GEOLOGIC MAP OF THE PODUNK CREEK QUADRANGLE, KANE COUNTY, UTAH

by

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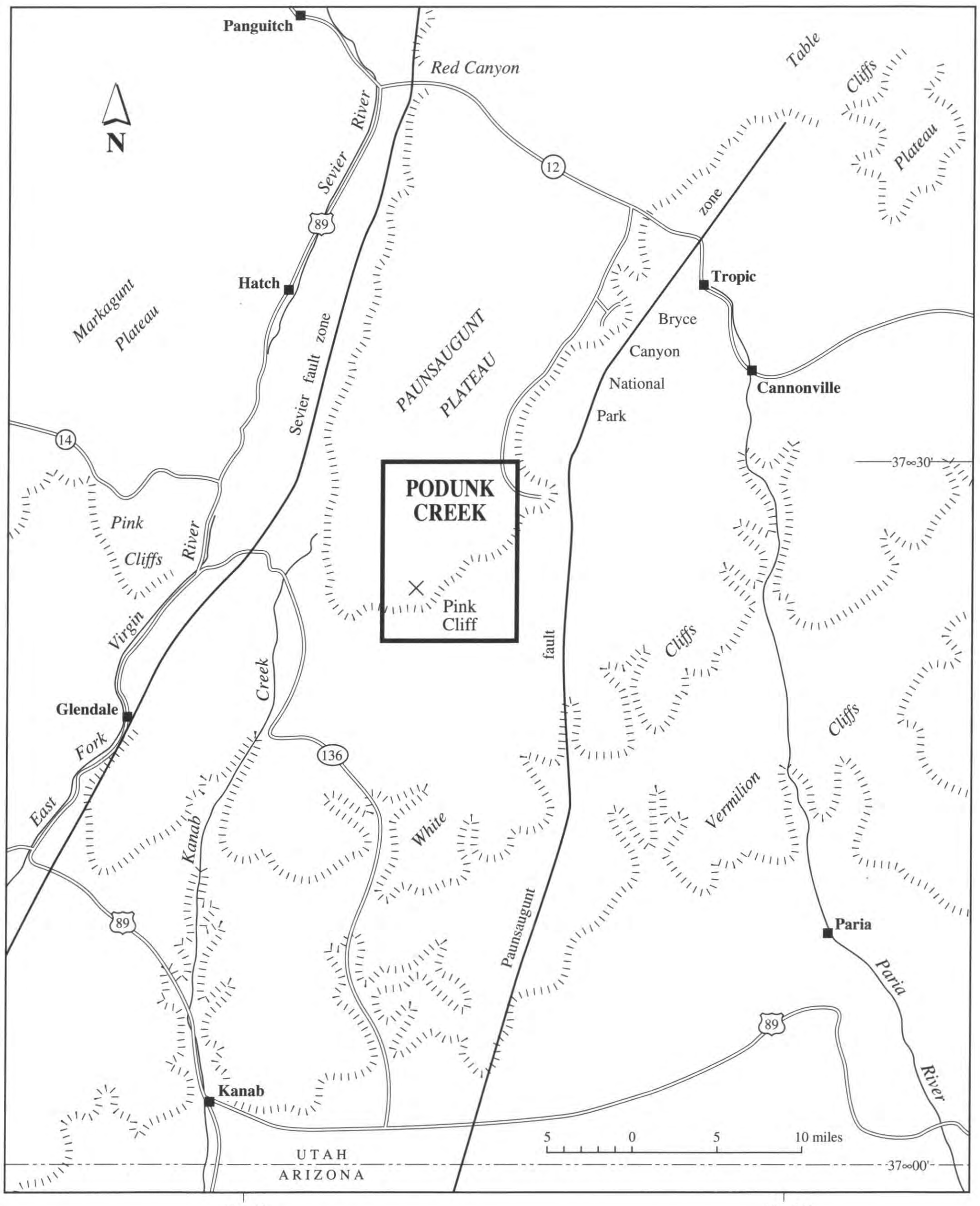

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ABSTRACT

The Podunk Creek quadrangle is located in north-central Kane County, covers the southeastern part of the Paunsaugunt Plateau, and includes a part of Bryce Canyon National Park. The approximately 2,700-foot-thick (825 m) section of exposed sedimentary rocks in the quadrangle ranges in age from Late Cretaceous to Eocene. Quaternary alluvium, mass-movement debris, pediment alluvium, and landslides cover these rocks. Volcanic flow and dike basalts of Quaternary age are present in the south-central part of the quadrangle.

The Paunsaugunt Plateau is capped by the Tertiary Claron Formation. The Claron forms prominent pink and white ridges and cliffs that border the plateau rim. The thin and discontinuous Cretaceous and Paleocene Canaan Peak Formation, locally present between the Claron and underlying Cretaceous strata, is mapped with the Claron. From the plateau, long ridges of Upper Cretaceous clastic rocks of the Kaiparowits(?), Wahweap, and Straight Cliffs Formations descend southward to valleys on the underlying poorly resistant Tropic Shale.

Strata in the quadrangle are inclined slightly to the north and north-northeast, with dips generally from 1 to 5 degrees. Two major unconformities are present within the Upper Cretaceous strata: one 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 the other at the top of the 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 second unconformity. Local near-vertical faults offset the Upper Cretaceous rocks below the plateau, but do not appear to cut the overlying Paleocene(?) and Eocene Claron Formation. However, the low-angle northward tilting affects both the Upper Cretaceous rocks and the Claron Formation.

Several geologic hazards, mostly mass-movement hazards, are present in the quadrangle, but the lack of development limits risks. Development is hampered by limited water resources. Coal beds are present in subsurface, but can not be mined economically under current market conditions.

INTRODUCTION

The Podunk Creek quadrangle covers the southeastern part of the Paunsaugunt Plateau (figure 1), meaning "Land of the Beavers" plateau in Ute. Elevations range from 6,700 feet (2,045 m) to almost 9,400 feet (2,870 m) above sea level. The southwest part of Bryce Canyon National Park is in the northeast part of the quadrangle.

The plateau 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 broad grassy stream valleys. Around the margins of the plateau are barren, abrupt, high, near-vertical, nearly continuous cliffs of the Claron displaying spectacular weathered monuments.

Radiating outwards from below the plateau cliffs, ridges of Upper Cretaceous sandstone and mudstone descend gradually as cliffs and slopes (figure 2). The country is moderately vegetated, with ponderosa pine high on the ridges giving way successively downwards to pinyon pine, juniper, and Gambel oak, and finally to sagebrush and rabbitbrush.

To the east of the Paunsaugunt Plateau are the major north-south-trending Paunsaugunt fault zone and the broad valley known as the Paria Amphitheater. This amphitheater heads to the north in the Table Cliffs Plateau and is flanked on the east by the Kaiparowits Plateau. To the west lies the Markagunt Plateau, separated from the Paunsaugunt Plateau by the major north-northeast-trending Sevier fault zone and the valleys of the Virgin and West Fork of the Sevier Rivers.

Although remote, with no permanent residents, the top of the plateau in the Podunk Creek quadrangle has an extensive system of unpaved fair-weather roads. All of these roads originate to the north at the only primary road crossing the Paunsaugunt Plateau, Utah Highway 12. What few primitive roads exist in the country below the plateau rim originate to the south and most, before reaching deep into the canyons, turn into rough tracks. Locked gates on these roads are the rule. Two roads in the quadrangle connect the top of the plateau with the lower region to the south; both of them pass through Meadow Canyon.

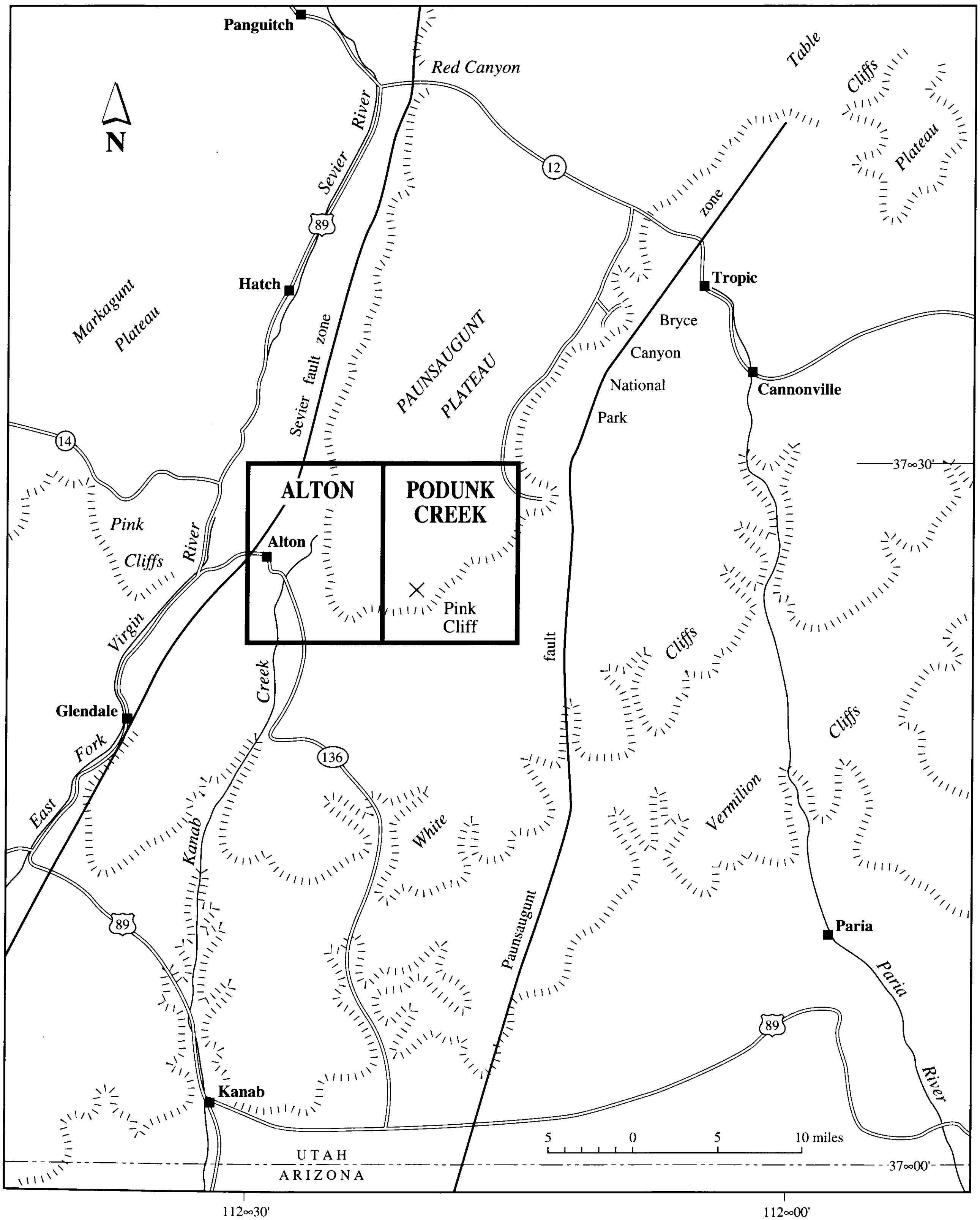

Figure 1. *Index map of the Paunsaugunt Plateau region, showing the Podunk Creek and Alton quadrangles. The highest point in the quadrangle (Pink Cliff) is indicated. The quadrangles were mapped together. The map is adapted from Gregory (1951, p. 3).*

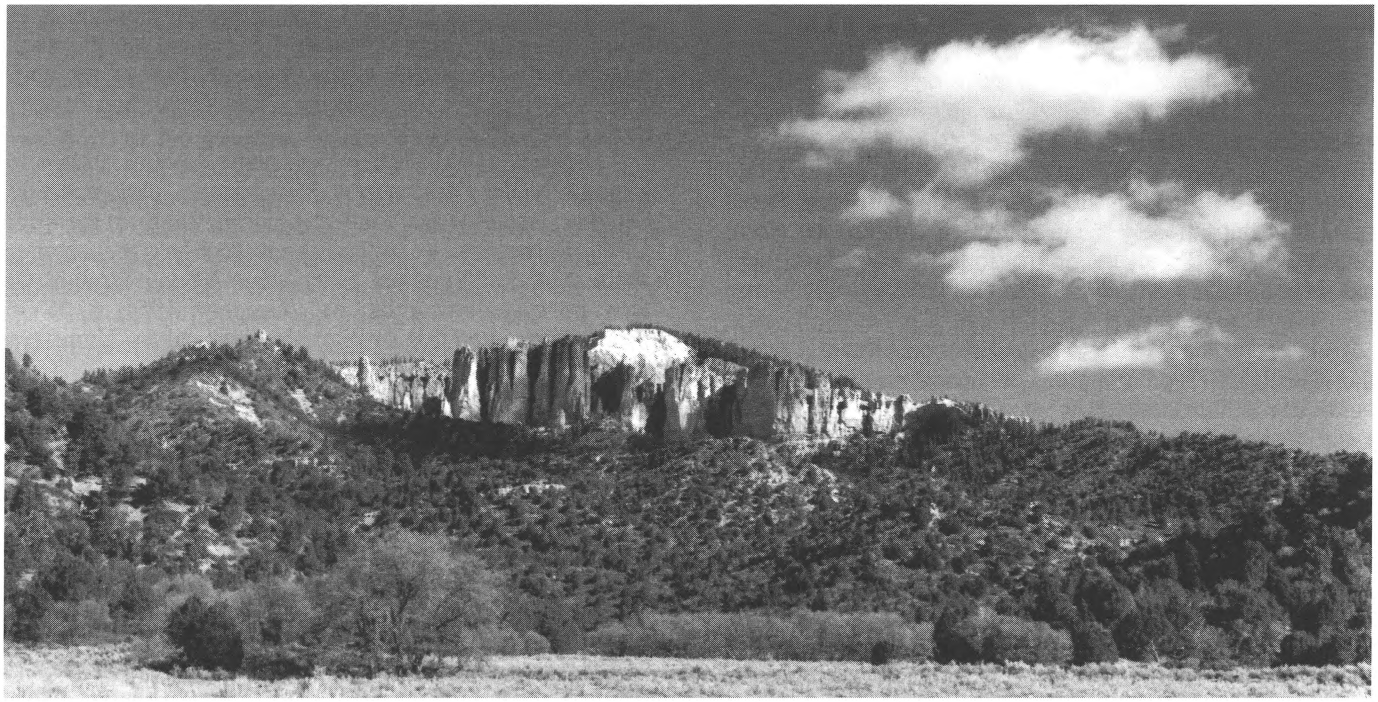

Figure 2. *South flank of the Paunsaugunt Plateau looking north up Tenny Canyon to Pink Cliff. The first known photograph of the Paunsaugunt Plateau in the literature (Dutton, 1880) is essentially of the same scene. In the left center, below the skyline, is an outlier of Claron Formation. Tenny Canyon provides the best exposed and most accessible Upper Cretaceous section in the study area. Measured sections from this canyon are in the appendix, Tilton (1991), and Gregory (1951, p. 62-65).*

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 to the east 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 southwest and south, respectively, of the Podunk Creek quadrangle. I mapped the geology of the Alton quadrangle to the west and that of the Podunk Creek quadrangle concurrently (Tilton, 1991, 2001). Bowers (1991) mapped the geology of Bryce Canyon National Park, which includes part of the Podunk Creek quadrangle. The southern portion of the Podunk Creek quadrangle was geologically mapped at a smaller scale by Doelling (1972). The Podunk Creek quadrangle is shown on 1:100,000-scale geologic maps of Kane County (Doelling and Davis, 1989) and on the Kanab 30 x 60-minute quadrangle (Sable and Hereford, 1990). Most of the fieldwork for my dissertation (Tilton, 1991) was performed between 1972 and 1975, with additional fieldwork in 1989 for my dissertation, and in 1992 for this report.

STRATIGRAPHY

Exposed sedimentary rocks in the Podunk Creek quadrangle are Late Cretaceous to Eocene in age and are approximately 2,700 feet (825 m) thick. Prominent volcanic rocks of Quaternary age exist in the south-central part of the quadrangle. Quaternary alluvium, mass-wasting debris, pediment alluvium, and landslides make up the surficial deposits in the quadrangle. Two major unconformities are present in Upper Cretaceous strata: one in the Smoky Hollow Member of the Straight Cliffs Formation, about 1,500 feet (460 m) below the top of Upper Cretaceous strata; and the other at the top of the undivided Wahweap and Kaiparowits(?) Formations.

Upper Cretaceous

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 on the southern margin of the Paunsaugunt Plateau, but only the upper Tropic is exposed in the quadrangle. The Tropic tends to erode into gentle slopes, broad flats, and deeply dissected stream valleys and tributary gullies.

In outcrop, mostly in the southeast corner of the quadrangle, the upper Tropic is a poorly exposed, medium-brownish-gray to medium-dark-gray, very thin-bedded, silty shale. The top of the unit interfingers with basal sandstones in 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 to 3 feet [0.6-0.9 m]) sandstone bed in the Tibbet Canyon. This contact is commonly covered by 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 study were established by Lawrence (1965) and are the same as those mapped by Goode (1973a, 1973b) in the Bald Knoll and Skutumpah quadrangles, and by Tilton (1991, 2001) in the adjoining Alton quadrangle. On the earlier map of Gregory (1951) the boundaries were inconsistently placed.

Fossil ammonite, oyster, and gastropod shells are common locally, whereas vertebrate material is rare in the Tropic. 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). Intertonguing mudstone and basal sandstone of the Tropic Shale and Tibbet Canyon Member of the Straight Cliffs Formation, respectively, mark the initial sand influx onto offshore marine facies. In the Podunk Creek quadrangle, a relatively thick transitional sequence of increasingly sandy beds is interlayered with the mudstone in the uppermost Tropic Shale.

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).

The Straight Cliffs Formation forms the lower half of the ridges radiating out from the southern Paunsaugunt Plateau. This unit is about 1,100 feet (335 m) thick in the area mapped, about the same thickness as reported for the type locality. 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 Podunk Creek quadrangle.

Gregory (1951), after measuring several stratigraphic sections in the Paunsaugunt Plateau area, indicated that he could not separate the Wahweap Formation from the Straight Cliffs 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), working on the Kaiparowits Plateau, divided the sandstone, mudstone, and coal of the Straight Cliffs Formation 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 Doelling (1972) and Doelling and Davis (1989) of the Alton and Podunk Creek quadrangles, and by Cashion (1961, 1967) to the west and by Goode (1973a, 1973b) to the south and southwest of the Podunk Creek quadrangle 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 gray-weathering gentle 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, 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 Podunk Creek quadrangle it is about 100 to 125 feet (30-40 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 and shell fragments associated with coarse quartz grains, in beds one foot (0.3 m) or more thick. Locally the elongated fossil shells of the oyster *Crassostrea soleniscus* are found upright in life position in the upper few feet (<1 m); look for them on top of the cliffs on the west side of the entrance to Tenny Canyon.

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. The contact is placed where the highest sandstone of the Tibbet Canyon is overlain by mudstone of the basal Smoky Hollow Member. A thin carbonaceous shale in the basal Smoky Hollow is persistent throughout the area. Where stacking of sandstone has resulted in more than one carbonaceous shale layer in the sequence, the contact is drawn at the top of the uppermost sandstone typical of the Tibbet Canyon. 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 the top of the Tibbet Canyon.

The sediments of this member were 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. They represent beach and bar sand deposits and possibly coastal dunes. 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).

In the south-central part of the Podunk Creek quadrangle in the upper Tibbet Canyon, stacked sandstone sheets 10 to 15 feet (3-5 m) thick (foreshore deposits, "beaches") separated by four carbonaceous shale layers (backbeach deposits, "swampy lagoons") were deposited as the sea left and returned in minor transgressions. 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 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. 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 125 to 140 feet (40-45 m) thick in the Podunk Creek 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 southern Paunsaugunt Plateau. 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. This unit is predominantly 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 chert and gray and reddish-brown quartzite, and a few beds of gray mudstone.

The upper contact of the Smoky Hollow Member is placed at the top of the calico bed, where it is overlain by gray mudstone, or darker and more resistant, mostly nonconglomeratic sandstone of the overlying John Henry Member. The contact between the middle two members is the most difficult to locate in the Straight Cliffs Formation in most of the Paunsaugunt Plateau, because it is hidden by slope wash and vegetation.

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 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).

Peterson (1969b) reported that the Smoky Hollow-John Henry contact corresponded 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 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.

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 to the northeast to east-northeast (Tilton, 1991). Large, elongate, horizontally positioned, external molds of tree trunks and limbs are common in some horizons.

John Henry Member (Ksj): The John Henry Member in the southern Paunsaugunt Plateau 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 550 to 650 feet (170-200 m) thick in the 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 this quadrangle. However, in the section measured at Tenny Creek (appendix), finely disseminated carbonaceous material was evident in the sandstone up to 136 feet (41 m) above the base, and a thin bed of carbonaceous material exists 40 feet (12 m) above the base.

Subdivisions of the John Henry Member 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 Podunk Creek quadrangle, neither marker beds nor stratigraphic breaks were found in this member. Locally, medium- and coarse-grained sandstone occurs in the Tenny Creek section in the lower 40 feet (12 m); the remaining sandstones are very fine- to fine-grained.

On outcrop in the 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 (for example gar teeth); 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 southern Paunsaugunt Plateau and are most common in the base of thick sandstone beds. A cursory examination of some specimens of the John Henry flora showed 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 inches [5-15 cm] thick) 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 sandstones. 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 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 high on the ridges that radiate from the Paunsaugunt 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 pine. 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 quadrangle. The total thickness of the Drip Tank in the Podunk Creek quadrangle is about 150 to 180 feet (45-55 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 of dark-gray, silicified limestone; red, silicified, fossil horn coral; gray, fossil glass sponge; gray, indurated conglomerate; and aphanitic igneous rock (figure 3). 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. 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 member.

At the exposed basal contact of the Drip Tank, or up to a few feet (<1 m) below it, a hard, dark-reddish-brown to brown, thin, but areally persistent, clay-ironstone bed is present. This appears to have formed from the percolation of ground water through the permeable Drip Tank sandstone into the relatively impermeable underlying John Henry mudstone. Iron, probably derived from the weathering of iron-containing minerals in the sandstone, was later precipitated as siderite in the clay below.

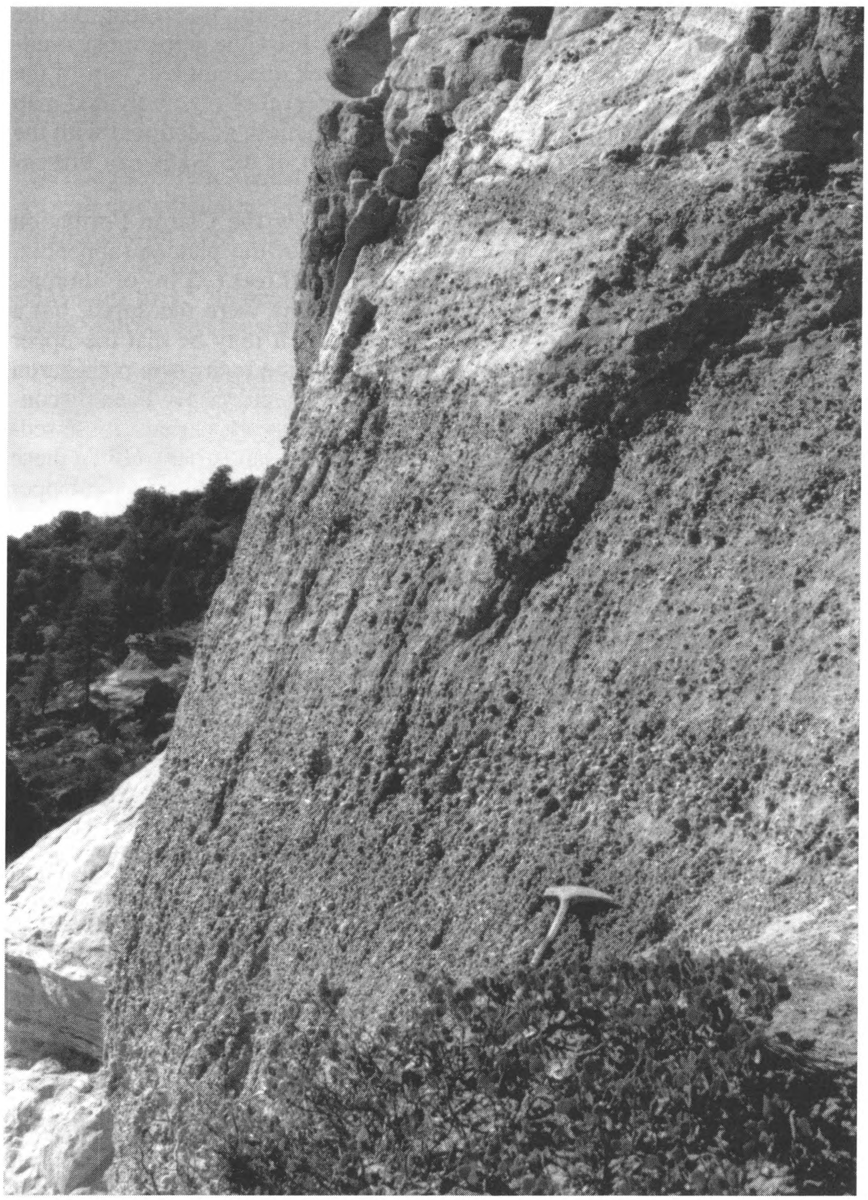

Figure 3. *Drip Tank Member at the head of Tenny Canyon. This moderately resistant sandstone locally forms prominent cliffs. Here a pebble conglomerate in the upper part is displayed. Note rock hammer for scale.*

The upper contact with the undivided Wahweap and Kaiparowits(?) unit is conformable and is placed at the top of the distinctive, light-gray sandstone in 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 Member is 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. This is because of its location in the stratigraphic column (near the mid-point in the Upper Cretaceous strata above the Tropic), its 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. 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 alluvial 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. The Wahweap and Kaiparowits Formations have been little studied relative to other Upper Cretaceous units of the southern Colorado Plateau, and different names have been used for these rocks in the study area. Therefore, the Wahweap and what may be the Kaiparowits Formation were mapped as an undivided unit in the Podunk Creek quadrangle.

In the quadrangle, this undivided unit consists of mostly brush-covered slopes of poorly resistant mudstone and moderately resistant sandstone. The only readily accessible outcrops of the Wahweap-Kaiparowits(?) in the Podunk Creek quadrangle are along the roads on the Paunsaugunt Plateau. These exposures are only of the uppermost part of the unit and are generally covered.

The Wahweap-Kaiparowits(?) unit is about 600 to 750 feet (180-230 m) thick in the Podunk Creek quadrangle. The lower part of the unit 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 mudstones 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 (10-12 m) for 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. Bivalves of the genus "*Unio*" (up to 4 inches [10 cm] long) and gastropods of the genera *Viviparus*, *Campeloma*, and *Physa* are tentatively identified from internal and external molds in sandstone.

In the upper part of the Wahweap-Kaiparowits(?) unit in the quadrangle, a sandstone bed up to 100 feet (30 m) thick is generally present. It is distinguished from sandstones of the lower part of the unit in that it contains: (1) some thin lenticular beds of granule-sized grains, scattered chert pebbles, and lenses of chert pebbles; (2) abundant "salt-and-pepper" grains in the uppermost portion of the sandstone bed; and (3) in containing large fragments (albeit few) of fossil dinosaur bones.

The upper portion of this upper sandstone bed in the Wahweap-Kaiparowits(?) is well exposed on top of the plateau in the valley of Upper Kanab Creek. Locally, this upper sandstone bed has characteristics intermediate between the sandstones lower in the upper part of my undivided unit and the Kaiparowits Formation east of the Paunsaugunt Plateau (see Gregory and Moore, 1931); it is massive, yet relatively poorly resistant, medium-gray "salt-and-pepper" colored, and contains fossil dinosaur bones.

Near Tropic in 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(?) of Sable and Hereford (1990) on 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 upper interval of my undivided map unit may be the Kaiparowits Formation, gradational with the Kaiparowits Formation, or be part of the Wahweap Formation.

In a stratigraphic section below the Claron Formation above East Fork Creek at the top of the plateau (appendix, Podunk Guard Station section), 240 feet (75 m) of alternating beds of mudstone and sandstone were measured, but a thick sandstone bed is not present. It may be that the upper sandstone bed was eroded off of some upthrown, pre-Claron fault blocks or the massive sandstone may have been discontinuous in its original extent; alternatively, perhaps these sediments are younger than the massive sandstone. Given these varied possibilities, the decision was made to map the Upper Cretaceous strata above the Straight Cliffs as undivided Wahweap Kaiparowits(?) Formations.

The upper contact of the Wahweap-Kaiparowits(?) unit is placed at the top of the highest sandstone or mudstone bed below the basal conglomerate of the Canaan Peak Formation, or in its absence, at the base of the 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-Kaiparowits(?) unit were deposited by streams. Measurements of cross-bedding in the sandstones suggest they were deposited by meandering streams flowing in directions ranging from north to east (Tilton, 1991). Sandstones of the lower part of the unit are lenticular channel deposits that are surrounded in wide lateral extent by overbank muds. 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 sandstones 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 to 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 Formation. At the head of Tenny Canyon, 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 (figure 4; appendix). Forty-five feet (14 m) of Canaan Peak conglomerate were measured near the Podunk Creek Guard Station (appendix). The Canaan Peak Formation lies unconformably on the eroded top of the Wahweap-Kaiparowits(?) unit. Although portrayed by Goldstrand (1990a, 1990b) 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 the paleocurrent directions of 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

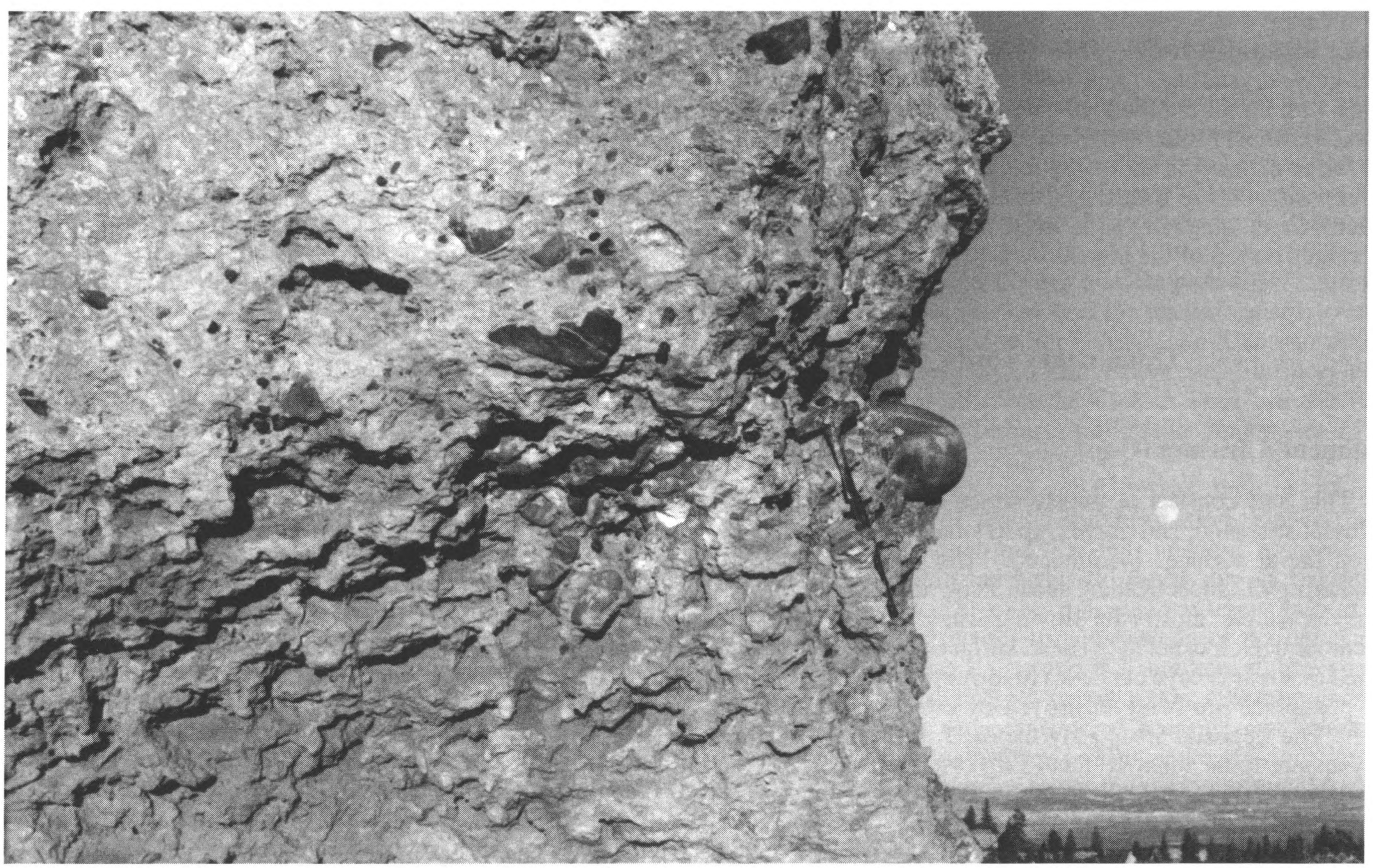

Figure 4. *Canaan Peak Formation in the base of the outlier of Claron Formation at the head of Tenny Canyon. It is a cobble-pebble conglomeratic sandstone. Note rock hammer at right for scale.*

name for its historical precedence. The Utah Geological Survey currently uses the name Claron; Anderson and Rowley (1975) discussed the reasoning involved.

The Claron Formation in the Podunk Creek quadrangle is about 800 feet (245 m) thick. It 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 Bryce Canyon National Park portion of the quadrangle. The uppermost member of the Claron, the variegated sandstone member, is not present in the quadrangle, and is now recognized as 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 Plateau), 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 by the author in these rocks. The pink member is about 600 feet (185 m) thick in the Podunk Creek quadrangle.

White member (Tcw): This member is mostly white to light-gray, crystalline, thick-bedded, hard and dense limestone, with minor interbeds of calcareous, gray mudstone. It characteristically has abundant calcite-crystal-filled vugs. The white member is about 200 feet (60 m) thick at its thickest exposure in the quadrangle on top the plateau. In the Podunk Creek quadrangle the white member forms the eroding ridges on top of the plateau.

Quaternary Units

Pediment Alluvium (Qap)

This unit consists of poorly sorted alluvial and locally colluvial silt, sand, and gravel (up to small cobbles) deposited on broad surfaces (pediments). The 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.

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 John Henry and Smoky Mountain Members of the Straight Cliffs Formation. 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 (includes talus, landslide debris, and colluvium) occurs on slopes below the cliffs bordering the plateau and on ridges and hills away from the cliffs. The 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 ages, 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. This material 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 next to existing drainages. This unit includes stream alluvium and terraces, and local, minor fan alluvium. The alluvium is predominantly sand and gravel in the headwaters of streams coming off the plateau and those flowing on 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. Alluvial deposits are probably mostly Holocene.

IGNEOUS ROCKS

A large mass of fine-grained, porphyritic olivine basalt (Qb), locally known as Black Knoll, caps the ridge east of Tenny Creek. Various extrusive textures are displayed, such as rough columnar jointing, scoria, glassy zones, and mixed scoriaceous and denser rock (agglomerates of Gregory, 1951). Recognizable pieces of Upper Cretaceous sedimentary rock are common xenoliths. Dikes branch off from the main mass for up to 500 feet (150 m); their thickness is difficult to determine. The flow portion is estimated to be about 100 feet (32 m) thick. For more information see Gregory (1951). Best and others (1980) dated basalts in the Skutumpah Creek, Long Valley Junction, and Asay Bench quadrangles (their samples #33, 28, 36) at 1.1±0.1, 0.56±0.06 and 0.52±0.05 Ma (uncorrected), respectively. Sample #33 probably came from remnants of the same flow as that at Black Knoll.

STRUCTURE

The Paunsaugunt Plateau is east of the Sevier fault zone and west of the Paunsaugunt fault zone (figure 1). Displacements along these two fault zones 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 zones, the Paunsaugunt Plateau is a block that is tilted to the northeast. 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 approximately north. 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 the west side of the plateau in the Alton and George Mtn. quadrangles. 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 (Tilton, 2001).

In the Podunk Creek quadrangle, Upper Cretaceous and Tertiary strata are inclined to the north and north-northeast, with dips generally from 1 to 3 degrees, and 5 degrees, respectively. A prominent northwest-trending vertical joint set is present in Upper Cretaceous sandstones; it is best displayed in the adjacent Alton quadrangle. Faults in the Podunk Creek quadrangle have two trends: north-northwest, with down-to-the-west offset; and northeast, with down-to-the-northwest offset. They are a few miles long. These faults are nearly vertical and have displacements (stratigraphic offset) of tens of feet to several hundred feet (~10-90 m). The fault planes are relatively sharp with little or no evidence of fault breccia or drag in adjacent beds. Therefore, they are not readily evident on the ground and are best located on aerial photographs. These minor near-vertical faults offset the Upper Cretaceous rocks below the plateau but do not appear to cut the Paleocene(?) and Eocene Claron Formation. Therefore, they may be related to Laramide-style deformation, rather than later Basin-and-Range extension.

GEOLOGIC HISTORY

Most of the Cretaceous history in the Podunk Creek 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 in the Sevier orogenic belt in southeastern Nevada and western Utah began in the Early Cretaceous (Armstrong, 1968). An unconformity spans most of the Early Cretaceous in the Paunsaugunt Plateau. In the Late Cretaceous, as the orogenic highlands eroded, clastic sediment was transported 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 the beveling of the top of the 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 Cretaceous depositional history and environments in the southern Paunsaugunt Plateau are presented by Tilton (1991).

The Tropic Shale was deposited in the Cretaceous Western Interior Seaway in the Paunsaugunt Plateau area in latest Cenomanian to mid-Turonian time. 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 uplifted, eroded, and cut by generally north-south-trending, near-vertical faults during Laramide-style deformation. Erosion truncated the upper part of the Upper Cretaceous section such that strata of the upper portion of the Wahweap 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. To the west, deposition of the Brian Head Formation (revised) occurred during the Oligocene, after Claron deposition. Volcanic material in Brian Head strata record the onset of volcanic activity.

After deposition of the Claron Formation, 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 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 only coal bed exposed in the Podunk Creek quadrangle is in the Smoky Hollow Member of the Straight Cliffs Formation. It locally reaches only a few inches in thickness. The coal is within the few feet (~1 m) of carbonaceous shale that forms the basal unit of the member.

In the Podunk Creek quadrangle, the buried coals of the Dakota Formation, which underlies the Tropic Shale, are reportedly in thin discontinuous beds with two persistent beds present (Meiiji Resource Consultants, 1980). No reserves were calculated because of insufficient information. One exploratory drill hole (AK-2-PC) into the coal was bored in the southeast corner of the Podunk Creek quadrangle (findings are presented in Bowers, 1977). Another drill hole (AK-1-SC) was bored in section 34, T. 39 S., R. 4 1/2 W. about 1,800 feet (550 m) south of the Podunk Creek quadrangle. No analyses of coal in AK-2-PC were reported. Analyses of coal from AK-1-SC indicated a rank between sub-bituminous "B" and "C" with low sulfur and ash from the lower bed of the "Smirl Coal" (Smirl zone named for the Smirl mine in the Alton quadrangle to the west). Of the two persistent coals found, the upper or Smirl zone is 12 feet (4 m) thick and the lower is 6 feet (2 m) thick (Meiiji Resource Consultants, 1980).

Overburden thicknesses increase rapidly northward in the Podunk Creek quadrangle such that economic underground mining would be limited to the south margin of the map area, where bedrock exposures are not under the Drip Tank Member of the Straight Cliffs Formation (H.H. Doelling, written communication, 1997). Extending coal thicknesses reported by Doelling (1972) and the U.S. Department of Interior (1975) from exposures 3 miles (4.8 km) south of the Podunk Creek quadrangle, an in-place resource of at least 100,000,000 short tons (91 million metric tons) of coal can be calculated (H.H. Doelling, written communication, 1997).

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), up to 6 feet (2 m) thick, and in the middle to upper part of the Drip Tank Member, up to 10 feet (3 m) thick. 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 in making concrete. Basalt rubble that might provide a limited source of durable stone aggregate is present below the igneous extrusive in the south-central part of the Podunk Creek quadrangle.

Water Resources

The streams of the Podunk Creek quadrangle can be divided into two groups: those on the plateau and those below the plateau. The stream system on the 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 East Fork of the Sevier River is a perennial stream and supports a breeding fish population.

The streams below the plateau flow south from several canyons cut in the Upper Cretaceous sandstone and mudstone. Fed by melting snow, these streams will generally flow through the spring. 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. Additional data on water resources are available in Goode (1964, 1966), Price (1980, 1981, 1982, 1983), Cordova (1981), Plantz (1983), and Doelling and Davis (1989).

Geologic Hazards

Several landslide deposits originate at the Straight Cliffs-Tropic Shale contact, in the Tropic Shale, and in the lower Straight Cliffs Formation, mostly in the southeastern portion of the quadrangle. There, 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 Formation. 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. Hazards exist for structures that are built on and next to landslide deposits. These deposits, once disturbed (especially in ways that allow additional water to enter the material), may begin to move again. Locally, other perched ground water in the thicker sandstone beds of the Straight Cliffs and Wahweap-Kaiparowits(?) Formations are indicated by boggy areas in the mudstone below; these areas should be considered when constructing roadways. Doelling and Davis (1989) and Harty (1991) provide additional information on landsliding in the area.

Much of the Tropic Shale contains expansive clays and is also subject to gulleying. The areas directly underlain by the Tropic are in the southeastern portion of the Podunk Creek quadrangle. Building on soils that have developed on the Tropic will require foundations designed to withstand expansion and contraction associated with these soils. Drainage of water away from structures built on these soils is helpful in reducing the intensity of soil movement. Where streams flow on the Tropic Shale, relatively deep arroyos have been cut by erosion along main streams and lateral gullies. Expansive clays are also present in other Cretaceous units in the area and can be recognized by "popcorn" weathering surfaces. Doelling and Davis (1989) and Mulvey (1992) provide additional information on expansive clays and gulleying in the area.

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

Any activity directly above, on, or below the bordering cliffs of the Paunsaugunt Plateau 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 Podunk Creek 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 nearby Sevier and Kanab fault zones. Such earthquakes might cause landslides and rock falls in the quadrangle. 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 Podunk Creek quadrangle offers relatively unspoiled nature accessed by limited unpaved roads. Roads on the plateau access meadows within wooded rolling country. Some of these roads lead to the edge of the Paunsaugunt Plateau where viewpoints on the top of the bordering cliffs of the Claron Formation can be reached. The differential weathering of the pink and white strata of the Claron has resulted in spectacular groups and ridges of etched tall monuments along the plateau rim.

A remote outpost of Bryce Canyon National Park, Yovimpa Point, can be reached by a short walk from the park boundary near the end of the road along Podunk Creek. There, a marked trail descends the plateau. Pink Cliff, the highest point on the south end of the Paunsaugunt Plateau, is in the south-central portion of the quadrangle. An open view of the county to the south is available from this vantage point.

Long wooded ridges and rocky canyons of Upper Cretaceous sandstone and mudstone, which descend southward from the plateau, are accessible to the general public only by hiking down from the top of the plateau. The Dixie National Forest extends to the upper reaches of this secluded area.

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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 - **Tenny Canyon Section.** Latitude 37°24'30" N. longitude 112°19'30" W. at base of section to latitude 37°22'30" N., same longitude, at top. Strata dip approximately 1 degree to the north-northeast. Measured with Jacob staff and tape by author from July 5-8, 1992. Revises section I measured for my dissertation (Tilton, 1991). Measured uphill from the base of conspicuous cliff on the west side of the entrance to Tenny Canyon in the SE1/4NE1/4 section 35, T. 39 S., R. 4 1/2W. Measurement was offset above unit 17 a short distance to the north, in SW1/4SE1/4 section 26 (same T. and R.), and further offset above unit 46 one mile to the north, in SE1/4SW1/4 section 23 (same T. and R.). From there measurement proceeded to the north up to an outlier of Canaan Peak and Claron Formations at the head of the canyon in the center NE1/4 section 23, T. 39 S., R. 4 1/2 W. This outlier, and the section below it, can be seen in the first known photograph of the bordering cliffs of the Paunsaugunt Plateau (Dutton, 1880).

	Top of Section	**Thickness (feet)**
	Claron Formation (incomplete)	
80.	Limestone, pink, massive, dense; "dirty"; about 65 ft to top of outlier	unmeasured
	Canaan Peak Formation:	
79.	Conglomerate, pebbles to cobbles, up to 15 inches in diameter in "salt-and-pepper" sandstone matrix; calcareous cement, grades upward into calcarenite in base of overlying Claron limestone	30
	Total Canaan Peak Formation	**30**
	Wahweap and Kaiparowits(?) Formations, undivided:	
	"upper sandstone":	
78.	Covered slope, sandy upper slope and sandstone ledges noted in lateral slopes	75
77.	Sandstone, yellowish-gray to grayish-orange, with minor beds in upper part being medium-gray (with abundant dark lithic grains), very fine- to fine-grained; cross-bedded, with some regular bedding; some contorted bedding and ripple-lamination in the top 3 ft; ironstone concretions common	30
	Total "upper sandstone"	**105**
	"lower part":	
76.	Mudstone, covered	35
75.	Sandstone, same as unit 61	43
74.	Mudstone, covered	35
73.	Sandstone, same as unit 61	9
72.	Mudstone, covered	65
71.	Sandstone, grayish-orange to moderate-yellowish-brown, very fine- to fine-grained; cross bedded; ripple-lamination in upper part	20
70.	Mudstone, light-gray, grayish-red and grayish-red-purple	75
69.	Sandstone, same as unit 61; bottom 4 ft has contorted bedding containing small mudstone chips	12
68.	Mudstone, covered	20
67.	Sandstone, same as unit 61	2
66.	Mudstone, light-gray and grayish-red-purple	40
65.	Sandstone, pale-reddish-brown, very fine-grained; massive; exhibits well-developed ripple-laminations	6
64.	Mudstone, covered	35
63.	Sandstone, grayish-orange, very fine- to fine-grained; cross-bedded	20
62.	Mudstone, light-gray in lower part and grayish-red-purple in upper part; contains a few thin sandstone beds	25
61.	Sandstone, moderate-yellowish-brown, very fine- to fine-grained; cross-bedded with some regular and ripple-laminated bedding; some casts and molds of bivalve and snail shells; several thin zones of fossil bone and teeth fragments	33
60.	Mudstone, light-gray	8
59.	Sandstone, moderate-yellowish-brown, very fine- to fine-grained; regular-bedded	2
58.	Mudstone, grayish-red-purple	23
57.	Sandstone, same as unit 55	15
56.	Mudstone, light-gray	25
55.	Sandstone, moderate-yellowish-brown, very fine- to fine-grained; cross-bedded with some contorted bedding	26
54.	Mudstone, light-gray and grayish-red-purple	50
	Total "lower part"	624
	Total Wahweap and Kaiparowits(?) Formations, undivided	**729**
	Straight Cliffs Formation:	
	Drip Tank Member:	
53.	Sandstone, moderate-yellowish-brown, very fine- to fine-grained; cross-bedded; forms resistant cap on unit below	4
52.	Conglomerate, light-gray pebbles of chert, quartz and silicified limestone; cross-bedded; exhibits cut-and-fill structures	20
51.	Sandstone, white to light-gray, with much dark-yellowish-orange iron-stain, very fine- to fine-grained; cross-bedded; contains beds with mudstone chips, beds with carbonized wood fragments, log casts, and cut-and-fill structures	80

Top of Section		Thickness (feet)
50.	Sandstone, light-gray, some dark-yellowish-orange iron-oxide stain, fine to medium grained	33
49.	Mudstone, blackish-red; indurated with iron oxide; mostly less than 1 ft thick	1
48.	Mudstone, medium-gray and grayish-red-purple	3
47.	Sandstone, light-gray "salt-and-pepper", fine-grained; massive; contorted cross-bedding in upper 2 ft	15
	Total Drip Tank Member	**156**

Note--Section offset approximately one mile to the north to SE$^1/_4$SW$^1/_4$ section 23, T. 39 S., R. 4$^1/_2$ W., using outcrop and rubble of the prominent white sandstone bed of the Drip Tank as a marker.

John Henry Member:

46.	Sandstone, same as unit 19; contains contorted bedding	9
45.	Mudstone, same as unit 20	11
44.	Sandstone, same as unit 19; contains contorted bedding	6
43.	Mudstone, same as unit 39; contains 1 ft thick sandstone bed 20.5 ft above base	41
42.	Sandstone, same as unit 19; contains log casts and petrified wood	34
41.	Mudstone, same as unit 39; contains 2-ft-thick sandstone bed 18 ft above base and 3.5-ft-thick sandstone bed 26.5 ft above base	44
40.	Sandstone, same as unit 19; regular-bedded near top	10
39.	Mudstone, medium-dark-gray, with some vertical portions purple-red; contains five sandstone beds less than 1 ft thick	55
38.	Mudstone and sandstone, interbedded (ratio 3:1); mudstone same as unit 20; sandstone same as unit 19	12
37.	Sandstone, same as unit 19	39
36.	Mudstone, same as unit 20	2
35.	Sandstone, same as unit 19; contains mudstone chips up to 5 inches in diameter	21
34.	Mudstone and sandstone, interbedded (ratio 3:1); mudstone same as unit 20; sandstone same as unit 19	20
33.	Sandstone, same as unit 19; contorted at top	16
32.	Mudstone, same as unit 20	16
31.	Sandstone, same as unit 19	2
30.	Mudstone, same as unit 20	3
29.	Sandstone, same as unit 19; contains beds with visible mica throughout; contorted bedding near the top	27
28.	Mudstone, same as unit 20	10
27.	Sandstone, same as unit 19	9
26.	Mudstone, same as unit 20	1
25.	Sandstone, same as unit 19	19
24.	Mudstone, same as unit 20	5
23.	Sandstone, same as unit 19; contains visible mica	19
22.	Mudstone, same as unit 20	6
21.	Sandstone, same as unit 19	16
20.	Mudstone, medium-gray	18
19.	Sandstone, grayish-orange, very fine- to fine-grained, cross-bedded	19
18.	Mudstone, light-medium-gray, weathers brown; contains two sandstone beds less than 1 ft thick	23

Note--Section offset a short distance to the north to SW$^1/_4$SE$^1/_4$ section 26, T. 39 S., R. 4$^1/_2$ W., by tracing unit 17.

17.	Sandstone, yellowish-gray, very fine- to fine-grained, cross-bedded; contains beds laminated with finely disseminated carbonaceous material	55
16.	Mudstone, same as unit 14	5
15.	Sandstone, same as unit 11	2
14.	Mudstone, medium-dark-gray	25
13.	Sandstone, same as unit 11	2
12.	Mudstone, light-medium-gray	4
11.	Sandstone, grayish-orange, very fine- to fine-grained	4
10.	Sandstone, grayish-orange, very fine- to medium-grained with some coarse grains; contains iron-oxide cement and thin beds of carbonaceous material in top 1.5 ft	26
9.	Mudstone, medium-gray	3
8.	Sandstone, grayish-orange, very fine- to fine-grained with some medium grains	10
	Total John Henry Member	**652**

Smoky Hollow Member:

7.	Sandstone, white to grayish-orange (some parts stained orange-brown with iron oxide), fine- to medium-grained with common coarse grains, cross-bedded; contains granules of quartz and small pebbles of chert and quartzite scattered throughout and in conglomerate lenses; "calico bed"	49
6.	Mudstone, medium- to medium-dark-gray, weathers brown; contains septarian nodules up to 2 ft in diameter 21 ft above base; abundant ironstone chips on slope 56 to 70 ft above base; sandstone beds (1 ft thick or less) at 3, 13, 41 and 50 ft above base	77
5.	Sandstone, light-medium-gray, very fine-grained	3
4.	Mudstone, carbonaceous, black; wood fragments	3
	Total Smoky Hollow Member	**132**

Top of Section	Thickness (feet)
Tibbet Canyon Member:	
3. Sandstone, grayish-orange, weathers dark-yellowish-orange, very fine- to fine-grained, moderately to well-sorted; massive; forms conspicuous cliff; laminated bedding with some cross-bedding in uppermost part; contains a few thin lenses of brown mudstone in upper half; abundant fossil oyster shells and shell fragments in beds approximately 1 ft thick at 75 ft and 85 ft above base, and in the top	115
2. Mudstone, medium- to medium-dark-gray; contains two thin sandstone beds	1
1. Sandstone, grayish-orange, very fine-grained	8
Total Tibbet Canyon Member	**124**
Total of four members of Straight Cliffs Formation	**1064**
Tropic Shale:	
Mudstone, medium-gray, very thin-bedded	unmeasured

2.--Podunk Guard Station Section. Latitude 37°29'30" N., longitude 112°18' W.. Strata dip approximately 4 degrees north. Measured up west side of road in valley of East Fork Creek in the NE1/4NE1/4 section 23, T. 38 S., R. 4 1/2 W., approximately 1/2 mile north of Podunk Guard Station, Kane County, Utah (Podunk Creek quadrangle). Measured by Jacob staff and tape by author for dissertation (1991).

Canaan Peak Formation (incomplete?):	
18. Conglomerate, up to cobble size, calcareous cement	45
Total measured Canaan Peak Formation	**45**
Wahweap and Kaiparowits (?) Formations, undivided (incomplete):	
17. Covered, forms slope below overlying resistant unit	25
16. Sandstone, yellow-brown, very fine- to fine-grained, subangular; thin- to medium-bedded, regular-bedded to low-angle cross-bedded in 0 to 3-ft-thick channels cut into top of unit. Sandstone, yellow-brown, fine- to medium-grained; massive; regular-bedded; concretions weather out of unit	6
15. Covered	35
14. Sandstone, gray, very fine- to fine-grained, subangular, abundant calcareous cement; poorly resistant	3
13. Mudstone, light-gray	30
12. Sandstone, yellow-gray-brown, very fine-grained, silty, thin- to medium-bedded; cross-bedded	3
11. Mudstone, predominantly gray, some red; a few thin sandstone beds; mostly covered	75
10. Sandstone, yellow-brown; thin- to medium-bedded; cross-bedded; lens	3
9. Mudstone, covered	17
8. Sandstone, lens	2
7. Mudstone, light-gray	12
6. Sandstone, yellow-brown, fine-grained; lens	2
5. Mudstone	3
4. Sandstone, yellow-brown, fine-grained; cross-bedded; mudstone chips; lens	2
3. Mudstone, gray	13
2. Sandstone, yellow-brown, very fine-grained, subangular; contorted cross-bedding in lower 3 to 4 ft; top 2 ft slabby and weathering back into slope; middle part regular-bedded with zones of 1 to 2 inch concretions	8
Total measured Wahweap and Kaiparowits(?) Formations, undivided	**239**
1. Covered and vegetated slope above stream valley	Unmeasured

UTAH GEOLOGICAL SURVEY
a division of the
UTAH DEPARTMENT OF NATURAL RESOURCES

Base map from U.S. Geological Survey
Podunk Creek 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°48'
228 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
Lori J. Douglas, Cartographer

GEOLOGIC MAP OF THE PODUNK CREEK QUADRANGLE, KANE COUNTY, UTAH

by

Terry L. Tilton

2001

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. On top of and 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 moving down onto areas underlain by Tropic Shale. Individual landslides are separated by dashed contact lines. 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 small cobbles) on broad surfaces above present drainages. Formed by deposition from flowing water in past; surfaces now abandoned. Thin cover to about 10 feet (3 m) thick.*

Qb Basalt - *Mass of fine-grained porphyritic olivine basalt locally known as Black Knoll. Various igneous textures including rough columnar jointing, scoria, glassy zones, and mixed highly vesicular and denser rock. Exposures of flow are up to 100 feet (30 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 local conglomerates of the Canaan Peak Formation, up to 45 feet thick, at the base. About 600 feet (180) thick.*

Kwk Wahweap and Kaiparowits(?) Formations, undivided - *Upper part is orangish-gray, fine-grained, in part salt-and-pepper gray 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 ratio of 1:1. Unconformity on top. About 600 to 750 feet (180-230 m) thick.*

Ksd Drip Tank Member of the Straight Cliffs Formation - *Massive, white to light-gray sandstone. Upper two-thirds of unit contains prominent conglomerate beds of granule-sized quartz and pebbles of chert. Casts of logs are locally common. 150 to 180 feet (45-55 m) thick.*

Ksj John Henry Member of the Straight Cliffs Formation - *Alternating sandstone and mudstone beds, with a sandstone-to-mudstone ratio of 2:1. Sandstones are grayish-orange, very fine- to fine-grained and cross-bedded. Mudstones are gray and pale-red-purple. 550 to 650 feet (170-200 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 predominantly gray mudstone, with a thin, persistent, carbonaceous shale in base. Unconformity between middle and upper parts. 125 to 140 feet (40-45 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. 100 to 125 feet (30-40 m) thick.*

Kt Tropic Shale - *Medium-brownish-gray, very thin-bedded, non-resistant silty shale. Upper part has interbeds of fine-grained sandstone and siltstone from interfingering with overlying unit. Base is not exposed in the quadrangle. About 700 feet (210 m) thick.*

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; arrows on cross section show offset*

Strike and dip of bedding

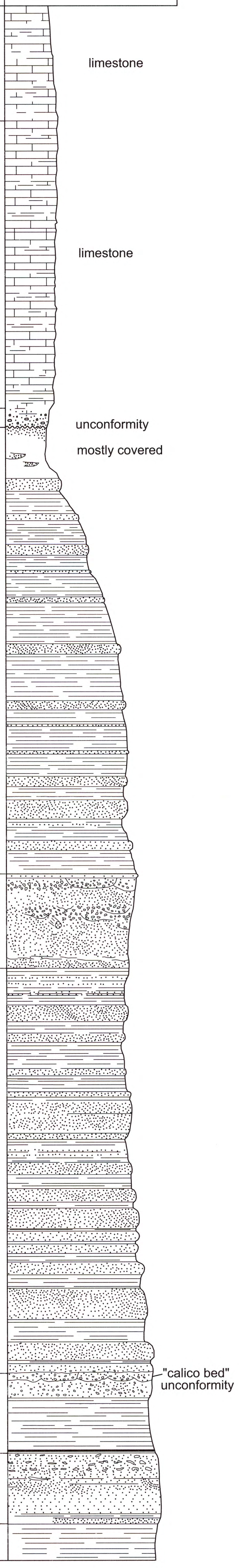
Strike of vertical joint

Line of cross section

Approximate line of measured section (appendix)

Lithologic Column

SYSTEM	SERIES	FORMATION	MEMBER	SYMBOL	THICKNESS feet (m)	LITHOLOGY
TERTIARY	Paleocene and Eocene	CLARON FORMATION (not measured at Tenny Canyon)	White member	Tcw	<200 (<60)	limestone
			Pink member	Tcp	600 (185)	limestone
		Canaan Peak Formation			0-45 (14)	unconformity
CRETACEOUS	Upper Cretaceous	Wahweap and Kaiparowits (?) Fms. undivided		Kwk	600-750 (180-230)	mostly covered
		Straight Cliffs Formation	Drip Tank Member	Ksd	150-180 (45-55)	
			John Henry Member	Ksj	550-650 (170-200)	"calico bed" unconformity
			Smoky Hollow Member	Kss	125-140 (40-45)	
			Tibbet Canyon Member	Kst	100-125 (30-40)	
		Tropic Shale		Kt	700 (210)	



Correlation of Map Units