyon, moving up from the NE$^1/_4$NW$^1/_4$ section 28 to the NE$^1/_4$NW$^1/_4$ section 21 (same T. and R.). Measurement further offset above unit 58 1.5 miles to the east, up and along ridge between Left Hand Canyon and the head of Kanab Creek, positioned in area of boundary between sections 22 and 23 (same T. and R.). Measurement was by Jacob staff and tape by the author (Tilton, 1991).

Top of Section **Thickness (feet)**

Wahweap and Kaiparowits(?) Formations, undivided (incomplete):

Top of ridge, unit eroded

80. Sandstone, very fine-grained 1
79. Mudstone, same as unit 77 20
78. Sandstone, grayish-orange, fine-grained; massive 5
77. Mudstone, light-gray and pale-red-purple 15
76. Sandstone, grayish-orange, fine- to medium-grained; regular-bedded 20
75. Mudstone, light-gray and pale-red-purple; contains four sandstone beds 1-2 ft thick 18
74. Sandstone, grayish-orange to moderate-yellowish-brown, fine-grained; massive; contains a few thin mudstone beds 20
73. Mudstone, same as unit 69 20
72. Sandstone, grayish-orange, very fine- to fine-grained 10
71. Mudstone, same as unit 69 6
70. Sandstone, very fine-grained 4
69. Mudstone, medium-gray and pale-red-purple to grayish-red purple; contains several thin sandstone beds 26
68. Sandstone, grayish-orange, fine-grained; cross-bedded and regular-bedded; contains thin beds and chips of mudstone 35
67. Mudstone, light- to dark-gray and grayish-red-purple; contains a few sandstone lenses less than one ft thick 65
66. Sandstone, grayish-orange in lower part and moderate yellowish-brown in upper part; very fine- to fine-grained; cross-bedded; massive; contains clastic blocks and chips, and a few lenses of light-gray mudstone with carbonaceous matter; much carbonized wood in lower part 100

65. Covered .45
64. Sandstone, pale-yellowish-brown, fine- to medium-grained; cross-bedded; appears to be a lens .20
63. Mudstone, medium-gray; contains a few sandstone lenses up to 1.5 ft thick .42
62. Sandstone, moderate-yellowish-brown, fine-grained; mostly regular-bedded with some cross-bedding (especially in basal part); contains beds with blocks and chips of light-gray mudstone near base; contains lenses of light- and dark-gray banded mudstone, up to 10 inches thick, throughout; beds appear to be a series of lenses; unit forms resistant cap on sandstone below .50
Total measured Wahweap and Kaiparowits(?) Formations, undivided .527

Straight Cliffs Formation:

Drip Tank Member:

61. Conglomeratic sandstone, white to light-gray; sequence of coarse quartz grains and pebble conglomerate lenses in cut and-fill channels in very fine- to fine-grained, "salt-and pepper" sandstone; cross-bedded; orange iron-oxide stain common .67
60. Sandstone, white to light-gray, very fine- to fine-grained, "salt-and-pepper"; cross-bedded; some orange iron-oxide stain in streaks; contains concretions and log casts .55
59. Mudstone, medium-gray and grayish-red (10R 5/2); with thin (0.3-0.5 ft thick) ironstone bed 8 ft above base .12

Note - Section above offset approximately 1.5 miles to the east, up and along ridge between Left Hand Canyon and the head of Kanab Creek, positioned in the area of boundary between sections 22 and 23, T. 38 S., R. 5 W.

58. Sandstone, grayish-orange, very fine- to fine-grained .39
57. Mudstone, medium-gray and grayish-red-purple .34
56. Sandstone, white, very fine- to fine-grained, "salt-and pepper"; generally weakly cemented with some resistant thin beds cemented with iron oxide . 18
Total Drip Tank Member .225

John Henry Member:

55. Ironstone, dark-yellowish-orange to dark-reddish-brown; resistant .1
54. Mudstone, medium-gray and pale-red (10R 6/2), weathers moderate-yellow-brown; forms slope .52
53. Sandstone, same as unit 45 .2
52. Mudstone, medium-dark-gray .3
51. Sandstone, same as unit 45 .3
50. Mudstone, medium-gray; weathers brown .6
49. Sandstone, same as unit 45 .1
48. Mudstone, medium-gray to pale-red (10R 6/2) .2
47. Sandstone, same as unit 45 .1
46. Mudstone, pale-red (10R 6/2) .2
45. Sandstone, grayish-orange, very fine- to fine-grained .3
44. Mudstone, medium-dark-gray .3
43. Sandstone, grayish-orange, very fine- to fine-grained; cross-bedded .50
42. Mudstone, medium-gray and grayish-red (10R 4/2) .10
41. Sandstone, grayish-orange, very fine- to fine-grained; cross-bedded with some ripple-drift lamination .22
40. Mudstone, medium-gray and pale-red (5R 6/2); contains 1-ft-thick sandstone bed 40 ft above base .52
39. Sandstone, grayish-orange, very fine- to fine-grained; massive; cross-bedded with some ripple-laminated beds; ironstone permineralized small twigs and wood fragments .22
38. Mudstone, medium-dark-gray .2
37. Sandstone, grayish-orange, very fine- to fine-grained .9
36. Mudstone, grayish-red (10R 4/2); contains two thin sandstone beds in lower part .23
35. Sandstone, grayish-orange, very fine- to fine-grained; cross-bedded; massive; contains petrified wood and log casts .24
34. Mudstone, medium-gray and pale-red (5R 6/2); forms slope .16
33. Sandstone, grayish-orange, very fine- to fine-grained; cross-bedded with some contorted beds near top .22
32. Mudstone, medium-gray and pale-red (5R 6/2); four sandstone beds from 0.5 to 2 ft thick in lower half .40
31. Sandstone, grayish-orange, fine- to medium-grained; cross-bedded with poorly developed ripple-lamination near top; small rounded light-gray mudstone chips in lenses .31
30. Mudstone, medium-gray and pale-red (5R 6/2) .13
29. Sandstone, grayish-orange, fine- to medium-grained; with 4- to 5-ft-thick zone of coarser sand and small pebbles 28 ft above base; cross-bedded; forms slope .43
28. Mudstone, medium-dark-gray .4
27. Sandstone, grayish-orange, fine- to medium-grained; cross-bedded; some iron-oxide staining; mostly slope; commonly weathers into spheroids about 2 ft in diameter .31
26. Mudstone, grayish-red; slope .3
25. Sandstone, grayish-orange, fine- to medium-grained; cross-bedded; some iron-oxide stain in streaks; mostly slope .18
24. Mudstone, medium-gray .1
23. Sandstone, grayish-orange, very fine- to fine-grained; some angiosperm leaf imprints .5
22. Mudstone, medium-dark-gray .7
21. Sandstone, grayish-orange, very fine- to fine-grained; cross-bedded; slope; some mudstone in float .47
20. Mudstone, grayish-red and medium-dark-gray .10
19. Sandstone, grayish-orange, very fine- to fine-grained; contains two 0.5-ft-thick, medium-gray mudstone beds .5

18. Sandstone, grayish-orange, very fine- to fine-grained; cross bedded; contorted bedding in upper 5 ft ... 19
17. Mudstone, pale-red-purple to grayish-purple; slope ... 4
16. Sandstone, grayish-orange, very fine- to fine-grained; coarser grains and granules of quartz, small pebbles of chert, and carbonized wood fragments in basal channels; cross-bedded; angiosperm leaf imprints ... 52
15. Mudstone, dark-gray; 2-inch-thick ironstone-indurated bed near middle ... 4

Total John Henry Member ... 668

Note - Section above offset to the north to ridge dividing the head of Reservoir Canyon, moving up from the NE1/4NW1/4 section 28 to the NE1/4NW1/4 section 21, T. 38 S., R. 5 W.

Smoky Hollow Member:

14. Sandstone, white to grayish-orange, mostly very fine- to medium-grained; coarse grains and granules of quartz, and pebbles up to 3 inches long of tan and black chert in lenses; cross-bedded; some orange iron-oxide cement and staining associated with coarser grained portions ["calico bed"?] ... 70
13. Mudstone, dark-gray ... 3
12. Sandstone, white, mostly very fine- to fine-grained, some medium-grained; common granules of quartz and small pebbles of chert and quartzite in zones; slope ... 28
11. Mudstone, medium-dark-gray; slope ... 5
10. Sandstone, grayish-orange, very fine- to fine-grained; mostly slope ... 17
9. Mudstone, medium-gray ... 2
8. Sandstone, grayish-orange, very fine-grained ... 1
7. Mudstone, medium- to dark-gray ... 1
6. Shale, carbonaceous, grayish-brown to dark-gray ... 2
5. Shale, carbonaceous, black; grades to low-grade coal in part ... 2
4. Shale, grayish-brown and grayish-red-purple; abundant carbonized plant debris and fossil shells of small fresh-water bivalves and snails ... 1

Total Smoky Hollow Member ... 132

Note - Section above offset to the north to end of north-trending ridge on east side of Reservoir Canyon, SE1/4SW1/4 section 28, T. 38 S., R. 5 W.

Tibbet Canyon Member:

3. Sandstone, grayish-yellow to grayish-orange, very fine- to fine-grained, with some thin lenses containing abundant medium grains; moderately to well-sorted; regular-bedded with cross-bedding in top 20 to 25 ft; massive, forms conspicuous cliff; fossil oyster shells and shell fragments present from 95 ft above base to top of unit, become most abundant in top 35 ft where shell material is commonly associated with coarse quartz grains in 1- to 3-ft-thick lenses ... 158
2. Mudstone, dark-gray ... 1
1. Sandstone, grayish-orange, fine-grained ... 2

Total Tibbet Canyon Member ... 161

Total of four members of Straight Cliffs Formation ... 1186

Tropic Shale:

Mudstone, medium-dark-gray; forms slope ... unmeasured

3. **WATER CANYON SECTION.** Measured up from base of sandstone cliff at south side of mouth of Water Canyon, SW1/4NE1/4 section 16, T. 39 S., R. 5 W., approximately 3.5 map miles east-southeast of Alton, Kane County, Utah (Alton quadrangle). Measurement was by Jacob staff and tape by the author (Tilton, 1991).

Top of Section — **Thickness (feet)**

Straight Cliffs Formation:

Smoky Hollow Member:

7. Sandstone, fine-grained with some medium and coarse grains, abundant granules of quartz; small pebbles of chert and quartzite in lower part ... 75
6. Mudstone, medium-light- to medium-gray ... 22
5. Sandstone ... 25
4. Mudstone, carbonaceous, gypsum crystals; upper 10 feet in slope ... 14

Total Smoky Hollow Member ... 136

Tibbet Canyon Member:

3. Sandstone, fossil oyster shell fragments ... 13
2. Mudstone, carbonaceous ... 8
1. Sandstone ... 99

Total Tibbet Canyon Member ... 120

Total of two lower members of Straight Cliffs Formation ... 256

Tropic Shale:

Mudstone ... unmeasured

4. **THOMPSON CREEK CANYON SECTION.** Measured up north-trending ridge northeast of spring in the NW1/4SE1/4 section 26, T. 39 S., R. 5 W. (approximately 6 map miles southeast of Alton), Kane County, Utah (Alton quadrangle). Offset above unit 2 to the

north one-eighth mile. Measurement continued from there to the base of Pink Cliffs in the SW1/4SE1/4 section 23 (same T. and R.). Measurement was by Jacob staff and tape by the author (Tilton, 1991).

Top of Section	**Thickness (feet)**
Canaan Peak Formation:	
26. Conglomerate, up to cobble size in matrix of "salt-and pepper" sandstone; well-cemented with calcite; fills channels in the underlying undivided Wahweap-Kaiparowits(?) unit	unmeasured
Wahweap and Kaiparowits(?) Formations, undivided:	
"upper sandstone":	
25. Sandstone, grayish-orange, very fine- to fine-grained; cross-bedded; contains abundant molds of bivalve and snail shells in several beds; chert pebbles common and abundant rounded mudstone clasts in upper part	105
24. Mudstone, medium-gray	2
23. Sandstone, grayish-orange, very fine- to fine-grained; cross-bedded	10
22. Mudstone, medium-gray	3
21. Sandstone, grayish-orange, very fine- to fine-grained; cross-bedded; molds of bivalves and snail shells near base; mostly slope	15
Total "upper sandstone"	135
"lower part":	
20. Mudstone, grayish-red-purple, some medium-light-gray near middle; some thin sandstone beds	20
19. Sandstone, same as unit 17; forms cliff	9
18. Mudstone, grayish-red-purple; forms slope	7
17. Sandstone, grayish-orange, very fine- to fine-grained; cross-bedded; contains ironstone-lined molds of what appear to have been tree branches and roots	39
16. Mudstone, medium-gray; contains a few thin sandstone beds	5
15. Sandstone, same as unit 7; friable; contains rounded small mudstone clasts in two beds 2 to 3 ft thick in upper third of unit	63
14. Mudstone, medium-light-gray and some grayish-red-purple; contains a few sandstone beds 1 ft thick or less	45
13. Sandstone, same as unit 7; fossil fresh-water snail shells near base; concretions less than 1 ft in diameter weather out on surface	38
12. Mudstone, medium-light-gray, grayish-red-purple in lower and upper parts; a few thin sandstone beds	38
11. Sandstone, same as unit 7; forms slope	35
10. Mudstone, medium-light-gray	2
9. Sandstone, grayish-orange, very fine- to fine-grained; contains rounded mudstone clasts in 1-inch-thick beds and ironstone-lined small pieces of wood	12
8. Mudstone, medium-light-gray and grayish-red-purple; thin sandstone beds common in lower 30 ft and less common in remainder of unit	7
7. Sandstone, grayish-orange, very fine- to fine-grained; cross-bedded	6
6. Mudstone, grayish-red-purple and some medium-gray, weathers brown; contains several sandstone beds	52
5. Sandstone, same as unit 7; contains contorted beds	21
4. Sandstone and mudstone, interbedded in 1- to 2-ft-thick beds (ratio about 1:1); sandstone same as unit 7; mudstone, light medium-gray and grayish-red-purple; unit forms slope	18
3. Mudstone, grayish-red-purple, weathers light-gray; 1-ft-thick sandstone bed 22 ft above base; 2-ft-thick sandstone bed near top	35
Total "lower part"	452
Total Wahweap and Kaiparowits(?) Formations, undivided	587

Note - Section above offset to the north approximately one-eighth mile.

Straight Cliffs Formation:	
Drip Tank Member:	
2. Sandstone, grayish-orange, weathers white to light-gray, very fine- to fine-grained; cross-bedded; massive; friable	190
Total Drip Tank Member	190
John Henry Member:	
1. Mudstone, medium-gray; contains less than 1-ft-thick bed of dark-reddish-brown ironstone 5 ft below top; forms slope	unmeasured

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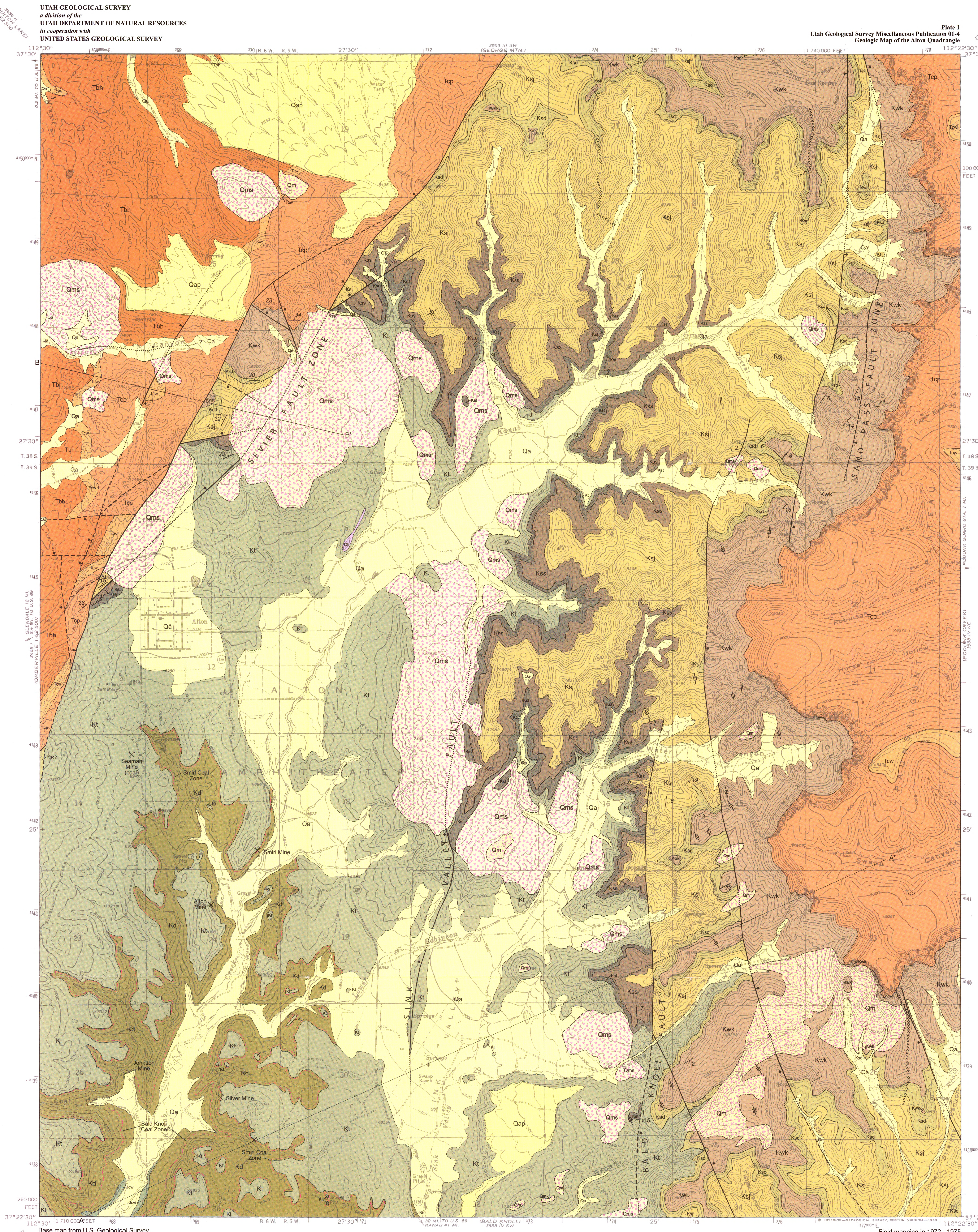


Base map from U.S. Geological Survey
Alton 7.5' Quadrangle, 1966

The Miscellaneous Publication Maps provide an outlet for authors who are not Utah Geological Survey staff. Not all aspects of this publication may conform to UGS style and content standards.

12°49'
230 mils

2001 MAGNETIC DECLINATION AT CENTER OF SHEET

SCALE 1 : 24,000

1 1/2 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

UTAH
QUADRANGLE LOCATION

Field mapping in 1972 - 1975, 1989 and 1992 by author
Additional mapping by E. G. Sable
Lori J. Douglas, Cartographer

GEOLOGIC MAP OF THE ALTON QUADRANGLE, KANE COUNTY, UTAH

by

Terry L. Tilton
(with mapping by E. G. Sable)

2001

UTAH GEOLOGICAL SURVEY
a division of the
UTAH DEPARTMENT OF NATURAL RESOURCES
in cooperation with
UNITED STATES GEOLOGICAL SURVEY

Description of Map Units

Qa Alluvium - *Includes stream and fan alluvium, and terrace deposits of unconsolidated clay, silt, sand, and gravel in and near existing drainages. Adjacent to the plateau these deposits are predominantly sand and gravel. Away from the plateau these deposits are mostly mud where streams cut the Tropic Shale. Thin cover to about 10 feet (3 m) thick.*

Qms Landslide deposits - *Unconsolidated hummocky deposits of mud and sand, commonly containing large blocks of sandstone. The bulk of the material is from the Straight Cliffs Formation covering areas underlain by Tropic Shale. Thin cover to about 100 feet (30 m) thick.*

Qm Mass-wasting debris - *Predominantly resistant white and pink limestone from the Claron Formation and cobbly gravel from the Canaan Peak Formation. Thin cover to about 10 feet (3 m) thick.*

Qap Pediment alluvium - *Poorly sorted silt, sand, and gravel (up to large cobbles) on broad surfaces above present drainages. Formed by deposition from flowing water in the past; surfaces now abandoned. Thin cover to about 10 feet (3 m) thick.*

Qb Basalt - *Dike of dense, black, fine-grained, porphyritic, olivine basalt. Exposure displays rough columnar jointing and xenoliths. Up to 100 feet (30 m) wide.*

Tbh Brian Head Formation (revised) - *Interbedded, continental, non-resistant, mostly gray sandstone, siltstone, mudstone, calcarenite, and limy mudstone. Only present in and northwest of the Sevier fault zone. Equivalent to the uppermost variegated sandstone member of the Claron Formation of Tilton (1991). About 200 feet (60 m) thick.*

Tcw White member of Claron Formation - *Massive, white to light-gray limestone, with some local thin interbeds of gray mudstone. Forms conspicuous cap on higher hills on top of plateau. About 200 feet (60 m) thick.*

Tcp Pink member of the Claron Formation - *Interbedded cliff-forming sequence of dense pink limestone, and minor limy mudstone and calcarenite. Includes conglomerates of the Canaan Peak Formation locally at the base, up to 30 feet (9 m) thick. About 600 feet (180 m) thick.*

Kwk Wahweap and Kaiparowits(?) Formations, undivided - *Upper part is orangish-gray, in part salt-and-pepper gray, fine-grained, sandstone, with some thin lenticular beds of granules and small chert pebbles. Lower part is alternating yellowish-gray and yellowish-brown, fine-grained sandstone and gray and grayish-red-purple mudstone beds at a 1:1 ratio. Unconformity on top. About 600 to 800 feet (180-240 m) thick.*

Ksd Drip Tank Member of the Straight Cliffs Formation - *Massive, white to light-gray sandstone. Upper two-thirds contains prominent conglomerate beds of granular quartz and pebbles of gray chert. Casts of logs are locally common. 185 to 215 feet (55-65 m) thick.*

Ksj John Henry Member of the Straight Cliffs Formation - *Alternating grayish-orange, very fine- to fine-grained, cross-bedded sandstone, and gray and pale-red-purple mudstone at a 2:1 ratio. About 670 feet (205 m) thick.*

Kss Smoky Hollow Member of the Straight Cliffs Formation - *Upper part is a distinctive, white to grayish-orange sandstone containing quartz granules and chert and quartzite pebbles ("calico bed"). Middle part is orangish-gray fine-grained sandstone and gray mudstone. Lower part is gray mudstone, with thin, persistent carbonaceous shale in base. Unconformity between middle and upper parts. About 135 feet (40 m) thick.*

Kst Tibbet Canyon Member of Straight Cliffs Formation - *Prominent, orangish-gray, massive, cliff-forming sandstone. Upper part is cross-bedded and contains abundant oyster shells. 120 to 160 feet (35-50 m) thick.*

Kt Tropic Shale - *Medium-brownish-gray to gray, very thin-bedded, non-resistant, silty shale; thin interbeds of fine-grained silty sandstone in upper part from interfingering with overlying unit. Base is commonly baked by burning of coal in the underlying Dakota Formation. About 700 feet (210 m) thick.*

Kd Dakota Formation - *Alternating fluvial gray mudstone and sandstone, with beds of coal, conglomerate, and bentonite. About 275 feet (85 m) thick.*

Jcw Winsor Member of the Carmel Formation -- *Light-yellow, fine-grained, cross-bedded sandstone. Unconformity on top. About upper 50 feet (15 m) exposed.*

Map Symbols

Contact - *dashed where approximately located*

Normal Fault - *dashed where approximately located or inferred; dotted where concealed; ball and bar on down-thrown side; X marks the point of reversal of offset on scissor(?) faults; arrows on cross section show offset*

6 Strike and dip of bedding

Strike of vertical joint

Horizontal joint

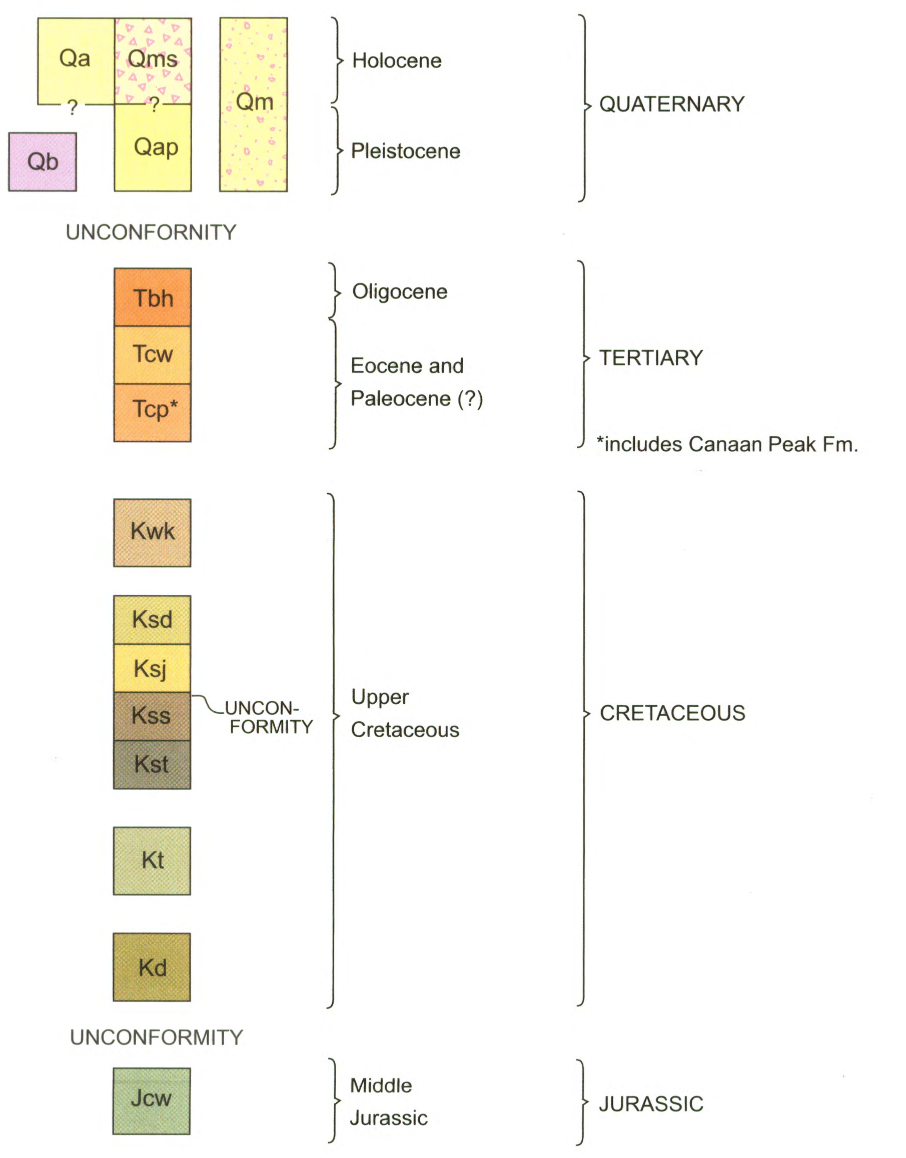
A — A' Line of cross section

Coal zone - approximately located

Coal mine or prospect

Approximate line of measured section (appendix)

Correlation of Map Units



Lithologic Column

SYSTEM	FORMATION	MEMBER	SYMBOL	THICKNESS feet	LITHOLOGY
TERTIARY	Brian Head Fm. (revised)		Tbh	~200	
	Claron Formation	White	Tcw	~200	unconformity
		Pink	Tcp	~600	
	Canaan Peak Fm.			0-30	unconformity
CRETACEOUS	Wahweap and Kaiparowits(?) Formations, undivided		Kwk	~600-~800	
	Straight Cliffs Formation	Drip Tank	Ksd	~205	
		John Henry	Ksj	~670	unconformity(?)
		Smoky Hollow	Kss	135	unconformity
		Tibbet Canyon	Kst	~140	
	Tropic Shale			~700	Smirl coal zone
	Dakota Fm.		Kd	275	Bald Knoll coal zone
JURASSIC	Carmel Formation	Winsor	Jcw	+50	unconformity