The Canaan Peak, Pine Hollow, and Wasatch Formations in the Table Cliff Region, Garfield County, Utah

GEOLOGICAL SURVEY BULLETIN 1331-B

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By WILLIAM E. BOWERS

CONTRIBUTIONS TO GENERAL GEOLOGY

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Description of two new stratigraphic units previously considered to be the lower part of the Wasatch Formation in southern Utah

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1972

UNITED STATES DEPARTMENT OF THE INTERIOR

ROGERS C. B. MORTON, *Secretary*

GEOLOGICAL SURVEY

V. E. McKelvey, *Director*

Library of Congress catalog-card No. 79-186492

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Stock Number 2401-2072

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THE CANAAN PEAK, PINE HOLLOW, AND WASATCH FORMATIONS IN THE TABLE CLIFF REGION, GARFIELD COUNTY, UTAH

By William E. Bowers

ABSTRACT

Recent geologic mapping in the northern part of the Kaiparowits Plateau and in the Table Cliff Plateau of southern Utah has shown that two distinct stratigraphic units formerly considered to be part of the Wasatch Formation (Eocene) are of Cretaceous and Paleocene(?) age. In the area of this report, the contact between the two new formations and the overlying Wasatch Formation is locally unconformable.

The lower unit, the Canaan Peak Formation (new name), is mostly pebble-cobble conglomerate and conglomeratic sandstone containing a few mudstone interbeds in the lower part. Late Cretaceous (Campanian) pollen and spores were in samples from mudstone interbeds in the lower part of the Canaan Peak Formation; the upper part is of Paleocene(?) age. The Canaan Peak Formation, ranging in thickness from 0 to about 1,000 feet, is unconformable on the Kaiparowits Formation (Upper Cretaceous).

The upper unit, the Pine Hollow Formation (new name), is predominantly red to purplish-gray mudstone, calcareous mudstone, or very fine grained clastic limestone. Sandstone beds and conglomerate lenses occur mostly in the lower part of the formation. The Pine Hollow Formation is generally conformable on and locally intertongues with the Canaan Peak Formation but, in places, appears to lie on an irregular low-relief surface formed on the Canaan Peak Formation. The Pine Hollow Formation ranges in thickness from 0 on the flanks of structural folds to about 400 feet near the trough of the Table Cliff syncline. No fossils or palynomorphs were recovered from the Pine Hollow, and the age is uncertain. A Paleocene(?) age is assigned.

The Wasatch Formation in the Table Cliff Plateau is divided into three informal members that are mappable units generally recognized by previous workers in the region. The formation consists of a lower pink fine-grained limestone member about 800 feet thick, a middle white limestone member about 550 feet thick, and an upper variegated sandstone member 300–600 feet thick. A few early to middle Eocene fresh-water mollusks were collected from the middle member. The lower part of the Wasatch is probably Paleocene in

age and in part correlative with the Flagstaff Limestone (Paleocene and Eocene?) of central Utah, but no definite paleontological evidence is available.

Use of the name Wasatch for lower Tertiary rocks in southern Utah has been questioned by some workers because of differences in age and lithology from the type Wasatch Formation (Eocene) in northeastern Utah. Some prefer the name Claron Formation, which has been used for similar strata west of Cedar Breaks National Monument, and other names have been proposed. The two upper members of the Wasatch Formation have been assigned by some geologists to the Brian Head Formation (Miocene?), now believed to include rocks older than Miocene, in the Cedar Breaks National Monument area. Because of existing confusion and uncertainty concerning strata assigned to the Brian Head Formation, the name is not used in the Table Cliff Plateau. Just north of the Table Cliff Plateau, the Wasatch Formation is overlain by a few hundred feet of Oligocene(?) white tuffaceous sediments and lower Miocene(?) latite welded tuffs.

INTRODUCTION

Two distinct stratigraphic units can be recognized between typical sandstones of the Kaiparowits Formation and a pink clastic limestone in the lower part of the Wasatch Formation on the Table Cliff Plateau, southwestern Utah (pl. 1). The units, the Canaan Peak and Pine Hollow Formations, named herein, are lithologically distinctive; they are bounded, at least locally, by an unconformity or a disconformity, and they are present over at least 100 square miles. Figure 1 shows one of the better exposures of the two formations and the typical forest-covered terrain of the Table Cliff region.

FIGURE 1.— View, looking north, near the head of Right Hand Allen Creek on the east side of the Table Cliff Plateau. The fluted cliffs (left background), about 1,500 feet high, are formed by the pink and white limestone members of the Wasatch Formation. Dark cliffs of conglomerate (right background) of the Canaan Peak Formation are overlain by light-colored slope-forming beds of the Pine Hollow Formation.

This report is an outgrowth of a detailed mapping program in the Kaiparowits Plateau of southern Utah that was started by the U.S. Geological Survey in 1963, primarily for the purpose of collecting information on coal resources in the region. Mapping was done on topographic base maps at a scale of 1:24,000. During fieldwork in the northern part of the Kaiparowits Plateau and around the Table Cliff Plateau (pl. 1), in the Canaan Peak, Griffin Point, Pine Lake, Sweetwater Creek, and Upper Valley 7½-minute quadrangles, mapping the contact between the Kaiparowits (Upper Cretaceous) and the Wasatch (lower Tertiary) Formations became a problem. In many places in southern Utah, the two formations are separated by a conspicuous unconformity.

A somewhat lengthy discussion of the Wasatch Formation is included in this report because beds previously assigned to the lower part of the Wasatch are described as new formations and because of problems connected with the use of the name Wasatch in southern Utah. This report is not intended as a solution to the Wasatch problem but rather as a step toward a better understanding of the Late Cretaceous and early Tertiary stratigraphy of the region.

Other geologists of the U.S. Geological Survey are mapping or have recently mapped in adjacent areas of southern Utah. I would like to thank W. B. Cashion, R. J. Hackman, Fred Peterson, E. V. Stephens, P. L. Williams, D. G. Wyant, and H. D. Zeller, all of the U.S. Geological Survey, for their encouragement, helpful advice, and constructive criticism.

PREVIOUS WORK

A thick sequence of fluvial and lacustrine limestone, limy mudstone, sandstone, and conglomerate caps much of the southern High Plateaus of Utah or underlies volcanic rocks and extends westward into the eastern Basin and Range province of southwestern Utah. These beds are separated from Late Cretaceous and older rocks in many places by an unconformity and, although generally considered by early geologists to be Eocene in age, are believed by some later workers to include rocks as old as Late Cretaceous. The spectacular Pink Cliffs along the southern margin of the High Plateaus of Utah and the colorful columns and spires of Bryce Canyon National Park and Cedar Breaks National Monument are the result of the weathering and erosion of these strata. Various names have been applied to these rocks, and correlation has been hampered by facies changes, lack of diagnostic fossils, major faults, and cover by volcanic rocks or Quaternary sediments.

The rocks of latest Cretaceous to early Tertiary age in the southern High Plateaus of Utah have commonly been referred to as the Wasatch Formation, whereas in the eastern Basin and Range province the name Claron Formation has been used for similar strata of Eocene(?) age. A historical sketch of the stratigraphic nomenclature applied to these rocks in southern Utah follows. The terminology used by previous workers for Tertiary rocks in the Table Cliff region is summarized in figure 2.

While doing reconnaissance work in southern Utah in 1872, Howell (1875, p. 270–271) examined a stratigraphic section at Last Bluff (now named Table Cliff Plateau) and assigned 2,850–3,450 feet of sedimentary rocks to the Tertiary. Howell recognized four units, the lowest of which consisted of 1,200–1,500 feet of gray arenaceous and argillaceous shales that later proved to be Cretaceous. In descending order, Howell's upper three units were:

	Feet
White to gray fresh-water limestone containing *Helix* and *Physa bridgerensis*	500
Pink fresh-water limestone with bands of blue toward the base	850
Purple and light-colored marls with conglomerate toward the base	300–600

In the Markagunt and Paunsaugunt Plateaus west of the Table Cliff Plateau, Dutton (1880, p. 159) recognized three units that he described from top to bottom as:

	Feet
White limestone and calcareous marl	300
Pink calcareous sandstone	800
Pink conglomerate	550

Dutton (p. 204) called these beds the Pink Cliff Series and referred to them on his generalized section as "southern Bitter Creek," considering them probably equivalent to part of the Bitter Creek beds of Powell (1876, p. 45–47) in the Uinta Mountains and the Wasatch Plateau to the north. Dutton (p. 159) described the rocks in the southern plateaus:

> The Pink Cliffs, which form such a striking feature in the scenery of the southern terraces, are exposures of fine-grained calcareous sandstone forming the middle member of the Bitter Creek. The same exposures are exhibited in the southern and southwestern flanks of the Markágunt around the entire promontory of the Paunságunt and in the circuit of the Table Cliff.

Dutton (p. 292) also mentioned the outlier of Tertiary rocks exposed on Kaiparowits Peak (here named Canaan Peak).

The name Wasatch was first used by Hayden (1869, p. 191) for predominantly red claystone, sandstone, and conglomerate of Tertiary age exposed along the Union Pacific Railroad in southwestern

Wyoming and northeastern Utah, and later workers traced some of the Wasatch-like beds to east-central and central Utah. Strata previously included in the Wasatch near the type area in northern Utah are now assigned (Mullens, 1971) to the Echo Canyon Conglomerate (Upper Cretaceous), Evanston Formation (Upper Cretaceous and Paleocene), and Wasatch Formation (Paleocene and Eocene). Richardson (1909, p. 382) extended the name Wasatch to include southern Utah when he assigned the varicolored beds unconformable on the Cretaceous in the Markagunt and Paunsaugunt Plateaus and in the Pink Cliffs to the Wasatch Formation (Eocene). Spieker (1946, p. 132–139) redefined the beds assigned to the Wasatch in central Utah as three formations — the North Horn (Upper Cretaceous and Paleocene), Flagstaff (Paleocene and Eocene?), and Colton (Eocene) — and expressed the likelihood that the Flagstaff equivalent is represented in the Wasatch of the southern plateaus.

Gregory and Moore (1931, p. 114–116) discussed the pink and white limestones that form the escarpment around the Table Cliff Plateau and similar beds capping Canaan Peak and, like Richardson, assigned them to the Wasatch Formation. Gregory and Moore (p. 116) described the unconformity separating the Wasatch Formation from the Cretaceous rocks and proposed the name Kaiparowits Formation (p. 106) for about 2,000 feet of dark very fine grained friable sandstone below the unconformity. The Kaiparowits Formation (Upper Cretaceous) of Gregory and Moore includes the lowermost unit that Howell had assigned to the Tertiary. Bissell (1949, p. 98) believed it probable that the lower half of the beds assigned by Gregory and Moore to the Wasatch Formation in the Kaiparowits region should be referred to the Upper Cretaceous and was probably correlative with the Price River and North Horn (lower part) Formations of central Utah.

In southwestern Utah, Leith and Harder (1908, p. 41–44) proposed the name Claron for similar lower Tertiary strata in the Iron Springs district west of Cedar City. The name Claron was used by Mackin (1954; 1960, p. 101) and Cook (1957, p. 37; 1960, p. 32; 1965, p. 54). Robison (1966, p. 28–29) preferred the name Claron to Wasatch for the beds in the Table Cliff and Paunsaugunt Plateaus, which include the white limestone that caps much of the Table Cliff Plateau. Robison reported a lower, pink member, which is about 1,000 feet thick and includes a basal conglomerate 20–300 feet thick, and an upper, white limestone member at least 600 feet thick.

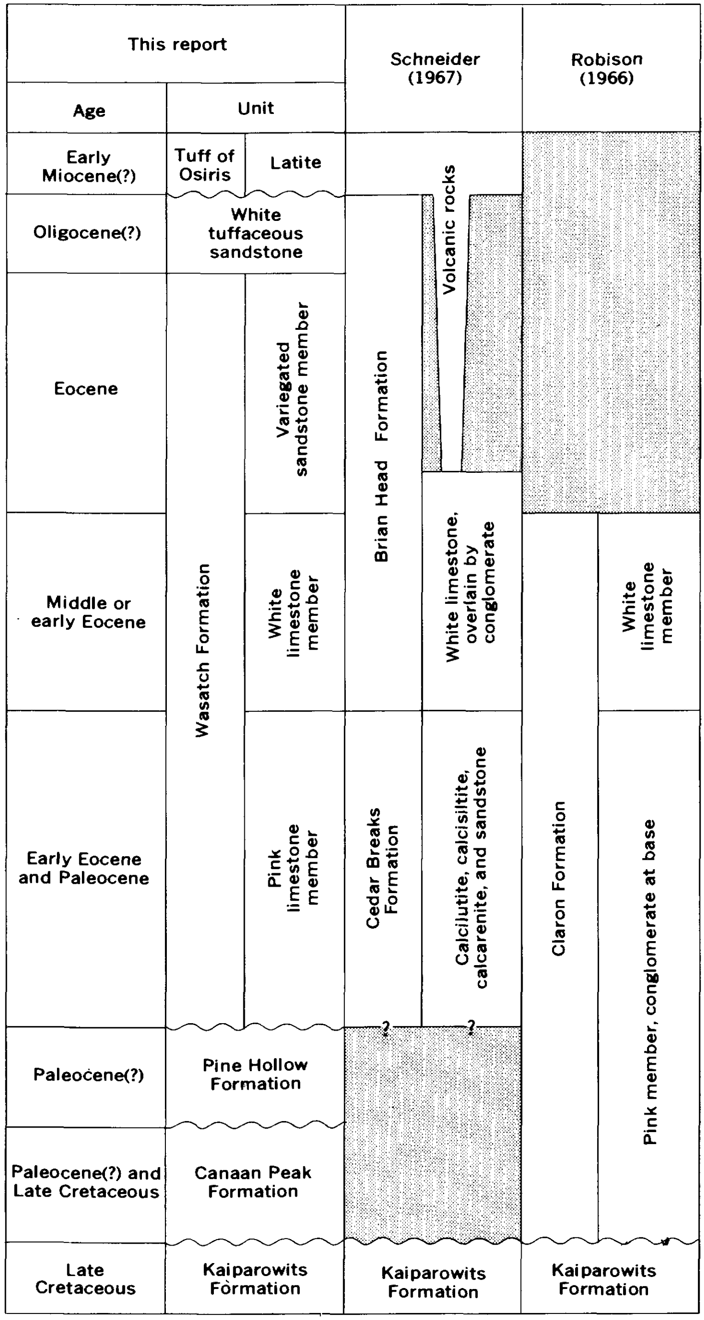
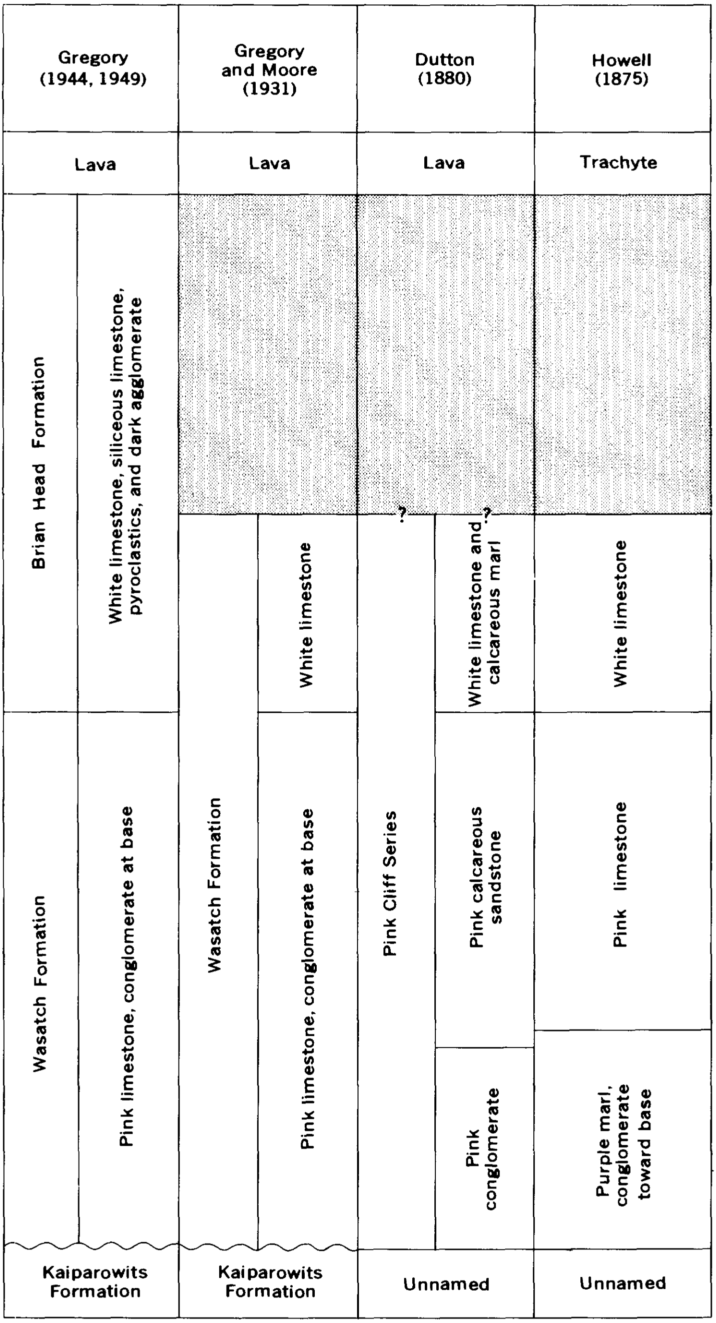


FIGURE 2. — Summary of stratigraphic names for Tertiary rocks
queries indicate uncertain



in the Table Cliff region. Hachures mark units not discussed; or undefined contacts.

Gregory, in some of his later reports (1944, p. 591–595; 1945, p. 106–108; 1949, p. 983), referred the white limestone, or "white Wasatch," in the Table Cliff Plateau to his Brian Head Formation, a sequence of sandstone, siliceous limestone, tuff, and volcanic rocks overlying the pink limestone of the Wasatch Formation in the Cedar Breaks National Monument area. He tentatively considered the Brian Head Formation to be Miocene(?) in age.

McFall (1955, p. 71–74), who measured a section at the south end of the Table Cliff Plateau that included the pink limestone and basal conglomerate part of Gregory and Moore's (1931) Wasatch Formation, recognized a basal conglomerate member and a limestone member. The pink beds of the Wasatch have been referred to informally as the Bryce Canyon beds by McFall and others after exposures at Bryce Canyon National Park. McFall (p. 78–84) followed Gregory's later terminology by assigning the white limestone above the pink beds in the Table Cliff Plateau to the Brian Head Formation. McFall included in the Brian Head about 600 feet of white limestone in the Table Cliff Plateau and 700–1,000 feet of overlying sandstone, tuffaceous sandstone, and tuff which is beneath the volcanic cap at the southern end of the Aquarius Plateau.

Schneider (1967, p. 153), in a study of the lower Tertiary continental sediments of central and south-central Utah, proposed the name Cedar Breaks Formation for the clastic limestones previously assigned to the Wasatch and Claron Formations, and he described a type section at Cedar Breaks National Monument. On the basis of two persistent mica zones and other stratigraphic and lithologic features, Schneider (p. 185–193) correlated the Cedar Breaks Formation with the Flagstaff Formation in the Pavant Range and with the pink limestone in the Paunsaugunt and Table Cliff Plateaus. He assigned the white limestone in the Table Cliff Plateau to the Brian Head Formation but pointed out (p. 150) that the Brian Head–Wasatch boundary relationship is not as clear in the Paunsaugunt, Table Cliff, and Aquarius Plateaus as elsewhere. Schneider measured a section in Water Canyon on the east side of the Table Cliff Plateau, assigned about 525 feet of the sequence to his Cedar Breaks Formation, and indicated (p. 164) that there was some question about the upper and lower boundaries of the formation.

The names Claron and Wasatch have both been used recently by the U.S. Geological Survey in reports of southern Utah. Averitt (1967) used the name Claron Formation in the Kanarraville area and suggested a correlation of the Claron with beds of the Wasatch Formation to the east along the south rim of the Markagunt Plateau mapped by Cashion (1967).

GENERAL DISCUSSION

Current fieldwork has shown that the units reported by Howell (1875, p. 270–271) in the Table Cliff Plateau can be recognized. Also recognized is an overlying variegated sandstone, siltstone, and mudstone unit that has been largely stripped from the top of the Table Cliff Plateau except where it is protected from erosion by younger latite welded ash-flow tuffs such as the cap rock at Barney Top (pl. 1, section B–B′). The lowest of Howell's three upper units, the purple and light-colored marls and conglomerate, is presented in this report as the Canaan Peak and Pine Hollow Formations (new names). The pink limestone unit of Howell (the Cedar Breaks Formation of Schneider) and the massive white limestone and the overlying variegated clastic unit (both assigned to the Brian Head Formation by Gregory, McFall, and Schneider) are considered in this report to be three members of the Wasatch Formation.

In view of the long accepted application of the name Wasatch to the lower Tertiary beds in the plateaus of southern Utah, the name is retained in this report pending clarification of regional stratigraphic relationships that include the Table Cliff, Aquarius, Sevier, and Paunsaugunt Plateaus.

Because of confusion and uncertainty in the use of the name Brian Head Formation, the name is not used by the writer in the Table Cliff Plateau. Threet (1952; 1963a, p. 107–108) discussed some of the problems concerning the Brian Head. The type Brian Head Formation (Miocene?) near Cedar Breaks National Monument included siliceous limestone, tuffaceous sediments, and volcanic agglomerates which, as more recent evidence indicates, are probably no younger than Oligocene (Mackin, 1960; Threet, 1963b, p. 140). In many places in southern Utah, the pink Wasatch limestones are overlain by white or light-gray beds of variable lithology consisting of combinations of sandstone, limestone, siliceous limestone, and tuffaceous sediments or tuff, which have been referred to alternately as "white Wasatch" or Brian Head Formation. The repeated use of these names has led some to assume that all the light-colored beds above the pink Wasatch are correlative whereas, in fact, their equivalence across the region has not been proved.

CANAAN PEAK FORMATION

GENERAL LITHOLOGY AND LOCATION OF TYPE SECTION

The Canaan Peak Formation of Late Cretaceous and Paleocene(?) age is named herein from exposures around Canaan Peak (pl. 1). The formation is mostly a coarse clastic unit characterized by gray, tan, light-brown, or pink conglomerates and conglomeratic sandstones, and it contains subordinate gray to red mudstones. A type section for the Canaan Peak Formation, measured on the south face of Canaan Peak at the head of Wahweap Creek, is accessible by foot and is about half a mile from the end of a logging road that approaches the northeast side of Canaan Peak from South Hollow or from a jeep trail that approaches the mountain from the southwest. The type section and selected partial measured sections are described in detail in "Stratigraphic Sections," and additional measured sections are shown in the generalized columnar sections, figure 3.

The Canaan Peak Formation is unconformable on the Upper Cretaceous Kaiparowits Formation, a largely dull-greenish-gray to bluish-gray very fine grained friable sandstone containing subordinate gray mudstone and light-brown lenticular sandstone interbeds. No conglomerates were observed in the Kaiparowits Formation in the vicinity of the Table Cliff Plateau.

DISTRIBUTION, THICKNESS, AND NATURE OF CONTACTS

The Canaan Peak Formation is rarely well exposed, and surface outcrops generally form steep-sided ridges and slopes covered by pebbles and cobbles. The unit displays a characteristic dendritic drainage pattern and a dark tone on aerial photographs.

The Canaan Peak Formation lies over a large area beneath pink and white limestone that forms the highest part of Canaan Peak (pl. 1), a northwest-trending ridge about half a mile long. The southernmost exposure of the formation is 2 miles southeast of Canaan Peak on the drainage divide between the south-flowing Wahweap Creek and the east-flowing drainage toward the Escalante River. North and east of Canaan Peak, the formation is covered in many places by coarse surficial deposits, composed largely of fragments and blocks of limestone derived from the Wasatch Formation. The formation can also be seen along the ridge east of South Hollow, to within 1¼ miles of Upper Valley where the rocks have been removed by erosion, and appears again in a belt around the base of the Table Cliff Plateau. Some of the better exposures of the upper part of the formation occur along Sweetwater Creek on the northwest side of the plateau.

The lower contact of the Canaan Peak Formation is generally obscured by pebbles and cobbles weathered out of the overlying conglomerate. Along the west side of the Table Cliff Plateau where exposures are fair, the beds above and below the contact appear to be nearly parallel, but the top of the Kaiparowits Formation is slightly irregular and locally channeled, and there appears to be a slight angular discordance in some places. On the south and west sides of Canaan Peak, the contact appears to be irregular, and local relief is possibly as much as 10 feet. Change in lithology across the contact is commonly abrupt, from very fine sandstone or mudstone of the Kaiparowits Formation to pebble-cobble conglomerate or conglomeratic sandstone of the Canaan Peak Formation.

East of the Table Cliff Plateau along the Dutton monocline (pl. 1), most of the lower contact of the Canaan Peak Formation is covered by surficial deposits, but in places the attitude of the beds indicates an angular discordance of as much as 10°–15° between the Canaan Peak and Kaiparowits Formations. The contact occurs near the synclinal bend of the Dutton monocline; where the Canaan Peak Formation is on the steep limb of the monocline, the conglomerate dips as much as 25° W., whereas the Kaiparowits appears to dip 35°–40°.

East of Canaan Peak, exposures are very poor, and the formation weathers to gravel-covered slopes on which the attitude of the underlying beds cannot be determined. In many places it is difficult to distinguish between exposures of bedrock and Quaternary gravel deposits derived in large part from the Canaan Peak Formation. In this area the Canaan Peak Formation lies west of the synclinal bend of the Dutton monocline where dips are low, whereas the Kaiparowits Formation is exposed on the steep limb of the monocline. There is an abrupt change in dip from about 35° to less than 10° across the synclinal bend and, although the flexure is sharp, part of the decrease in westward dip is probably due to an angular discordance between the Canaan Peak and Kaiparowits Formations.

In most places in the Table Cliff Plateau, the Canaan Peak Formation is overlain by the red to purplish-gray fine clastic sediments of the Pine Hollow Formation and, where the contact can be observed, the beds generally appear to be conformable and locally intertongue. A cross section through the southern part of the Table Cliff Plateau (section A–A′, pl. 1) shows some irregularity of the projected Canaan Peak–Pine Hollow contact that

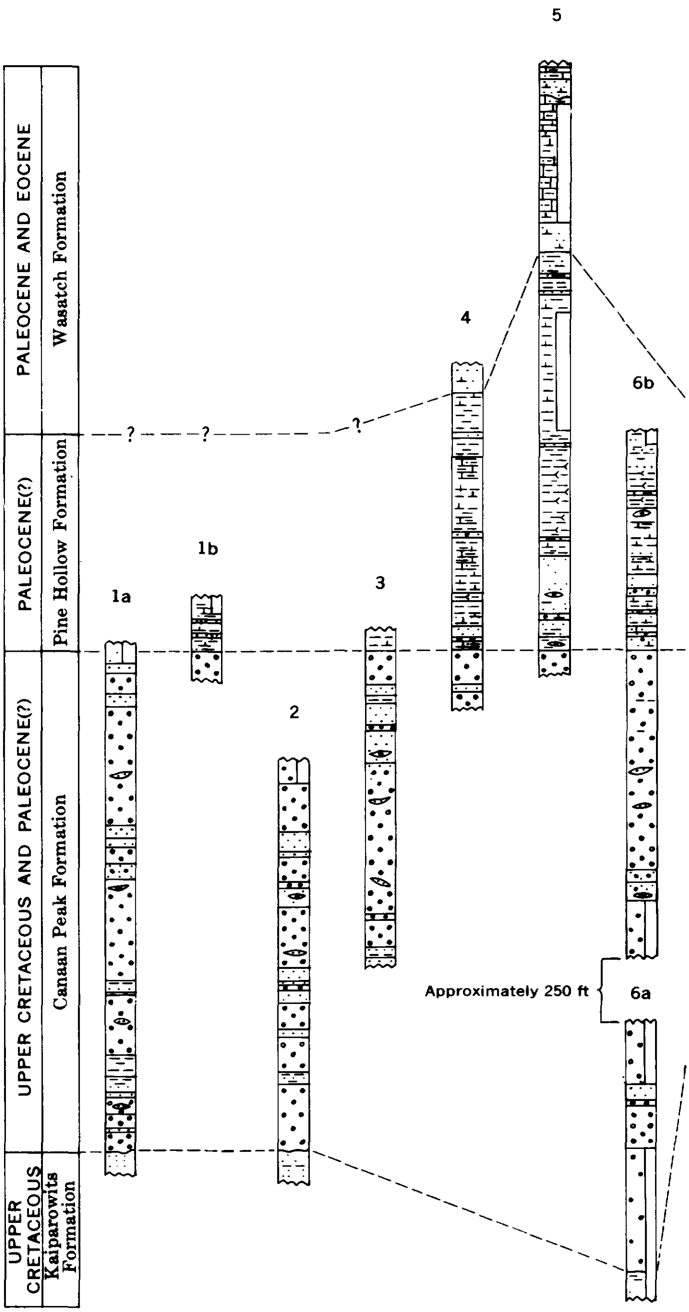
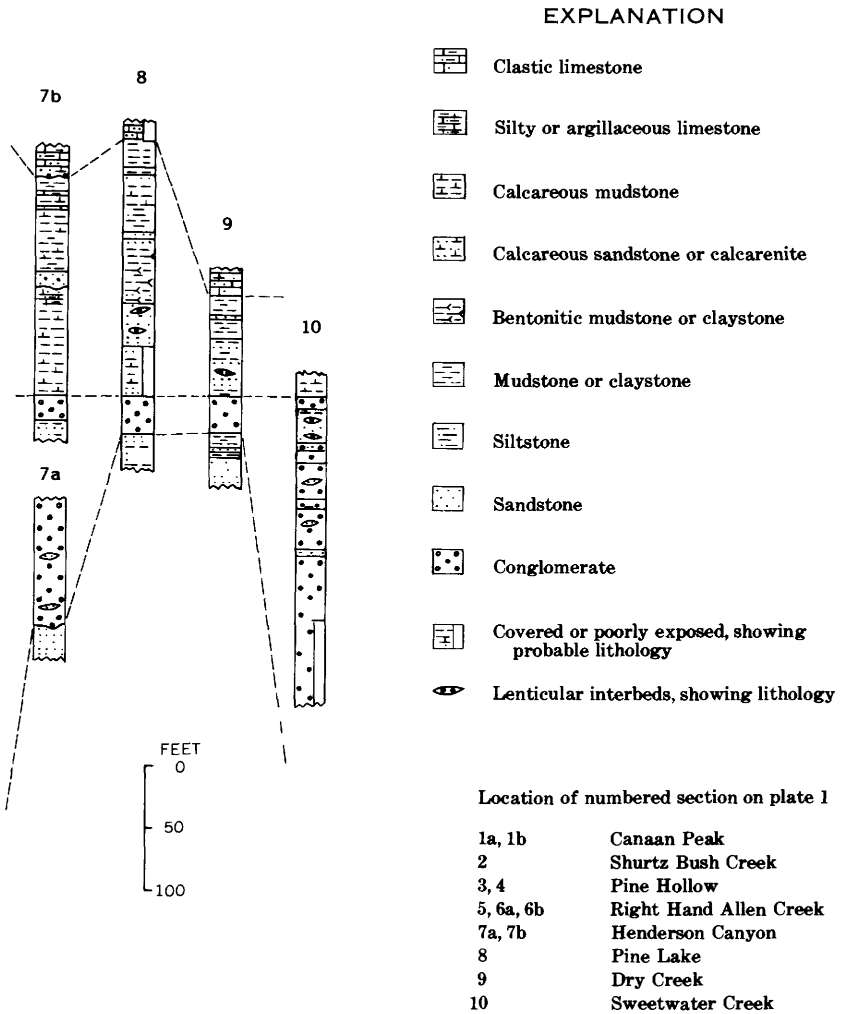


FIGURE 3. — Generalized columnar sections of

indicates considerable variance in the thickness of both formations near the trough of the Table Cliff syncline and generally abrupt thinning to the west.

At several localities on the west side of the Table Cliff Plateau, the contact between the pink limestone member of the Wasatch Formation and the Canaan Peak Formation and older rocks directly under it is an angular unconformity. The beds of the Wasatch Formation in these areas are horizontal or dip gently to the north or northwest, and the Canaan Peak Formation dips



the Canaan Peak and Pine Hollow Formations.

10°–20° to the east along the east flank of the Johns Valley anticline. Where the Pine Hollow Formation is between the Canaan Peak and Wasatch Formations, the Pine Hollow appears to be conformable with the Canaan Peak. Just southeast of Pine Lake, however, there appears to be a slight overlap and pinchout of the Pine Hollow over truncated Canaan Peak, but the exposure is too poor to determine the precise relationship.

From Mud Spring Draw northward to Birch Creek (pl. 1), the Canaan Peak Formation is in fault contact with the Wasatch Formation, which is faulted down to the west.

The Canaan Peak Formation ranges considerably in thickness, from about 40 feet near Pine Lake to possibly as much as 1,000 feet near the trough of the Table Cliff syncline. The formation is 400–600 feet thick northward along the east side of the plateau west of the Dutton monocline and extends northward along the monocline beneath the Aquarius Plateau. The Canaan Peak is probably truncated by the Wasatch where the Wasatch overlaps the Dutton monocline, but the relationship is obscured by surficial cover on the slopes south of Griffin Top. The formation covers a wide area north of Mud Spring Draw where several hundred feet is exposed although the base is covered.

COMPOSITION OF CLASTS

Pebbles and cobbles in the coarsest clastic beds of the Canaan Peak Formation are composed mostly of quartzite, chert, and dense to fine-grained porphyritic igneous rocks. Less common lithologies are sandstone, siltstone, conglomerate, argillite, and limestone. Proportions of clast lithologies reported here are estimates based on a limited number of grab samples of conglomerate and general observations made during field mapping. No detailed pebble counts of large samples were made.

Cooley (1960) made a systematic analysis of gravels and conglomerates in the Glen Canyon–San Juan region, including conglomerate at the base of the Wasatch Formation in the Bryce Canyon and Escalante areas. Observations on clast composition and proportions reported here are in general agreement with the findings of Cooley (p. 22–23).

Quartzite generally composes 10–40 percent of the clasts but locally may compose as much as 90 percent. Most of the quartzite, massive and very fine grained to fine grained, is grayish white, buff, and light brown. Pink, purplish-gray, and varicolored banded varieties become more common higher in the section, but white and buff colors predominate.

Chert, including jasper and other dense siliceous rocks, composes 15–40 percent of the clasts. The most common colors are black, buff, brown, and red. Some chert pebbles contain Paleozoic fossils, mostly corals and bryozoans. Some of the transparent siliceous material in the clasts contains small cavities and mineral inclusions that resemble features commonly seen in silicified tuff.

Igneous clasts, constituting as much as 40 percent of observed clast samples, fall into the general field classification of felsite and tuff. Light gray, cream, pink, and red-hued are common colors. Feldspars and mafic minerals are commonly strongly altered, and some clasts are so badly decomposed that they disintegrate when removed from the matrix.

Proportions of the major lithologic types (quartzite, chert, and igneous clasts) vary considerably, both laterally and vertically, in the formation. They may be in nearly equal proportions, or one major type may exceed the total of the other two. Of the minor clast lithologies, limestone is scarce and in places seems to be absent in the lower part of the formation. Limestone occurrence, which increases upward in the section, is most common in the uppermost beds. Limestone clasts are generally light to medium gray or light brown and in many places are associated with chert. The coarser clasts are generally set in a matrix of poorly sorted subrounded to subangular fine- to coarse-grained "salt and pepper" sandstone composed mainly of fragments of quartz and the material that makes up the larger clasts.

Nearly all clasts are rounded to well rounded, and maximum size exceeds 12 inches in diameter. Quartzite, the predominant lithology of the largest clasts, occurs as boulders as much as 15 inches in diameter on the west side of the Table Cliff Plateau. In the vicinity of Canaan Peak, the larger clasts are approximately 10 inches in diameter.

Gregory and Moore (1931, p. 155) described a conglomerate at the base of the Wasatch Formation that contains well-rounded smooth pebbles of pink, gray, white, and red quartzite, black chert, rhyolite porphyry, and many kinds of dense igneous rocks. According to Gregory and Moore, the conglomerate was seen in position only on the west slopes of the Paunsaugunt Plateau where it contains quartz, quartzite, and rhyolite pebbles. The boulder piles reported by Gregory and Moore (p. 115) along the head of the Little River (now named Little Creek) on Canaan Peak are derived from the Canaan Peak Formation.

SOURCE AND MODE OF DEPOSITION

The abundance of igneous clasts and the relative scarcity of limestone clasts are interesting features of a large part of the Canaan Peak Formation. Cooley (1960, p. 23) suggested that the scarcity of limestone clasts in the basal Wasatch might be due to the distance from the source area. Clasts described in Upper Cretaceous and lower Tertiary conglomerates north and northwest of the area are mostly quartzite and limestone with little or no igneous material.

West of the Table Cliff Plateau, igneous clasts are reported in rocks assigned to the Wasatch or Claron Formation. Cook (1957, p. 46) reported altered igneous rocks in conglomerate in the lower part of the Claron in the Pine Valley Mountains, and Thomas and Taylor (1946, p. 29) reported a basal conglomerate in the Wasatch made up of pebbles and cobbles of quartzite and some dense igneous rocks in the Parowan area. Gregory (1950, p. 61), though he mentioned igneous clasts in the basal Wasatch, did not report any igneous clasts in conglomerates that he assigned to the Kaiparowits Formation (p. 51).

Moderate quantities of feldspar and quartz granules in southwestern facies of the Straight Cliffs and Wahweap Formations (both of Late Cretaceous age) in the southeastern Kaiparowits region suggest that igneous or metamorphic rocks were probably present in the southwestern source area of those formations (Peterson, 1969, p. 198–200 and fig. 65; oral commun., 1971). The Kaiparowits Formation is arkosic and contains considerable quantities of altered feldspar (Robison, 1966, p. 27). Lohrengel (1968) indicated a probable western source area in central or southern Nevada for the Kaiparowits Formation.

Textures of the igneous clasts in the Canaan Peak Formation are those typical of hypabyssal intrusive or volcanic extrusive rocks. The nearest intrusive rocks exposed west of the Table Cliff Plateau occur in the Pine Valley Mountains, but these apparently intrude the Claron Formation and some of the overlying extrusive rocks and, therefore, are younger than the Canaan Peak Formation. Intrusive igneous rocks are widespread in eastern Nevada, and some are probably related to mid-Mesozoic orogeny and intrusion in that area (Misch, 1960; Misch and Hazzard, 1962; Armstrong and Hansen, 1966; Armstrong, 1968). The abundant quartzite clasts in the Canaan Peak Formation also indicate a probable western source area where lower Paleozoic quartzites were exposed by deformation in the Sevier orogenic belt (Armstrong, p. 445).

In general, sedimentary features such as sorting, stratification, and texture seem to be fairly uniform throughout the formation, both laterally and vertically; lenses, channels, and cross-stratification are typical of coarse fluvial deposits. The upper 50–100 feet of the formation, which locally intertongues with the Pine Hollow Formation, commonly appears to be somewhat more massive, coarser, and less well sorted and stratified. Clasts are predominantly quartzite, and there is a noticeable increase in the proportion of limestone clasts. Locally the conglomerate consists of pebbles and cobbles randomly distributed in a sandstone or sandy mudstone matrix. This conglomerate is well exposed in the upper part of the formation near the head of Right Hand Allen Creek (measured section 6b, fig. 3) where part of the conglomerate has a matrix of red sandy mudstone.

One or more unrecognized unconformities within the Canaan Peak Formation is possible, owing to the coarse nature of the deposit, the extreme variation in formation thickness, and the generally poor exposures. Because at least the lower beds of the formation have been deformed on the flanks of folds on both sides of the Table Cliff Plateau, one might expect sedimentary material from the rising folds to be shed into the Table Cliff syncline, and thus the upper part of the Canaan Peak conglomerate which locally intertongues with the Pine Hollow Formation might be interpreted as redistributed material that, genetically, is more closely related to the Pine Hollow Formation. Because of poor exposures, however, no distinction is possible, and for mapping purposes the formational boundary is placed at the top of the highest recognizable massive persistent conglomerate.

Available evidence indicates that there was considerable crustal instability in south-central Utah before and after the deposition of the Canaan Peak Formation. Thickness variations and facies changes in rocks of early Late Cretaceous age in the southern Kaiparowits region are evidence of sedimentation that occurred while slight but significant deformation was in progress (Peterson, 1969, p. 154). West of the Table Cliff region the Sevier orogenic belt was active in western Utah and eastern Nevada through most of Cretaceous time (Armstrong, 1968, p. 451–452 and fig. 7), and Late Cretaceous (early Laramide) tectonism occurred in central Utah (Spieker, 1946, p. 152–155).

The unconformity at the base of the Canaan Peak as well as a possible local unconformity about 400 feet below the top of the Kaiparowits Formation along the limb of the Dutton monocline suggest that there was tectonism shortly before deposition of the Canaan Peak Formation. Therefore, some movement on the Dutton monocline probably began as early as late Campanian time.

The lower part of the Canaan Peak Formation is Campanian in age as indicated by the fossil pollen and spores. If relatively rapid deposition of the coarse conglomeratic beds is assumed, the entire formation could be Late Cretaceous in age, but, because of local intertonguing with the Pine Hollow Formation as well as some differences in lithology and bedding characteristics of the uppermost beds discussed previously, the upper part of the Canaan Peak Formation is tentatively assigned to the Paleocene(?). Deposition of the lower part of the Canaan Peak Formation followed a period of erosion and was probably penecontemporaneous with late Sevier or early Laramide movements that affected foreland depositional basins east of the Sevier orogenic belt (Armstrong, 1968, p. 434–435).

About 7,000 feet of sediments was deposited in the Table Cliff region during Late Cretaceous time. The flood of coarse clastics deposited as the Canaan Peak Formation in the upper part of the section was probably produced by intense deformation in the Sevier orogenic belt. Locally, there were lacustrine environments, as indicated by palynomorphs (table 1) in mudstones interbedded with conglomerate in the lower part of the Canaan Peak Formation.

Some of the folding in the area is post-Canaan Peak and pre-Wasatch and occurred during some later phase of Laramide deformation, probably in Paleocene time. The angular unconformity separating the Wasatch Formation from the Canaan Peak Formation is most apparent on the Johns Valley anticline where more than 2,500 feet of sedimentary rocks was removed from the crest of the fold prior to deposition of the Wasatch Formation. This means that a considerable hiatus beneath the Wasatch on the Johns Valley structure is partly represented beneath the Table Cliff Plateau by rocks of the Canaan Peak and Pine Hollow Formations. It is not known what part of the section that is missing on the crest of the anticline was removed by pre-Canaan Peak erosion.

AGE AND CORRELATION

From paleobotanical evidence R. H. Tschudy of the U.S. Geological Survey determined a Late Cretaceous (Campanian) age for the lower part of the Canaan Peak Formation. Two samples collected from the type section on the south side of Canaan Peak

(D4437A and D4437B, table 1) and one from northeast side (D4008B) yielded a characteristic Late Cretaceous plant microfossil assemblage. On the basis of control data from Montana, the assemblage indicates a Campanian age, which is older than the Maestrichtian (Lance or Hell Creek) age generally assigned to the underlying Kaiparowits Formation. Because of the relatively abundant florule and the absence of younger (Tertiary) elements in any of the samples, it seems highly unlikely that these plant microfossils represent the reworking and deposition of older material. Large carbonized plant fragments are common, and one petrified log about 20 feet long and as much as 3 feet in diameter was in the lower part of the Canaan Peak Formation.

TABLE 1. — Palynomorphs from the Kaiparowits and Canaan Peak Formations

[Microfossils identified by R. H. Tschudy. Numerical values indicate number of species.]

Genus or code species	Kaiparowits Formation		Canaan Peak Formation		
	D4008A	D4100	D4008B	D4437A	D4437B
Proteacidites	×	2	×	3	2
Araucariacites[1]	×	×	×	×	×
Aquilapollenites	2	....	×	2	....
Tricolpites aff. *T. interangulus* Newman	×	×			
Inaperturopollenites	×	....	×	×	×
Eucommiidites	×				
Azolla[2]	×				
Ghoshispora[2]	×	×	×	×	....
Erdtmanipollis		×			
Rugubivesiculites[1]		×	×	×	×
Aquilapollenites cf. *A. senonicus*		×			
Classopollis		×	....	×	×
Kuylisporites (Hemitelia)[1]		×	....	×	....
Ephedra (striate)		×	....	×	....
Aequitriradites			×	....	×
Schizaea			×	×	....
Abietineaepollenites				×	....
Zlivisporis				×	....
Anemia				×	....
Appendicisporites				×	....
Interporopollenites					×
BCP_3-r16 (new genus)[1]				×	....

[1] On the basis of control data from Montana, *Araucariacites*, *Rugubivesiculites*, *Kuylisporites*, and BCP_3-r16 indicate an age older than Maestrichtian.

[2] On the basis of control data from Montana, *Azolla* and *Ghoshispora* indicate fresh-water (lacustrine) deposition.

PALEOBOTANICAL LOCALITY

D4008A: About 4 miles north-northeast of Canaan Peak in approximately the SE¼ sec. 16, T. 36 S., R. 1 E. (unsurveyed), Upper Valley quadrangle, Garfield County, Utah. From carbonaceous mudstone in upper part of Kaiparowits Formation.

D4008B: Same locality as D4008A, 380 feet higher on slope to the west. From carbonaceous mudstone interbed in conglomerate about 100 feet above base of Canaan Peak Formation.

D4100: At base of slope 1,400 feet north of Dry Creek in the NE¼NW¼ sec. 12, T. 35 S., R. 2 W., Sweetwater Creek quadrangle, Garfield County, Utah. From dark mudstone near top of Kaiparowits Formation.

D4437A: Near head of Wahweap Creek on south face of Canaan Peak in the SW¼SE¼NW¼ sec. 9, T. 37 S., R. 1 E., Canaan Peak quadrangle, Garfield County, Utah. From carbonaceous mudstone 57 feet above base of type section of Canaan Peak Formation.

D4437B: Same locality as D4437A. From lenticular mudstone 215 feet above base of Canaan Peak Formation.

According to Tschudy, the palynomorphs from the Canaan Peak Formation are suggestive of Claggett or Judith River equivalence (middle to lower Campanian). Several genera indicate an age older than Maestrichtian (Lance or Hell Creek). It may be that some of the genera were able to exist longer in southern Utah than in Montana. Marine beds of earliest Campanian age occur in the upper part of the Straight Cliffs Formation (Peterson, 1969, p. J17; oral commun., 1970), and the presence of about 4,000 feet of sedimentary rocks, including all of the Wahweap and Kaiparowits Formations, between the Canaan Peak Formation and the lowest Campanian rocks would seem to favor a younger (possibly middle to late Campanian) age for the lower part of the Canaan Peak. A definite age assignment will depend on collection and examination of more samples from the Kaiparowits and Canaan Peak Formations. The Canaan Peak Formation is probably equivalent to parts of the Price River Formation (Upper Cretaceous) and North Horn Formation (Upper Cretaceous and Paleocene) in central Utah.

Fossils from the underlying Kaiparowits Formation include fresh-water mollusks collected by Gregory and Moore (1931, p. 107) and studied by J. B. Reeside, Jr. Reeside assigned an age of middle to late Montana (approximate middle Campanian-Maestrichtian) to the mollusks and considered them to be similar to the fauna of the Fruitland Formation of New Mexico. Later collections by Gregory (1951, p. 42–43) from the Paunsaugunt Plateau were also studied by Reeside, and the formation was assigned a late Montana age on the basis of these invertebrates and a small collection of fragmentary vertebrate material examined by C. W. Gilmore. Lohrengel (1968), on the basis of a palynological study, considered the Kaiparowits Formation to be latest Cretaceous in age.

A few fresh-water clams and snails collected from the light-colored sandstone and mudstones in the upper part of the Kaiparowits Formation during the present investigation could be dated only as probable Late Cretaceous (D. W. Taylor, written commun., 1967). However, evidence from two samples collected from the upper part of the Kaiparowits Formation and three samples from the overlying Canaan Peak Formation (table 1), all submitted for pollen and spore analysis, suggests that the Kaiparowits Formation may be considerably older than previously believed.

PINE HOLLOW FORMATION

GENERAL LITHOLOGY AND LOCATION OF TYPE SECTION

The Pine Hollow Formation is herein named for exposures in Pine Hollow on the southeastern side of the Table Cliff Plateau (pl. 1). The formation is mainly a very fine grained to fine-grained clastic unit that occurs between the Canaan Peak Formation and the pink limestone member of the Wasatch Formation. The unit previously has been included in the Wasatch Formation. The Pine Hollow Formation, which consists of gray, purplish-gray, and red mudstone, bentonitic mudstone or claystone, and calcareous mudstone or earthy argillaceous limestone, contains lenticular interbeds of gray to red fine to coarse sandstone or conglomeratic sandstone, mostly in the lower part. The overall color of the formation varies from pale lavender to bright red.

The type section for the Pine Hollow Formation was measured near the head of the north fork of Pine Hollow, a tributary of Upper Valley Creek, on the southeast side of the Table Cliff Plateau. Pine Hollow can be reached by an unimproved forest road that leaves the Upper Valley highway near Dead Mare Wash. The last 1¼ miles to the outcrop must be traveled on foot from where the Pine Hollow road turns southwest to cross a low divide into the Dead Mare drainage. Several generalized sections of the Pine Hollow Formation are shown on the columnar sections (fig. 3), and selected sections are described in detail in "Stratigraphic Sections." Some of the sections are more accessible and, in part, better exposed than the type section.

The type section in Pine Hollow contains about an average thickness for the formation and seems to be fairly representative of the lithology. The formation is typical of the continental deposits of the region in that lithology, which, though it varies both laterally and vertically in detail, forms a distinct mappable unit in overall character.

DISTRIBUTION, THICKNESS, AND NATURE OF CONTACTS

In the Table Cliff Plateau, the Pine Hollow Formation is in a narrow band below the pink limestone member of the Wasatch. The unit is relatively soft and nonresistant, and outcrops generally form moderate to steep slopes below cliffs of pink Wasatch limestone. Locally, the Pine Hollow Formation contains beds of highly bentonitic mudstone or claystone and, where unimproved roads cross these strata, travel is difficult in wet weather.

The Pine Hollow Formation on Canaan Peak is generally covered by forest, soil, or surficial debris composed of limestone from the Wasatch Formation. On the main ridge of Canaan Peak, good exposures of the Wasatch occur only at the south end where several hundred feet of pink and white limestone beds dip as much as 35° W., whereas the Canaan Peak Formation just southwest of the main ridge dips as much as 12° E. Although the white beds on Canaan Peak strongly resemble, and are probably equivalent to, the white limestone member of the Wasatch Formation, they occur at an altitude about 500 feet lower than the base of the white limestone member in the Table Cliff Plateau. The beds of Wasatch limestone are mostly shattered, and some fractures are filled with calcite crystals. The strike of the limestone beds follows the trend of the main ridge, which is northwesterly. Therefore, most, and possibly all, of the Wasatch Formation on Canaan Peak is interpreted as a large gravity or toreva-block slide lying on beds of the Canaan Peak and Pine Hollow Formations.

The Pine Hollow Formation appears to be thickest near the axis of the Table Cliff syncline where it is about 400 feet thick, and it generally thins to the north and west to 100 or less feet. Measured section 5 (fig. 3) at the head of Right Hand Allen Creek contains at least 320 feet but, because the upper part of the formation is partly obscured by slump and talus from the overlying Wasatch, the upper contact cannot be placed with accuracy.

On the east flank of the Johns Valley anticline, the Pine Hollow Formation pinches out or is truncated by the Wasatch Formation. The unit also pinches out on the Dutton monocline north of Main Canyon, but the nature of the contact is obscured because the area is covered by soil and surficial deposits.

The basal beds of the Pine Hollow Formation, where exposed, generally appear to be conformable on, and in several places intertongue with, the Canaan Peak Formation. In general, the contact and the overlying and underlying beds dip gently toward the axis of the Table Cliff syncline. Some irregularity of the contact was observed near the head of Right Hand Allen Creek (section A–A′, pl. 1; section 6b, fig. 3), where the lowermost beds of the Pine Hollow Formation appear to overlap westward a surface with a few feet of relief on the top of the Canaan Peak Formation. Here the beds above and below the contact dip about 5° southwestward into the syncline.

The upper contact with the Wasatch Formation at most places in the central part of the Table Cliff Plateau appears to be conformable, but it is marked by a sharp lithologic and color break, from purplish-gray or red mudstone of the Pine Hollow Formation to tan or pale-orange calcareous sandstone or calcarenite of the Wasatch Formation. Commonly the contact is marked by a break in slope, and in many places on the east and west sides of the Table Cliff Plateau it is marked by a line of springs and seeps. The upper contact is commonly obscured by debris from the more resistant limestone in the Wasatch.

On the northwest side of the Table Cliff Plateau, on the east flank of the Johns Valley anticline, there appears to be a slight angular discordance between the Pine Hollow Formation and the overlying Wasatch. This was observed at measured section 7b (fig. 3) and northward where the Pine Hollow Formation dips gently to the northeast and the overlying Wasatch is flat or dips gently to the north or northwest. Though no extensive erosion or channeling of the uppermost Pine Hollow beds was observed away from the Johns Valley anticline, the discordance evident near the Johns Valley fold and the generally coarser material in the basal Wasatch beds would tend to support the possibility of an unconformable relationship throughout the area.

North of Sweetwater Creek, the Pine Hollow Formation is thin, and the upper contact, at the first resistant ledge-forming beds of calcarenite or limestone typical of the basal Wasatch Formation, is difficult to map. Locally, an interval of red mudstone, as much as 30 feet thick and similar to that in the Pine Hollow Formation, occurs above the lower resistant calcarenite or limestone beds. This is interpreted as a probable intertonguing relationship between the Pine Hollow and Wasatch Formations in the basin northeast of the Johns Valley anticline.

SOURCE AND MODE OF DEPOSITION

The fine-grained clastic sedimentary rocks that predominate in the Pine Hollow Formation suggest deposition in a low-energy fluvial and lacustrine environment. As mentioned previously, the basal beds intertongue locally with coarse conglomerate of the Canaan Peak Formation. Conglomeratic sandstones and thin lenticular conglomerates that occur within the Pine Hollow Formation, generally in the lower part, seem to be similar in composition to the Canaan Peak sandstones and conglomerates. The conglomerates are thin, generally less than 5 feet thick, and limited in extent compared with the Canaan Peak conglomerate.

There is a significant increase in calcium carbonate content, both as cementing material and as limestone clasts, in the Pine Hollow Formation; the proportion of calcareous beds seems to be intermediate between the relatively low calcium carbonate content of the Canaan Peak Formation and the predominantly clastic limestone of the Wasatch Formation. The increase in limestone clasts probably reflects an increasing exposure of limestone in the source area.

The Pine Hollow Formation is considered to be largely postorogenic, but it may have been deposited as the influence of Laramide deformation was waning in the Table Cliff region. The Pine Hollow Formation thickens in the Table Cliff syncline and along the Dutton monocline; it is not known to what extent this thickening is due to subsidence during deposition as opposed to the filling of an existing depression between highs in the vicinity of the Johns Valley and Dutton folds. The low-angle unconformity between the Pine Hollow and Wasatch Formations on the east flank of the Johns Valley anticline indicates that some movement followed deposition of the Pine Hollow Formation.

AGE AND CORRELATION

No paleontological evidence is available for dating the Pine Hollow Formation because no megafossils were found in the formation and samples examined for palynomorphs were barren. Assigning a Late Cretaceous and Paleocene(?) age to the Canaan Peak Formation and a Paleocene age to the lower part of the Wasatch Formation requires assignment of the Pine Hollow to Paleocene(?). In the absence of any precise dating information, however, a latest Cretaceous age cannot be discounted. The Pine Hollow may be partly equivalent in age to the North Horn Formation of central Utah.

In gross lithology the Canaan Peak and Pine Hollow Formations resemble, respectively, the Price River (Upper Cretaceous) and North Horn (Upper Cretaceous and Paleocene) Formations in central Utah. The Price River is mostly conglomerate and sandstone, and the North Horn consists of variegated shales and associated conglomerates, sandstones, and fresh-water limestones. Spieker (1949, p. 24) reported that the coarse clasts in the Price River conglomerates are mainly quartzites and that limestone clasts are rare and locally absent. Limestone clasts are more common in the North Horn conglomerates. As discussed previously, limestone clasts are rare in the lower part of the Canaan Peak conglomerates and become more common in the uppermost beds and in the conglomeratic units of the Pine Hollow Formation. Lithologic comparisons are of questionable value, however, because of lateral facies changes, intergradation, and intertonguing inherent in sediments deposited in the alternating piedmont, floodplain, and lacustrine environments that prevailed in central and southern Utah east of the orogenic belt in Late Cretaceous and early Tertiary time. Spieker (1949, p. 28–30) pointed out the unreliability of basing correlations on lithology without the actual tracing of beds.

The structural relationship between the Canaan Peak, Pine Hollow, and Wasatch Formations near the Johns Valley anticline appears to be analogous, on a much smaller scale, to the relationship described by Spieker (1949, p. 48–51) between the Price River, North Horn, and Flagstaff Formations along the Wasatch monocline in Sixmile Canyon, about 100 miles north of the Table Cliff Plateau. The North Horn Formation (Upper Cretaceous and Paleocene) is locally separated from the Flagstaff Limestone (Paleocene and Eocene?) by an angular unconformity that changes, within a short distance, to a conformable contact with no apparent break (Spieker, 1946, p. 134). The probable interfingering of the Pine Hollow and Wasatch Formations northeast of the Johns Valley anticline could be similar to the intertonguing of the North Horn and Flagstaff Formations.

At the north end of the Johns Valley anticline (section C–C′, pl. 1), the Canaan Peak and Pine Hollow Formations dip to the east; the Wasatch Formation, which overlaps the older rocks, dips to the west. The westward dips are a result of post-Wasatch monoclinal flexing and faulting along the trend of the Paunsaugunt fault zone. The later westward flexing would result in some unfolding of dips on the east flank of the older Johns Valley anticline.

WASATCH FORMATION

For present mapping of the Table Cliff Plateau, the Wasatch Formation is divided into three informal members that are given generalized descriptive names similar to those used by previous workers in the region. From bottom to top, the units are the pink limestone member, the white limestone member, and the variegated sandstone member.

PINK LIMESTONE MEMBER

The lower member of the Wasatch Formation in the Table Cliff region is principally a sequence, averaging about 800 feet in thickness, which consists of dense to fine-grained clastic limestones, limy mudstones, calcareous sandstones, and minor conglomerate. When viewed from a distance, the member is pale orange or pink. Individual beds in the unit are gray, tan, white, pink, or red. Schneider (1967, p. 157) studied samples from measured sections of these beds (his Cedar Breaks Formation) and reported that the rocks are composed in large part of calcilutite and calcisiltite with some argillaceous calcisiltite, calcarenite, quartz siltstone, sandstone, and conglomerate. The rocks vary laterally and vertically in the unit, and bedding ranges from thin to massive. Resistance to weathering varies considerably in different beds, locally producing notched cliffs and fluted columns and spires similar to, though not as extensively developed as, those in Bryce Canyon. Along the northeast side of the Table Cliff Plateau and on the slopes below Griffin Top, the unit mostly forms moderate to steep forested slopes.

No fossils were recovered by the writer from the pink limestone member. Though a few broken shell fragments occur in some thin dark limestone beds in the upper part, no identifiable shells were found. McFall (1955, p. 76) collected one species of gastropod from 250 feet above the base of the Wasatch that was identified by Aurèle La Rocque as *Physa bridgerensis* Meek and assigned to the Eocene. La Rocque (1960, p. 40) later reported *Physa bridgerensis* from part of the Flagstaff Limestone in central Utah that he assigned to the Paleocene. The limited evidence available seems to support a probable correlation of the pink limestone member in the Table Cliff Plateau with part of the Flagstaff Limestone (Paleocene and lower Eocene?).

WHITE LIMESTONE MEMBER

The middle member of the Wasatch Formation in the Table Cliff Plateau appears to be conformable on the pink limestone member and is mostly massive light-gray to white hard dense to finely crystalline limestone containing minor thin interbeds of yellowish-gray siltstone or mudstone. Locally, the massive limestone contains small vugs filled with calcite crystals. The member averages about 550 feet in thickness in the Table Cliff Plateau, and the generally resistant limestone caps most of the plateau and forms the conspicuous white rim above the cliffs of pink limestone. Northeastward along the slopes below Griffin Top, the white limestone member thins to less than 200 feet southeast of Griffin Top, probably by gradation or intertonguing into coarser clastic sediments over the structural high formed by the Dutton monocline. Surficial deposits cover most of the Wasatch Formation on the slopes south of Griffin Top, obscuring the nature of the thinning of the white limestone member.

The white limestone member in the Table Cliff Plateau yielded a small collection of fresh-water mollusks identified by D. W. Taylor (written commun., 1967). The collection included *Physa pleromatis* White and ?*Physa bridgerensis* Meek. According to Taylor, the collection is early to middle Eocene but not earliest Eocene (Gray Bull horizon of Granger, 1914). The member is, at most, correlative with only the upper part of the Flagstaff, and it could be younger. This would mean that the member might also be, in part, correlative with the Green River Formation. Locally in the Wasatch Plateau, lacustrine sedimentation appears to have been continuous from Flagstaff into Green River time (La Rocque, 1960, p. 8), and it seems reasonable to assume that the same condition could have existed in the Table Cliff region. It should be pointed out that, although the white limestone in the Table Cliff Plateau may be, in part, of Green River age, the lithology and depositional environment are very different from those of typical Green River beds.

VARIEGATED SANDSTONE MEMBER

The upper member of the Wasatch Formation is composed of interbedded red, pink, and purplish-gray very fine grained friable sandstone, siltstone, mudstone, and limy mudstone and gray to white fine- to medium-grained sandstone and calcareous sandstone. A unit of gray to light-brown medium- to coarse-grained sandstone and pebble conglomerate as much as 40 feet thick occurs in many places at the base. The conglomerate contains conspicuous black chert pebbles and lighter colored pebbles of limestone and quartzite. The member, about 300 feet thick where it is separated by a slight angular unconformity from latite flows capping Barney Top, increases to more than 600 feet near the head of Birch Creek west of Griffin Top. The lower part of the member at Barney Top is poorly exposed but appears to be predominantly friable red and purplish-gray very fine grained sandstone or siltstone above the basal sandstone and conglomerate. In the northern part of the Table Cliff Plateau, a greater proportion of white sandstone interbeds appears in the unit. At Birch Creek white calcareous sandstone and gray "salt and pepper" sandstone are interbedded with pink, red, and purple-hued sandstone and mudstone.

The basal conglomerate is missing at Birch Creek, and red friable sandstone lies on the white limestone member. Some of the coarser sandstones appear to be slightly tuffaceous, particularly in the upper part of the member. Because of its friable nature the member is commonly buried beneath debris from the overlying volcanic rocks. Some of the better exposures occur along the head of Birch Creek. The exact nature of the lower contact with the white limestone member is obscured owing to generally poor exposures. Where the basal conglomerate is present, one would expect some channeling of the top of the white limestone. At the head of Corn Creek on the northeast side of the Table Cliff Plateau, a fairly good exposure shows a sharp contact; that the lowermost layer of pebbles of the conglomerate is imbedded in the top of the white limestone would seem to indicate a conformable relationship.

No fossils were found in the variegated sandstone member. On the basis of stratigraphic position, the member is considered to be Eocene in age. In color and lithology the variegated sandstone member somewhat resembles the predominantly clastic Colton Formation, occurring between, and intertonguing with, the Flagstaff and Green River Formations in parts of central Utah (Spieker, 1949, p. 34, and fig. 3, p. 12). Similarities between the white limestone and variegated sandstone members and the Flagstaff and Colton sequence near Mount Terrel north of the Table Cliff region are discussed in the following section on the regional distribution of the Wasatch Formation. At present, knowledge of the variegated sandstone member, particularly with regard to its northward extent beneath the volcanic rocks, is insufficient to relate it with certainty to the Colton Formation.

The upper member of the Wasatch is overlain at Birch Creek by several hundred feet of white highly tuffaceous sandstone, volcanic breccia, and latite welded tuff that caps the southern Aquarius Plateau. Locally, the white tuffaceous sandstone contains unidentified white tubular plant(?) remains very much like those found in white tuffaceous beds in the southeastern Sevier Plateau and in the type Brian Head Formation near Cedar Breaks National Monument. The white tuffaceous sandstone seems to be a distinctive unit and is not included in the Wasatch Formation. The nature of the contact between the upper member of the Wasatch Formation and the white tuffaceous sandstone in the southern Aquarius Plateau is not known because of cover by volcanic debris. The unit is believed to grade laterally northward into tuffaceous and calcareous beds containing siliceous limestone that may be unconformable on the upper member of the Wasatch Formation.

The latite welded tuff overlying the white tuffaceous beds in the southern Aquarius Plateau on Griffin Top and lying directly on the lower part of the variegated sandstone member of the Wasatch Formation in the Table Cliff Plateau at Barney Top is the tuff of Osiris (P. L. Williams, oral commun., 1970) which is radiometrically dated as probable early Miocene(?) (Damon, 1968, p. 42) from a sample collected from the Sevier Plateau by P. D. Rowley.

REGIONAL DISTRIBUTION

Field observations in areas adjacent to the Table Cliff region indicate that more detailed mapping of the lower Tertiary sedimentary rocks in the Paunsaugunt, Sevier, and southern Aquarius

Plateaus will be required to understand the regional stratigraphic relationships better. Comparative petrographic studies and radiometric age dating might provide evidence that would permit more precise correlation of these strata across the southern High Plateaus of Utah and perhaps with some of the prevolcanic sedimentary rocks north of the Marysvale volcanic field.

On the basis of brief reconnaissance west of the Table Cliff Plateau, the writer believes that the white limestone beds that dip slightly to the northwest on the lower slopes near the mouth of Hunts Creek in the southeastern part of the Sevier Plateau are equivalent to the white limestone member in the Table Cliff Plateau. The two white limestone beds in the Sevier Plateau appear to be several hundred feet thick—including a separation by possibly 100 feet of yellowish-gray sandstone—and contain unidentified fresh-water gastropods. Yellowish-gray siltstone and mudstone near the middle of the white limestone member in the Table Cliff Plateau may be a basinward facies of the yellow sandstone in the southeastern Sevier Plateau.

Schneider (1967, sec. 3, p. 152) reported conglomerate and associated channeling assigned to the basal Brian Head Formation overlying his pink Cedar Breaks Formation on Limekiln Creek on the west side of the Sevier Plateau northeast of Panguitch. The conglomerate was examined briefly by the writer, and, though outcrops are widely scattered and some faulting is involved, an attempt was made to trace it eastward across the southern part of the Sevier Plateau; what is believed to be the same conglomerate intertongues with the uppermost part of the white limestone in the vicinity of the west fork of Hunts Creek.

Schneider (1967, p. 152) considered the massive white limestone in the Table Cliff Plateau to be a facies of Gregory's Brian Head Formation. If the relationship reported in the previous paragraph is correct, the basal Brian Head reported at Limekiln Creek would be equivalent to only the upper part of the white limestone in the Table Cliff Plateau.

No evidence of an erosional break at the base of the white limestone member was observed in the Table Cliff Plateau. The contact commonly occurs at a sharp color break, but locally some fairly massive white limestone beds occur in the upper part of the pink limestone member, making it difficult to recognize the contact in areas of poor exposure. At Limekiln Creek, however, the relationships suggest at least a disconformity at the top of the pink limestone (Schneider's Cedar Breaks–Brian Head contact). This would mean that a basal conglomerate probably less than 50 feet thick and a depositional break at Limekiln Creek about 20 miles west of the Table Cliff Plateau are represented in the Table Cliff Plateau by more than 500 feet of aphanitic to microcrystalline white limestone. The conglomerate at Limekiln Creek is overlain by a sequence of interbedded red, white, and gray sandstone that resembles parts of the variegated sandstone member of the Wasatch Formation of this report in the Table Cliff Plateau. The red, white, and gray beds at Limekiln Creek are overlain by a thick sequence of green highly tuffaceous sediments, volcanic conglomerate, and flows.

The writer, in company with R. J. Hackman of the U.S. Geological Survey, visited scattered outcrops along the west side of the Aquarius Plateau north from Birch Creek. Hackman (oral commun., 1969) has mapped several faults parallel to the west face of the Aquarius Plateau north of Birch Creek; the volcanic cap of the plateau is downfaulted on the west along these faults.

A topographic feature, Black Ridge, runs northward along the west flank of the Aquarius Plateau from near Birch Creek to North Creek, a distance of about 5 miles. Black Ridge appears to be a major downfaulted block on the west flank of the Aquarius Plateau, part of a series of faults that parallel the trend of the Paunsaugunt fault. Scattered rock exposures along the slopes beneath the volcanic rocks capping Black Ridge, when viewed from the highway west of the plateau, appear to be the pink limestone member of the Wasatch overlain by the white limestone member. On the basis of closer examination of these outcrops and structural considerations, the writer believes that these beds exposed along Black Ridge are equivalent to the variegated sandstone member of the Wasatch overlain by beds of white calcareous and tuffaceous sandstone, white siliceous limestone, and bands of dark chalcedony.

According to Gregory (1944, p. 590), the Wasatch Formation decreases abruptly in thickness northward from the abandoned town of Widtsoe (pl. 1), and the white limestone becomes so siliceous, even tuffaceous, that it is indistinguishable from the classic Brian Head Formation. The northernmost outcrop of the white limestone member of the Wasatch that was seen by the writer west of the trend of Black Ridge occurs just northwest of the mouth of Birch Creek canyon and east-southeast of the junction of Birch Creek and Horse Creek. Here the white limestone dips about 8° NW. and lies about 1,500 feet lower than its altitude near the head of Birch Creek.

The writer believes that some of the beds north of Birch Creek considered by Gregory (1944, p. 590) to be the pink and overlying white limestones of the Wasatch Formation are actually the variegated sandstone member of this report overlain by white tuffaceous sedimentary rocks equivalent to the white tuffaceous beds between the Wasatch Formation and the volcanic rocks near the head of Birch Creek. This means that, stratigraphically, the base of the white beds exposed along Black Ridge would be at least 1,000 feet higher than the base of the white limestone member in the Table Cliff Plateau.

Schneider (1967, p. 165, and loc. I, p. 146) reported a partial section of his Cedar Breaks Formation near the north end of Black Ridge in the vicinity of North Creek about 5 miles north of Birch Creek. Here he measured 534 feet of red very fine grained clastic sedimentary rocks, separated from overlying beds by an angular unconformity. White calcareous and tuffaceous sandstone and siliceous limestone overlie the red beds in that area. The writer believes that the beds assigned to the Cedar Breaks Formation at North Creek are equivalent to the variegated sandstone member of the Wasatch rather than to the pink limestone member.

From the southern end of the Aquarius Plateau, the Wasatch Formation overlaps eastward progressively older rocks on the pre-Wasatch folds. Exposures are rare because of cover by forests and volcanic debris, but R. J. Hackman and the writer located several Wasatch outcrops in the area. An outcrop of the white limestone member topped by black chert pebble conglomerate common to the base of the variegated sandstone member was found north of Twitchell Creek about 3 miles northeast of Griffin Top and 2 miles east of Barker Reservoir. Some 9 miles farther to the northeast in the vicinity of Rogers Peak near the crest of the Escalante monocline, what is believed to be the same dark chert pebble conglomerate appears to lie on Jurassic rocks.

In the Table Cliff region the chert pebble conglomerate common to the base of the variegated sandstone member is a good marker bed and can be traced for a distance of about 25 miles to the northeast from the southern part of the Table Cliff Plateau. As mentioned previously, however, the conglomerate pinches out westward near the head of Birch Creek west of Griffin Top.

In the vicinity of Mount Terrel, about 50 miles north-northeast of the Table Cliff region, a thick white limestone unit is overlain by chert pebble conglomerate and red beds, a stratigraphic sequence similar to the white limestone and variegated sandstone members of the Wasatch Formation in the Table Cliff region. Williams and Hackman (1971) mapped the white limestone near Mount Terrel as Flagstaff Limestone and the conglomerate and red beds as Colton Formation. About 12 miles northwest of Mount Terrel, McGookey (1960, p. 599) reported 529 feet of Colton Formation thinning toward the west.

The depositional environment in the Table Cliff region when the variegated sandstone member was deposited on the white limestone member seems to have been similar to the environment near Mount Terrel when the conglomerate and red beds of the Colton were deposited on the white lacustrine limestone of the Flagstaff. However, because of the distance involved and the fact that the intervening area is covered by volcanic rocks of the Fish Lake, Awapa, and Aquarius Plateaus, any suggested correlation of the sequence near Mount Terrel with beds in the Table Cliff region must at present be considered highly speculative.

STRATIGRAPHIC SECTIONS

Type section of the Canaan Peak Formation

[Sections 1a and 1b (fig. 3). Section 1a measured on south face of Canaan Peak up tributary at head of Wahweap Creek in the SE¼NW¼ sec. 9, T. 37 S., R. 1 E., Salt Lake meridian, Garfield County, Utah. Section 1b offset one-fourth mile east of top of section 1a]

	Thickness (ft)
Section 1b:	
Pine Hollow Formation (part):	
25. Siltstone, mottled pink, white, and gray, calcareous, soft; covered above	5
24. Limestone, white, very fine grained; weathers to lumpy or irregular surface	1
23. Mudstone, tan, calcareous; grades to mottled red in upper part; poorly exposed	10
22. Limestone, like unit 24	1
21. Siltstone or silty limestone, mottled yellow, pink, and gray, calcareous, soft; grades to claystone in upper 2 ft; base of Pine Hollow Formation	12
Total measured Pine Hollow Formation	29
Section 1a:	
Canaan Peak Formation:	
20. Sandstone, light-gray to light-brown, fine-grained, flat-bedded, hard, resistant; ledge former; limestone debris above; approximate top of Canaan Peak Formation	6
19. Conglomerate, pebble to cobble, light- to brownish-gray, poorly stratified	15
18. Sandstone, tan to gray, coarse-grained, conglomeratic; contains pebble lenses and stringers	10

Section 1a — Continued

	Thickness (ft)
Canaan Peak Formation — Continued	
17. Conglomerate, pebble to cobble, light- to brownish-gray, poorly stratified; about 5 percent of unit is lenticular interbeds of fine- to coarse-grained sandstone	95
16. Sandstone, light-gray to light-brown, medium- to coarse-grained, conglomeratic, resistant	10
15. Sandstone, tan, fine-grained, resistant; ledge former	6
14. Conglomerate, pebble, brownish-gray, massive; about 5 percent of unit is small cobbles	14
13. Sandstone, light-brown, coarse-grained, conglomeratic	2
12. Conglomerate, pebble to cobble, light-brown, massive; contains some cobbles as large as 9 in. in diameter	10
11. Sandstone, tan, medium-grained, lenticular	2
10. Conglomerate, pebble to cobble, light-gray to brown, poorly stratified; paleobotanical sample D4437B from thin lenticular carbonaceous mudstone bed about 10 ft below top; poorly exposed gray sandstone and mudstone in lower 10 ft	89
9. Conglomerate, pebble to cobble, light-gray to brown, massive; pebbles predominate, scattered cobbles as much as 8 in. in diameter; contains a few lenticular sandstone interbeds as much as 1.5 ft thick in upper 20 ft	51
8. Mudstone, light-gray; contains scattered light-brown ironstone concretions a few inches in diameter; poorly exposed	16
7. Mudstone, light-gray, arenaceous; contains white siltstone galls, isolated pebbles, and scattered carbonized wood fragments; carbonaceous in lower 4 ft; paleobotanical sample D4437A from 1 ft above base	13
6. Sandstone, tan (weathers rust), fine-grained, flat-bedded, friable	4
5. Conglomerate, pebble, light-gray to brown; contains a few thin sandstone lenses; pebbles are mostly 1 or 2 in. in diameter; upper 5 ft contains coarser pebbles and is about 10 percent small cobbles	14
4. Conglomerate, pebble to cobble, gray to tan; about 15–20 percent of unit is cobbles as much as 6 in. in diameter	20
3. Sandstone, whitish-gray, fine- to medium-grained; lower half is conglomeratic and contains lenses of pebbles and cobbles	4
2. Conglomerate, pebble to cobble, brownish-gray to light-brown, poorly stratified; contains cobbles as much as 7 in. in diameter in upper 5 ft; base is concordant with unit below, but contact is slightly irregular	14
Total Canaan Peak Formation	395
Kaiparowits Formation (part):	
1. Sandstone, light- to brownish-gray, "salt and pepper," very fine grained, friable	10
Total measured Kaiparowits Formation	10

Type section of the Pine Hollow Formation

[Section 4 (fig. 3) measured near the head of the north fork of Pine Hollow on the southeast side of the Table Cliff Plateau in approximately the NE¼SE¼ sec. 3, T. 36 S., R. 1 W., Salt Lake meridian, Garfield County, Utah]

	Thickness (ft)
Wasatch Formation (part):	
12. Calcarenite, light-gray, fine- to coarse-grained, thick-bedded to massive, crossbedded; water seep at base; appears conformable on unit below	15
Total measured Wasatch Formation	15
Pine Hollow Formation:	
11. Mudstone, gray, highly argillaceous; grades to red, mottled-gray mudstone in upper half	32
10. Sandstone, gray, medium- to coarse-grained, calcareous, lenticular	5
9. Mudstone, red to pale-purple (weathers purplish gray); isolated irregular patches are mottled white	15
8. Limestone, pale-purple, clastic, silty and arenaceous; soft and nonresistant but contains a few harder irregular white patches; 1.5-ft bed of dark claystone 47 ft above base; parts of unit poorly exposed	60
7. Sandstone, tan, conglomeratic, calcareous; contains scattered pebbles less than 1 in. in diameter	4
6. Mudstone, calcareous, and argillaceous limestone; light gray to red (weathers pale purplish gray), nonresistant; poorly exposed	45
5. Mudstone, pink to light-purplish-gray, bentonitic	5
4. Mudstone, red, calcareous; contains white very fine grained calcarenite interbeds 1–3 ft thick	20
3. Sandstone, light-gray to red, fine- to coarse-grained, locally conglomeratic; contains pebble conglomerate 1.5 ft thick at base	15
2. Limestone, argillaceous, lenticular, nonresistant, mottled red, yellow, and gray	6
Total Pine Hollow Formation	207
Canaan Peak Formation (part):	
1. Conglomerate, pebble to cobble, tan to light-brown, massive; contains thin lenses of light-brown fine- to coarse-grained sandstone	25
Total measured Canaan Peak Formation	25

Partial measured section of the Pine Hollow and Canaan Peak Formations

[Section 6b (fig. 3) measured near head of Right Hand Allen Creek in approximately the SE¼NE¼ sec. 24, T. 35 S., R. 1 W. (unsurveyed), Salt Lake meridian, Garfield County, Utah]

	Thickness (ft)
Pine Hollow Formation (part):	
20. Claystone, red, soft; poorly exposed; units above are covered by surficial deposits	3
19. Claystone, medium-gray, soft	1
18. Sandstone, white to light-gray, fine-grained	1
17. Claystone, medium-gray, bentonitic	21

Pine Hollow Formation (part) — Continued	Thickness (ft)
16. Mudstone; reddish or purplish gray in upper half grading to light-gray in lower half	15
15. Mudstone, light-gray, calcareous; contains small white limestone concretions	2
14. Mudstone, red, bentonitic; contains scattered pebbles as much as 0.5 in. in diameter	10
13. Limestone, red, silty to argillaceous, and highly calcareous mudstone; contains scattered pebbles and irregularly shaped pods of very fine grained sandstone and, in a few places, thin beds of white earthy limestone less than 1 ft thick; contains a few lenses of conglomeratic sandstone less than 2 ft thick in upper 20 ft	55
12. Sandstone, white, very fine grained to fine-grained, massive; locally mottled pink	10
11. Sandstone, light-gray, fine-grained, conglomeratic, lenticular; contains scattered pebbles as much as 2 in. in diameter	5
10. Mudstone, red, calcareous, soft	1
9. Sandstone, white, medium-grained, calcareous, lenticular	2
8. Mudstone, red, calcareous, and silty argillaceous limestone; contains scattered white limestone concretions	10
7. Limestone, white, medium-grained, arenaceous, lenticular	2
6. Mudstone, red, calcareous; contains white fine-grained calcareous sandstone interbeds less than 4 in. thick	10
5. Limestone, light-gray, fine- to medium-grained, arenaceous, hard; contains scattered small subangular pebbles; weathers to rough surface	9
4. Sandstone, light- to pinkish-gray, fine- to coarse-grained, conglomeratic, calcareous; about 10 percent of unit is crossbedded lenses and channels of pebble conglomerate having pebbles as much as 3 in. in diameter	10
Total measured Pine Hollow Formation	167

Canaan Peak Formation (part):	
3. Conglomerate, pebble to cobble, light-brown to tan, pink, or red; poorly stratified; forms thick massive unit; upper 23 ft is gray to tan cobble conglomerate containing cobbles as much as 8 in. in diameter in a calcareous sandstone matrix; a few light-brown fine- to coarse-grained sandstone lenses as much as 3 ft thick 115–151 ft above base; cobbles as much as 6 in. in diameter in lower 20 ft	174
2. Sandstone, light- to pinkish-gray, fine-grained, massive; contains pebble lenses and pods and isolated rounded fragments of "salt and pepper" sandstone	10
1. Sandstone, light-gray, conglomeratic; locally stained pink or yellowish brown; contains irregular pods of siltstone or fine-grained sandstone showing contorted color banding. A few lenses of red mudstone and small pebble conglomerate contain multicolored pebbles as much as 3 in. in diameter in upper 5 ft; covered below	15
Total measured Canaan Peak Formation	199

Partial measured section of the Pine Hollow Formation

[Section 8 (fig. 3) measured on north side of wash half a mile north-northeast of the Pine Lake campground in approximately the NW¼NW¼ sec. 19, T. 35 S., R. 1 W. (unsurveyed), Salt Lake meridian, Garfield County, Utah]

	Thickness (ft)
Pine Hollow Formation (part):	
6. Mudstone, purplish-gray, argillaceous, and claystone; partly covered by surficial limestone debris from above; covered above; approximate top of Pine Hollow Formation	20
5. Mudstone, red, arenaceous; contains scattered pebbles as much as 2 in. in diameter; white fine-grained sandstone interbeds as much as 2 ft thick in upper 10 ft	51
4. Sandstone, white, fine-grained, friable; locally stained red	5
3. Sandstone, reddish-brown, conglomeratic, lenticular, resistant	2
2. Mudstone, red to medium-gray, bentonitic; mostly gray in middle of unit; small pebbles scattered in arenaceous upper and lower 10 ft	52
1. Sandstone, white to pink, very fine grained, friable, poorly stratified; contains a few lenses of conglomerate having pebbles as much as 4 in. in diameter; base is estimated to be 40 ft above top of Canaan Peak Formation; covered below	35
Total measured Pine Hollow Formation	165

Partial measured section of the Canaan Peak Formation

[Section 10 (fig. 3) measured just north of the road along Sweetwater Creek, 400 feet west of bench mark 7984 in the SE¼SE¼ sec. 24, T. 34 S., R. 2 W., Salt Lake meridian, Garfield County, Utah]

	Thickness (ft)
Pine Hollow Formation (part):	
10. Mudstone, red, calcareous; poorly exposed on top of ridge	5
Total measured Pine Hollow Formation	5
Canaan Peak Formation (part):	
9. Conglomerate, pebble to cobble, gray to pink; contains quartzite cobbles as much as 7 in. in diameter and scattered gray limestone pebbles	10
8. Sandstone, gray to tan, conglomeratic, calcareous; locally stained pink; a 3-ft-thick bed of red arenaceous mudstone at top	27
7. Sandstone, light-brown, coarse; contains scattered pebbles	3
6. Conglomerate, pebble, tan to light-brown; contains a few small cobbles	15
5. Conglomerate, pebble to cobble, light-gray; cobbles composed mostly of white quartzite, as much as 5 in. in diameter; local sandstone lenses	25
4. Conglomerate, pebble to cobble, tan to light-brown; poorly stratified; a thin red-mudstone bed having scattered pebbles and small limestone nodules occurs about 5 ft below top; contains cobbles as much as 7 in. in diameter in upper 10 ft	40
3. Sandstone, light-brown, medium- to coarse-grained, resistant; ledge former	5
2. Conglomerate, pebble to cobble, tan to light-brown, massive, poorly stratified; contains lenticular sandstone interbeds and layers of cobbles as much as 8 in. in diameter; dark chert pebbles are numerous in some beds	55

Canaan Peak Formation (part) — Continued	*Thickness (ft)*
1. Conglomerate, pebble to cobble, light-brown; mostly covered slope obscured by gravel from above; base of section on road; covered below	80
Total measured Canaan Peak Formation	260

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