Four New Members of the Upper Cretaceous Straight Cliffs Formation in the Southeastern Kaiparowits Region Kane County, Utah

By FRED PETERSON

CONTRIBUTIONS TO STRATIGRAPHY

GEOLOGICAL SURVEY BULLETIN 1274-J

Description of new stratigraphic units in a coal-bearing formation of southern Utah

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1969

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

William T. Pecora, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price 30 cents (paper cover)

CONTENTS

ILLUSTRATIONS

CONTRIBUTIONS TO STRATIGRAPHY

FOUR NEW MEMBERS OF THE UPPER CRETACEOUS STRAIGHT CLIFFS FORMATION IN THE SOUTHEASTERN KAIPAROWITS REGION, KANE COUNTY, UTAH

By FRED PETERSON

ABSTRACT

The Straight Cliffs Formation is divided here into four new members in the southeastern Kaiparowits region of south-central Utah. In ascending order, the members and their thicknesses at the type localities are the Tibbet Canyon Member, 104 feet; the Smoky Hollow Member, 116 feet; the John Henry Member, 741 feet; and the Drip Tank Member, 141 feet. The Tibbet Canyon and Drip Tank Members are generally cliff forming sandstone units, whereas the Smoky Hollow and John Henry Members are ledge- and slope-forming units composed of interbedded sandstone, mudstone, and coal. The John Henry Member contains the major coal resources of the Kaiparowits region.

The Straight Cliffs Formation was deposited in marine and nonmarine environments on the southwest side of the Late Cretaceous Western Interior seaway. The Tibbet Canyon Member was deposited mainly in beach and shallow-water marine environments, and the Smoky Hollow Member was deposited in fluvial, flood-plain, lagoonal, and paludal environments. A period of regional erosion occurred at the end of deposition of the Smoky Hollow Member, and an unconformity separates the Smoky Hollow Member from the overlying John Henry Member. The John Henry Member was deposited in marine and nonmarine environments similar to those of the two underlying members, and the Drip Tank Member was deposited in fluvial environments.

Fossil evidence indicates that the Tibbet Canyon and Smoky Hollow Members are middle to about early late Turonian in age and correlate approximately with the middle of the Carlile Shale in the standard reference sequence for the Western Interior. The John Henry and Drip Tank Members are about middle Coniacian to early Campanian in age and correlate approximately with the middle and upper parts of the Niobrara Formation.

INTRODUCTION

The Straight Cliffs Sandstone was named by Gregory and Moore (1931, p. 91) for exposures along the Straight Cliffs escarpment several miles south of Escalante, Utah, in the northern part

of the Kaiparowits Plateau (fig. 1). In most parts of the plateau the formation contains significant amounts of rocks other than sandstone, and for this reason Peterson and Waldrop (1965, p. 62–63) applied the more general name Straight Cliffs Formation to the formation.

Recent mapping in the southeastern Kaiparowits region indicates that the Straight Cliffs Formation can be divided into four members, and observations by the writer indicate that these members can be recognized elsewhere in the Kaiparowits Plateau. In ascending order, the members herein named are the Tibbet Canyon Member, the Smoky Hollow Member, the John Henry Member, and the Drip Tank Member. The Smoky Hollow and John Henry Members are subdivided into several informal units on the basis of characteristic associations of sedimentary structures, lithologies, or fossils.

Although the main purpose of this report is to describe the new members, the report also describes for the first time an intraformational unconformity that separates the Smoky Hollow Member from the John Henry Member. The best evidence of the unconformity is found in the southeastern Kaiparowits region, but the unconformity may extend throughout the Kaiparowits Plateau.

FIELDWORK AND ACKNOWLEDGMENTS

This report is a byproduct of a comprehensive stratigraphic study and geologic-mapping program in the Kaiparowits region that has been in progress since 1963. The purpose of the work is to evaluate the occurrence and distribution of coal beds in order to classify Federal lands for their coal resources. Mapping was done at the scale of 1:24,000, and sections of parts of the Straight Cliffs Formation were measured about 1–2 miles apart along outcrops of the formation. Lateral relations were determined by tracing key sandstone beds and member contacts in the field. Other geologists in the mapping program are W. E. Bowers, E. V. Stephens, H. A. Waldrop, and H. D. Zeller, all of the U.S. Geological Survey. W. A. Cobban, also of the Survey, identified the fossils. Capable assistance in the field was given by C. J. Flynn, G. W. Horton, B. E. Law, O. L. Ligon, and R. L. Sutton.

TIBBET CANYON MEMBER

The Tibbet Canyon Member is named for a cliff-forming sandstone unit at the base of the Straight Cliffs Formation that lies above the generally slope forming Tropic Shale. The member was informally named the lower sandstone member of the Straight Cliffs Formation by Peterson and Waldrop (1965, p. 63). The Tibbet Canyon is well exposed in the southwestern and central

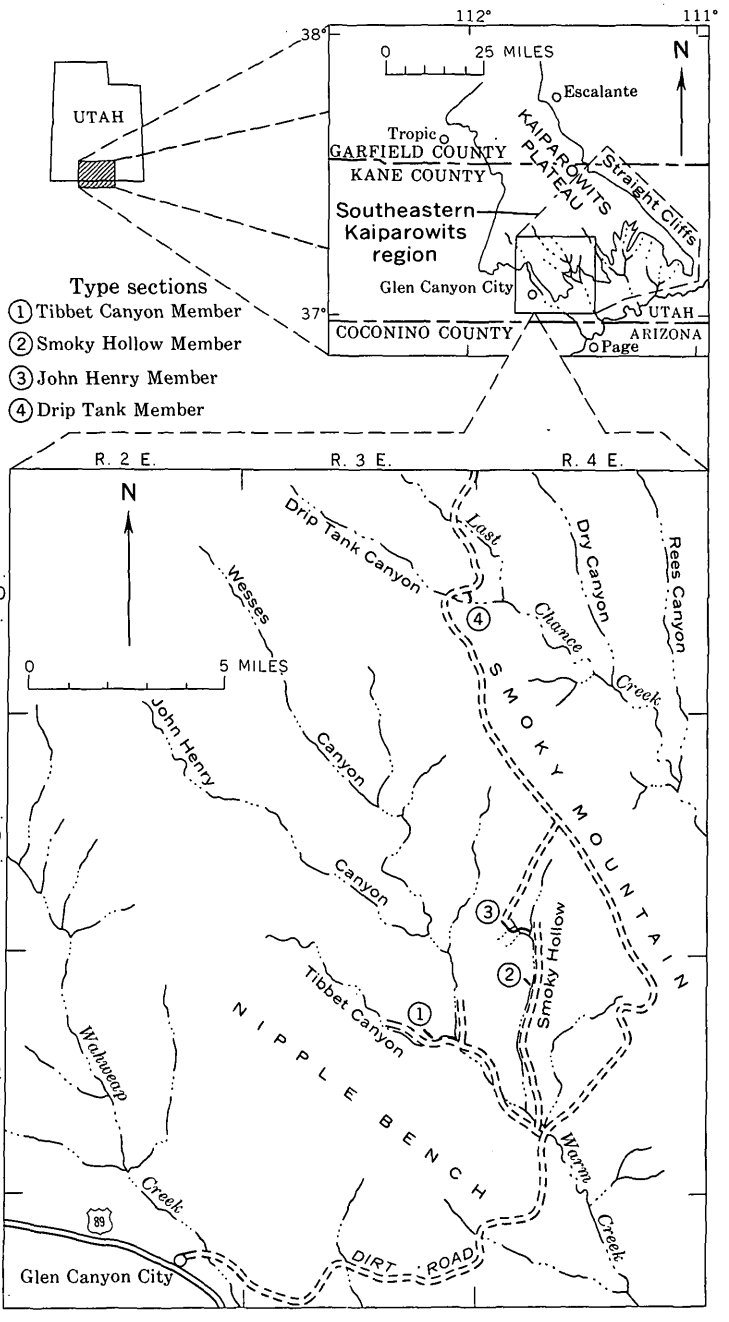

FIGURE 1. — Southern part of Kaiparowits Plateau and location of type sections of members in Straight Cliffs Formation.

parts of the region, but farther northeast, and especially at the Straight Cliffs escarpment, the member is largely concealed by talus. The type locality of the Tibbet Canyon Member is near the mouth of Tibbet Canyon (fig. 1) and is shown in figure 2. The type section is illustrated in figure 3, and the measured section is given at the end of the report.

The Tibbet Canyon Member is about 70–185 feet thick in the southeastern Kaiparowits region. In the northwestern Kaiparowits region, near Tropic, Utah, the lowest unit in a section measured by J. C. Lawrence (in Robison, 1966, p. 23) and tentatively assigned by the writer to the Tibbet Canyon Member is 84 feet thick.

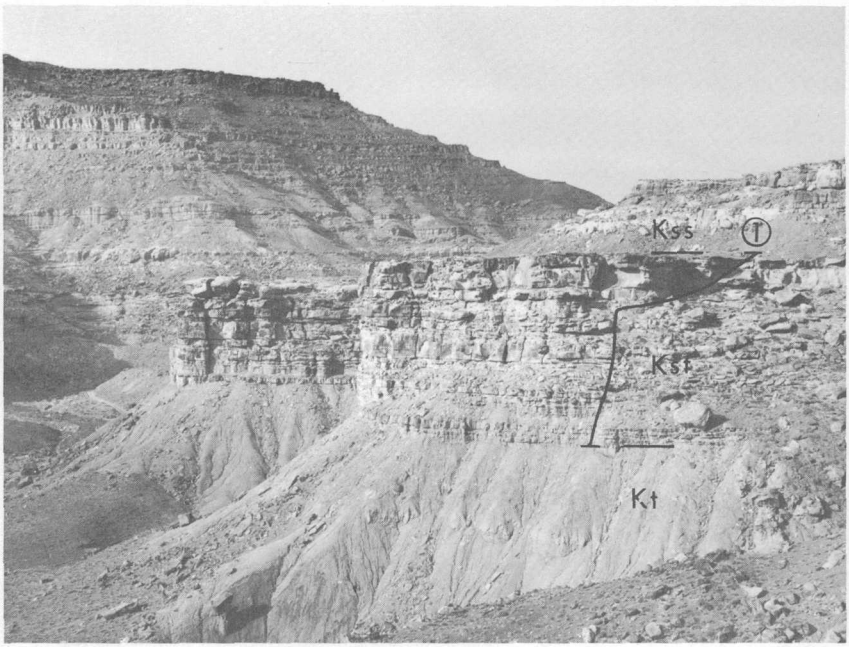

FIGURE 2. — Type locality of Tibbet Canyon Member. View is toward the west on the north side of Tibbet Canyon. 1, Type measured section; member is 104 feet thick. Kt, Tropic Shale; Kst, Tibbet Canyon Member; Kss, Smoky Hollow Member.

The Tibbet Canyon is composed mainly of yellowish-gray to grayish-orange very fine grained to medium-grained horizontally stratified and cross-stratified sandstone. The lower part of the member is interbedded with dusky-yellow to light-olive-gray mudstone beds that are southwestward- or southward-thinning tongues of the Tropic Shale. The lower contact is generally placed at the base of the lowest persistent sandstone bed, but at several

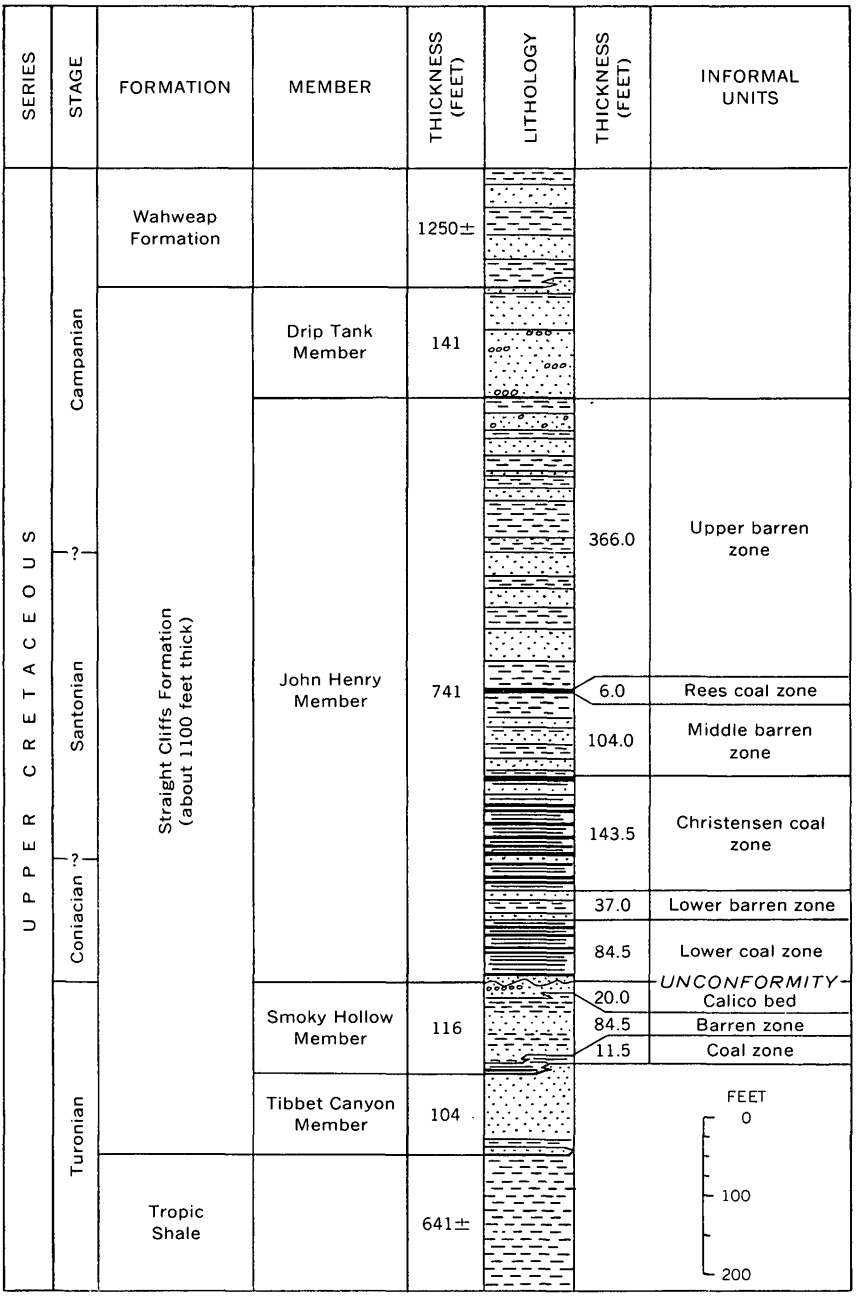

FIGURE 3. — Composite columnar section of members in Straight Cliffs Formation at type localities in southern part of Kaiparowits Plateau, Utah.

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localities the vertical sequence of beds is entirely gradational, and the lower contact is placed arbitrarily where sandstone is the dominant lithology. The upper contact is generally sharp and is placed where the cliff-forming sandstone of the Tibbet Canyon Member is in contact with the lowest overlying mudstone, carbonaceous mudstone, or coal bed of the Smoky Hollow Member.

Evidence that the Tibbet Canyon was deposited in beach and shallow-marine environments includes fossils—inoceramids, cephalopods, shark teeth, and *Ophiomorpha* sp.—and its stratigraphic position between underlying offshore marine beds in the Tropic Shale and overlying lagoonal and paludal beds in the Smoky Hollow Member. A vertical sequence of bedding structures that is typical of beach and nearshore marine deposition of sandstone beds in the John Henry Member is rarely present and, consequently, is of little value for interpreting environments of deposition in the Tibbet Canyon Member. The Tibbet Canyon was deposited during a northward or northeastward regression of the shoreline of the Late Cretaceous Western Interior seaway.

The pelecypod *Inoceramus howelli* White was found in the Tibbet Canyon Member and, according to W. A. Cobban (oral commun., 1966), indicates a middle Turonian age and suggests an approximate correlation of the Tibbet Canyon with the Blue Hill Shale Member of the Carlile Shale in the standard reference sequence for the Western Interior (Cobban and Reeside, 1952).

SMOKY HOLLOW MEMBER

The Smoky Hollow Member is a cliff- and slope-forming unit of interbedded sandstone, mudstone, carbonaceous mudstone, and coal that lies above the cliff-forming Tibbet Canyon Member. Strata of the Smoky Hollow Member were included in the lower part of the middle member of the Straight Cliffs Formation by Peterson and Waldrop (1965, p. 63–64). Subsequent investigation has shown that an unconformity divides the middle member of Peterson and Waldrop into two units that are herein named the Smoky Hollow and John Henry Members of the Straight Cliffs Formation. The Smoky Hollow is moderately well exposed in the southwestern and central parts of the region, but farther northeast, and especially along the Straight Cliffs escarpment, the member is generally concealed by talus. The type locality of the Smoky Hollow Member is on the west side of Smoky Hollow (fig. 1) and is shown in figure 4. The type section is illustrated in figure 3, and the measured section is given at the end of the report.

The Smoky Hollow Member is about 24–132 feet thick in the southeastern Kaiparowits region. In the northwestern Kaiparowits

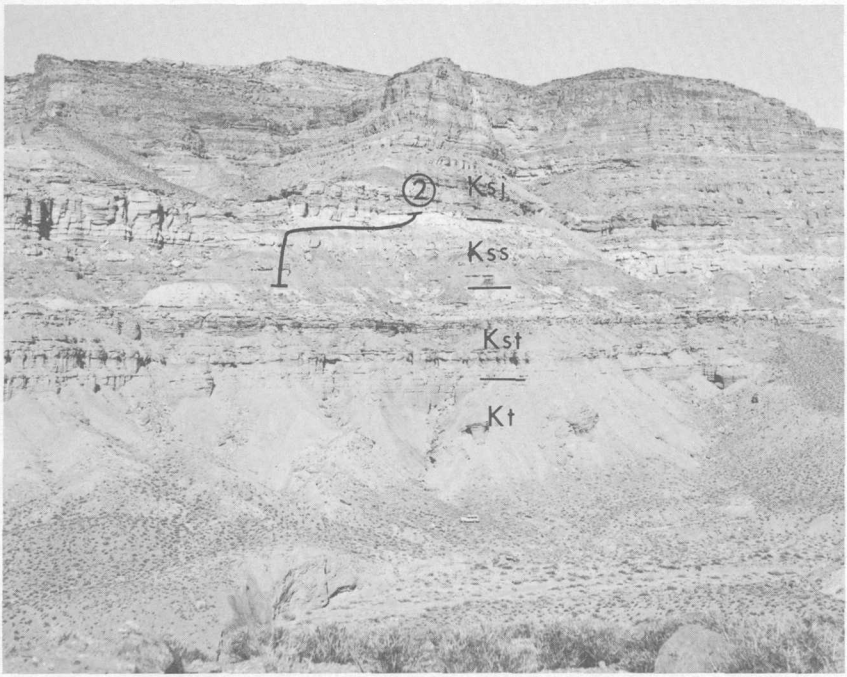

FIGURE 4. — Type locality of Smoky Hollow Member. View is toward the west across Smoky Hollow. 2, Type measured section; member is 116 feet thick. Kt, Tropic Shale; Kst, Tibbet Canyon Member; Kss, Smoky Hollow Member; Ksj, John Henry Member.

region, the group of beds that includes units 2–9 above the base of a section measured by J. C. Lawrence (in Robison, 1966, p. 23) and tentatively assigned by the writer to the Smoky Hollow Member is 231 feet thick. About 9 miles northwest of Escalante, Utah, the Smoky Hollow is about 331 feet thick (E. V. Stephens, oral commun., 1967).

The Smoky Hollow consists of three informal units: a coal zone at the base, a barren zone in the middle, and the Calico bed at the top (fig. 5). The coal zone ranges in thickness from 0 to about 47 feet and contains pale-brown to black carbonaceous mudstone and coal beds that range in thickness from 0 to about 4 feet but generally are less than 2 feet thick. The barren zone, so named because it lacks coal, is about 13–110 feet thick. It contains dusky-yellow to light-olive-gray bentonitic mudstone interbedded with pale-yellowish-brown and grayish-orange very fine grained to medium-grained horizontally stratified and cross-stratified sandstone. Scattered quartz and chert granules and chert pebbles occur locally in the sandstone beds. The Calico bed ranges

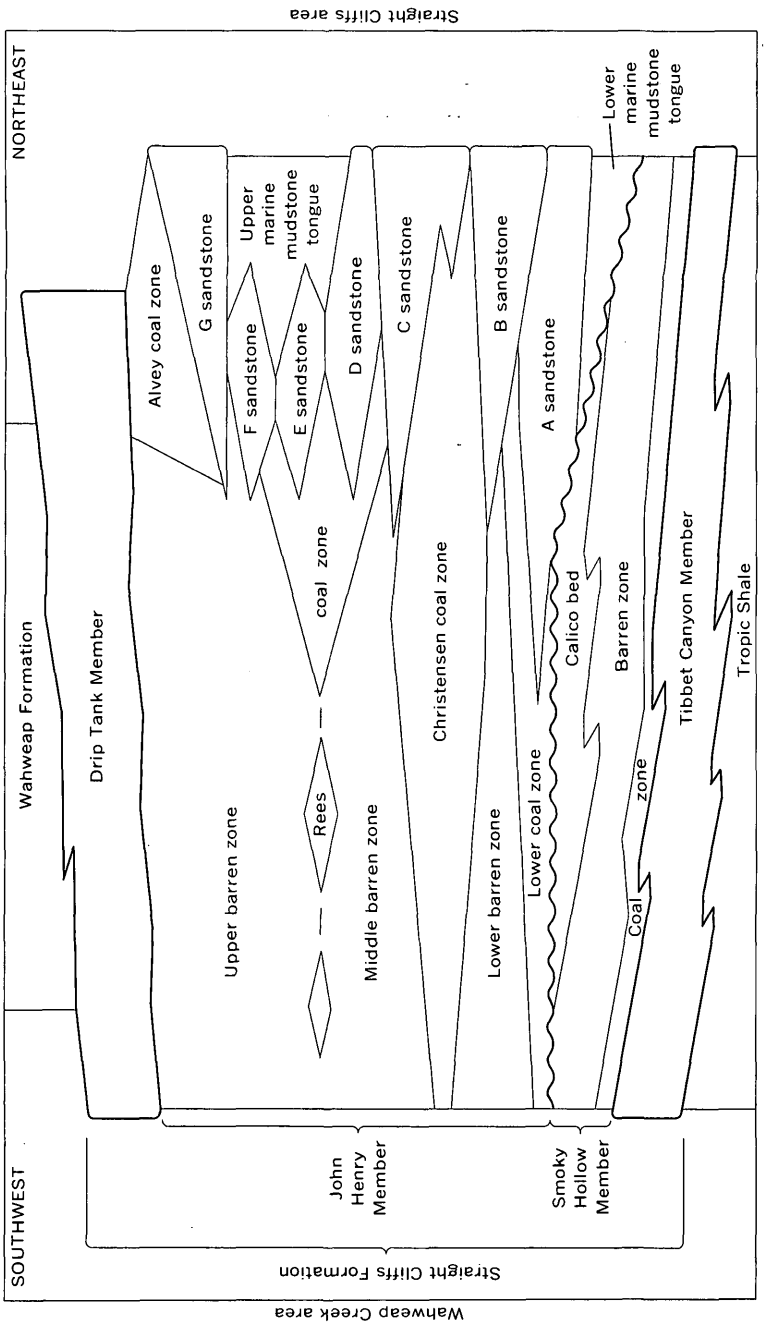

FIGURE 5. — Relations of members and informal units in the Straight Cliffs Formation, southeastern Kaiparowits region, Utah.

in thickness from 0 to about 51 feet and consists of white to very light gray fine- to coarse-grained poorly sorted cross-stratified sandstone. Locally, scattered quartz and chert granules, chert pebbles, or conglomerate lenses are common. The Calico bed interfingers with the upper part of the barren zone and is unconformably overlain by the John Henry Member.

The Smoky Hollow Member was deposited in a variety of nonmarine environments. The presence of coal and carbonaceous mudstone suggests deposition of the coal zone in paludal and lagoonal environments. The barren zone contains sandstone and mudstone strata that were deposited in fluvial and flood-plain environments. Fluvial sandstones in the barren zone contain abundant low- and high-angle medium-scale trough cross-stratification, crossbedding that dips down the axis of channels, and cut-and-fill structures. Ripple cross-laminae are common in the upper 1–3 feet of many of these beds. Very thin bedded to thin-bedded mudstone and interbedded laminated, ripple cross-laminated, or ripple drift-laminated sandstone are interpreted as flood-plain deposits because they are found between the fluvial sandstones. The dusky-yellow to light-olive-gray bentonitic mudstone beds are especially common in strata interpreted as flood-plain deposits in the southeastern Kaiparowits region. The Calico bed contains channels and other bedding structures similar to those in the fluvial sandstones of the barren zone, although the Calico bed generally lacks ripple cross-lamination and is composed of more poorly sorted sandstone. These criteria suggest that the Calico bed was deposited mainly in fluvial environments. The above data and the interfingering of the Smoky Hollow Member with the Tibbet Canyon Member (fig. 5) indicate that the Smoky Hollow Member was deposited in fluvial, flood-plain, lagoonal, and paludal environments on the landward or generally southwest side of beach or shallow-marine sands of the Tibbet Canyon Member.

Fossils diagnostic of age have not been found in the Smoky Hollow, but the lower part of the member grades northeastward into the upper part of the Tibbet Canyon Member (fig. 5), which contains *Inoceramus howelli* White. This indicates that the lower part of the Smoky Hollow is middle Turonian in age. Because the Smoky Hollow Member consists of a continuous sequence of beds, lacks unconformities, and interfingers with the Tibbet Canyon Member, the upper part of the Smoky Hollow Member is probably only slightly younger than the lower part. Thus, the Smoky Hollow Member is middle Turonian to perhaps early late Turonian in age. In terms of the standard reference sequence for the Western Interior region (Cobban and Reeside, 1952), the Smoky Hollow Member

correlates approximately with the upper part of the Blue Hill Shale Member and possibly with the lower part of the Turner Sandy Member of the Carlile Shale.

UNCONFORMITY

Detailed mapping disclosed that an unconformity separates the Smoky Hollow Member from the overlying John Henry Member and that this unconformity is the only clearly defined stratigraphic horizon in the Straight Cliffs Formation that can be traced throughout the region. The lateral persistence of the unconformity in a sequence of lenticular and interfingering marine and nonmarine beds suggests that the unconformity has greater stratigraphic significance than any of the numerous local unconformities in the Straight Cliffs Formation. Evidence of the unconformity is divided into three categories: local evidence that can be recognized at the outcrop; regional evidence from thickness variations and truncation of strata across a wide area; and paleontological evidence that indicates the period of time represented by the unconformity.

Local evidence of the unconformity is as follows:

1. Bedding planes at the top of the Smoky Hollow Member that dip at low angles are truncated by strata at the base of the John Henry Member (fig. 6).
2. Fluvial channel sandstones at the base of the John Henry rest on an erosion surface that is cut down as much as 10 feet into the top of the Smoky Hollow (fig. 7); however, local relief on the unconformity is generally less than 5 feet where channel sandstones are not present.
3. A basal brown conglomeratic sandstone bed of the John Henry Member contains lithologic and bedding features which suggest that it formed as a residual deposit on the Calico bed after regional erosion had ended (fig. 6). This sandstone bed is medium gray to pale yellowish brown and weathers pale brown. It is about 0–15 feet thick and consists of fine- to coarse-grained well-cemented sandstone that contains carbonaceous grains and flecks, thin lenses of carbonaceous mudstone, and scattered quartz and chert granules and chert pebbles which occur locally as small conglomerate lenses. Bedding is generally indistinct, but locally it is irregularly horizontal and very thin bedded to thin bedded; cross-stratification is rare. Vertical external molds of plants that were probably root systems also occur locally. The general lack of current bedding structures and the similar size and composition of the grains, granules, and pebbles in this bed and

FIGURE 6. — Unconformity (arrows) between Calico bed at top of Smoky Hollow Member and overlying basal brown conglomeratic sandstone bed of John Henry Member in Tibbet Canyon (NE¼SW¼SE¼ sec. 10, T. 42 S., R. 3 E.). Note low-angle truncation of bedding planes in Calico bed.

in the Calico bed suggest that much of the material in the basal brown conglomeratic bed was weathered from the Calico bed. The basal brown conglomeratic sandstone bed interfingers with other strata in the John Henry Member, and the bed is only present at the base of the nonmarine part of the John Henry Member, which is in the southwestern and central parts of the region.

4. Conglomerate lenses of chert and quartzite pebbles and cobbles occur locally as a basal conglomerate at the bottom of the marine part of the John Henry Member in the northeastern part of the region.

Regional evidence of the unconformity is found in low-angle truncation of the Smoky Hollow Member in the southwestern and northeastern parts of the region. Near Wahweap Creek about 3 miles east-southeast of Glen Canyon City, the Calico bed at the top of the Smoky Hollow Member was removed by erosion before deposition of the John Henry Member, and the John Henry rests directly on the barren zone of the Smoky Hollow Member (fig. 5). In this area the Smoky Hollow is only 24 feet thick. In the central

FIGURE 7. — Fluvial channel sandstone at base of John Henry Member (Ksj) resting on erosion surface cut into Calico bed at top of Smoky Hollow Member (Kss) in Smoky Hollow (NE¼SE¼SE¼ sec. 32, T. 41 S., R. 4 E.). A sharp contrast between the white Calico bed and the darker sandstones of the John Henry Member is evident. Calico bed is about 18 feet thick on either side of channel.

part of the region the Calico bed is present and the Smoky Hollow Member is 121 feet thick. The upper approximately 60 feet of the Tibbet Canyon Member in the central area grades southwestward into the lower part of the Smoky Hollow Member, resulting in a total of 181 feet of strata in the central area that is equivalent to or younger than the 24 feet of Smoky Hollow in the Wahweap Creek area. From these figures it is apparent that an approximate minimum of 157 feet of Smoky Hollow Member was removed from the southwestern part of the region prior to deposition of the overlying John Henry Member.

The Calico bed was also eroded from the northeastern part of the region prior to deposition of the John Henry Member (fig. 5). Although detailed stratigrapic relations cannot be determined accurately because of talus cover, no interfingering of the Smoky Hollow and Tibbet Canyon Members is known to occur in this area, and the contact between these members is apparently a time-equivalent or nearly time equivalent surface. The Smoky Hollow is 31 feet thick at the east end of the Straight Cliffs escarp-

ment and 121 feet thick in the central area, so that an approximate minimum of 90 feet of strata is inferred to have been eroded from the Smoky Hollow Member in the area at the east end of the Straight Cliffs escarpment before deposition of the John Henry Member.

The above-mentioned figures of at least 157 feet of erosion in the southwestern part of the region and 90 feet of erosion in the northeastern part of the region indicate the minimum amount of strata that was removed prior to deposition of the John Henry Member. Considerably more strata were probably deposited and subsequently eroded from the top of the Smoky Hollow Member because local evidence of the unconformity is found in the central area and because the Calico bed and the Smoky Hollow Member are thicker in the northwestern part of the Kaiparowits Plateau.

Robison (1966, p. 20) found that a conglomeratic sandstone bed in the Tropic, Utah, area ranges in thickness from 60 to 360 feet. This sandstone bed is probably the Calico bed, and the greater thickness of the Calico bed in the Tropic area suggests either northwestward depositional thickening or that the Smoky Hollow Member may have been considerably thicker in the southeastern Kaiparowits region before erosion and subsequent deposition of the John Henry Member. The presence of the unconformity in the Tropic area may account for the anomalous range in thickness of Robison's (1966, p. 20) lower member of the Straight Cliffs Formation, which probably includes the Tibbet Canyon, Smoky Hollow, and John Henry (lower part) Members. In a section 9 miles northwest of Escalante, Utah, measured by E. V. Stephens (oral commun., 1967), the Calico bed is 104 feet thick and the Smoky Hollow Member is 331 feet thick. These measurements also suggest that northwestward depositional thickening occurred or that the Smoky Hollow may have been thicker in the southeastern Kaiparowits region.

Fossil evidence also suggests the presence of an unconformity between the John Henry and Smoky Hollow Members. In strata below the unconformity, the part of the Smoky Hollow above the youngest part of the Tibbet Canyon (fig. 5) does not contain fossils diagnostic of age, but the Tibbet Canyon Member contains the middle Turonian fossil *Inoceramus howelli* White. The presence of this fossil and the apparently continuous deposition of the Tibbet Canyon and succeeding beds of the Smoky Hollow Member suggest that the upper part of the Smoky Hollow is of middle Turonian or early late Turonian age. In strata above the unconformity, the lower marine mudstone tongue of the John Henry

Member contains *Inoceramus stantoni* Sokolow and *Protexanites shoshonensis* (Meek) in a bed about 50–70 feet above the base, and these fossils indicate an age no older than about middle Coniacian, according to W. A. Cobban (oral commun., 1966) and Scott and Cobban (1964, p. L15).

The paleontological evidence suggests that the approximate minimum time-stratigraphic interval represented by the unconformity includes the uppermost part of the Turonian Stage and the lower part of the Coniacian Stage. In terms of the standard reference sequence for the Western Interior region, strata correlative with the upper part of the Carlile Shale and the lower and lower middle parts of the Niobrara Formation were eroded or never deposited in the southeastern Kaiparowits region.

The unconformity at the Carlile-Niobrara boundary has been reported in other parts of the Colorado Plateau: by Dane (1960) in the San Juan Basin of New Mexico, and by Hunt, Averitt, and Miller (1953, p. 83) in the Henry basin of south-central Utah. Reconnaissance studies by the writer suggest that the unconformity is probably present in Black Mesa basin of northeastern Arizona at the base of the marine shale tongue of the Toreva Formation.

JOHN HENRY MEMBER

The John Henry Member is named for a cliff- and slope-forming unit of interbedded sandstone, mudstone, carbonaceous mudstone, and coal that lies below the cliff-forming Drip Tank Member. The John Henry was included in the upper part of the middle member of the Straight Cliffs Formation by Peterson and Waldrop (1965, p. 63–64). The member is moderately well exposed in the southwestern part of the region. In the central part of the region where many of the coal beds have been burned, the member is generally concealed by talus accumulations of baked mudstone and sandstone, and exposures are best near the bottoms of dry washes. In the northeastern part of the region, slope-forming units of coal and mudstone are generally concealed by talus and soil. The type locality of the John Henry Member is in Smoky Hollow, about 3 miles east of John Henry Canyon (fig. 1); it is shown in figure 8. The type section is illustrated in figure 3, and the measured section is given at the end of the report.

The John Henry Member is about 660 feet thick in the southwestern part of the region and thickens irregularly northeastward to about 1,080 feet near the Straight Cliffs escarpment. In the northwestern Kaiparowits region, the group of beds that includes

units 10–31 above the base of a section measured by J. C. Lawrence (in Robison, 1966, p. 21–23) and tentatively assigned by the writer to the John Henry Member is 657 feet thick.

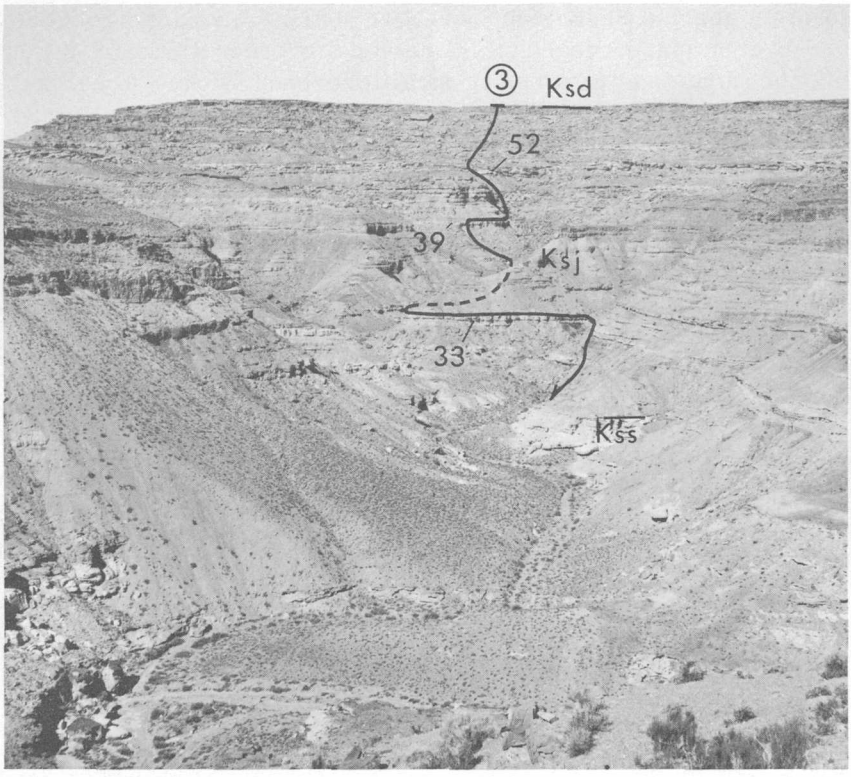

FIGURE 8. — Type locality of John Henry Member. View is toward the west across Smoky Hollow up small tributary canyon. 3, Type measured section; member is 741 feet thick. 33, 39, 52 indicate prominent sandstone units in measured section at end of report. Kss, Smoky Hollow Member; Ksj, John Henry Member; Ksd, Drip Tank Member.

The John Henry Member consists of a predominantly nonmarine facies in the southwestern and central parts of the region and a predominantly marine facies in the northeastern part. The predominantly nonmarine facies consists of six informal units that are distinguished primarily by the presence or absence of coal. In ascending order, these are lower coal zone, lower barren zone, Christensen coal zone, middle barren zone, Rees coal zone, and upper barren zone. Typical lithologies in the nonmarine facies include pale-yellowish-brown to grayish-orange very fine grained to medium-grained horizontally stratified and cross-stratified sand-

stone, dusky-yellow to light-olive-gray bentonitic mudstone, dark-gray to black carbonaceous mudstone, and coal.

The predominantly marine facies in the northeastern part of the region at the Straight Cliffs escarpment consists of five cliff-forming marine sandstone beds, two marine mudstone tongues, and two nonmarine coal zones. In ascending order, these are lower marine mudstone tongue, A sandstone bed, B sandstone bed, Christensen coal zone, C sandstone bed, D sandstone bed, upper marine mudstone tongue, G sandstone bed, and Alvey coal zone. The upper marine mudstone tongue grades southwestward into the E and F sandstone beds. Typical lithologies in the marine facies include very light gray to moderate-yellowish-brown very fine grained to fine-grained horizontally stratified and cross-stratified sandstone and light-olive-gray mudstone. Conglomerate lenses of quartz granules, chert pebbles, and quartzite pebbles and cobbles are locally present in the lower marine mudstone tongue and in the A sandstone bed. The generalized relations of the various units in both the marine and the nonmarine facies of the John Henry Member are shown diagrammatically in figure 5.

The John Henry Member contains coal deposits of considerable economic potential, and several companies are drilling to evaluate the subsurface extent and continuity of the coal beds. The lower coal zone generally contains coal beds that are less than 3 feet thick. Locally, however, one or two of the coal beds are thicker than 4 feet, and the thickest bed found measured 12.6 feet. The Christensen coal zone contains the thickest and most extensive coal beds in the region. This zone generally includes one to four coal beds that are 4 feet or more thick, and the thickest bed found measured 29.6 feet. The Henderson coal zone of Robison (1966, p. 37) in the Tropic, Utah, area is probably correlative with the Christensen coal zone. The Rees coal zone contains one or two coal beds that are less than 3 feet thick in the southwestern part of the region, but in the central part of the region this zone contains as many as three coal beds that are 4 feet or more thick, and the thickest bed found measured 9.5 feet. Most of the Alvey coal zone has been eroded from the southeastern Kaiparowits region, but one bed is 11.8 feet thick. Doelling (1967, p. 8, coal zones A and B) found several coal beds that were more than 4 feet thick in the Alvey coal zone near Escalante, Utah. The Christensen and Alvey coal zones are named at the suggestion of H. D. Zeller of the U.S. Geological Survey after coal mines in the northern part of the Kaiparowits region. The Rees coal zone is named for Rees Canyon, a small tributary canyon to Last Chance Creek canyon in the central part of the southeastern Kaiparowits region.

The John Henry Member was deposited in a variety of marine and nonmarine environments. The nonmarine facies of the member contains lithologies and bedding structures that are similar to those in the Smoky Hollow Member and that indicate deposition in fluvial, flood-plain, paludal, and lagoonal environments. Sandstone and mudstone beds in the marine facies of the member contain marine fossils that include inoceramids, cephalopods, shark teeth, and *Ophiomorpha* sp. The A through G marine sandstone beds locally contain a vertical sequence of bedding structures that aids in distinguishing these beds from nonmarine sandstones. The lower part of the sequence contains horizontal stratification and low-angle medium- to large-scale trough cross-stratification, the middle part contains low- and high-angle medium-scale trough cross-stratification, and the upper part contains very low angle (less than about 5°) medium- to large-scale wedge-planar cross-stratification. Bedding structures and sequences similar to these have been found in sands deposited in modern beach and shallow-water environments (Hoyt and Weimer, 1963; McKee, 1957; Thompson, 1937), and similar criteria have been used for interpreting beach and shallow-water environments of deposition for certain Cretaceous marine sandstones in Wyoming (Jacka, 1965) and Colorado (Masters, 1967). The criteria listed above and the interfingering relations shown in figure 5 indicate that the nonmarine facies was deposited in fluvial, flood-plain, lagoonal, and paludal environments and that the marine facies was deposited in beach, shallow-water, and offshore marine environments.

Fossils that are diagnostic of age are scarce in the John Henry Member, but several collections allow reasonably good correlation and age assignments. *Inoceramus stantoni* Sokolow and *Protexanites shoshonensis* (Meek) were found in the lower marine mudstone tongue; *Inoceramus (Volviceramus) involutus* Sowerby was found in the A sandstone bed; *Inoceramus* sp. which has a truncate anterior margin came from about the top of the upper marine mudstone tongue; and *Inoceramus* cf. *I. (Cordiceramus) müllerі* Petrascheck was found in the G sandstone bed. According to W. A. Cobban (written commun., 1966) and Scott and Cobban (1964, p. L15, and table 2), these fossils indicate that the lower part of the John Henry Member is middle and (or) late Coniacian in age, the middle part is Santonian in age, and the upper part is approximately early Campanian in age. The John Henry Member correlates approximately with the middle and upper parts of the Niobrara Formation at Pueblo, Colo. (Scott and Cobban, 1964), and the lower and upper marine mudstone tongues correlate approxi-

mately with the Mulatto and Satan Tongues, respectively, of the Mancos Shale in the San Juan Basin, N. Mex. (Cobban and Reeside, 1952, chart 10b, col. 15).

DRIP TANK MEMBER

The Drip Tank Member is a cliff-forming sandstone unit that is resistant to erosion and generally supports an irregular bench or stripped structural surface at the top of the Straight Cliffs Formation. The lower part of the member generally forms cliffs, but talus accumulations conceal the lower contact in many places. The upper part of the member and the lower part of the overlying Wahweap Formation are generally stripped back and form a broad bench. Windblown sand on this bench and talus accumulations at the foot of bluffs composed of the Wahweap Formation conceal the uppermost part of the Drip Tank Member in many places. The member was informally named the upper sandstone member of the Straight Cliffs Formation by Peterson and Waldrop (1965, p. 64). The type locality of the Drip Tank Member is near the mouth of Drip Tank Canyon (fig. 1) and is shown in figure 9. The type section is illustrated in figure 3, and the measured section is given at the end of the report.

The Drip Tank Member is about 141–255 feet thick in the southeastern Kaiparowits region. In the northwestern Kaiparowits region, the highest unit in a section measured by J. C. Lawrence (in Robison, 1966, p. 21) and tentatively assigned by the writer to the Drip Tank Member is 523 feet thick.

The Drip Tank Member consists mainly of pale-yellowish-brown to grayish-orange fine- to medium-grained cross-stratified sandstone. The well-cemented lower 30–80 feet contains scattered quartz and chert granules and chert pebbles or scattered conglomerate lenses. Sandstone and mudstone pebbles and cobbles, petrified logs, and bone fragments are also found in the lower part, and scattered lenses of mudchip conglomerate occur near the top of the member. Dusky-yellow to light-olive-gray bentonitic mudstone lenses as much as 20 feet thick are scarce but may occur in any part of the member.

The lower part of the Drip Tank Member probably interfingers with the upper part of the John Henry Member, but this cannot be demonstrated conclusively because talus conceals the contact in many places. Where exposures are good, the lower contact is placed at the top of the highest mudstone bed underlying the thick cliff-forming sandstone of the Drip Tank Member. The upper part of the Drip Tank Member interfingers with the lower part of the Wahweap Formation, and where exposures are good the upper

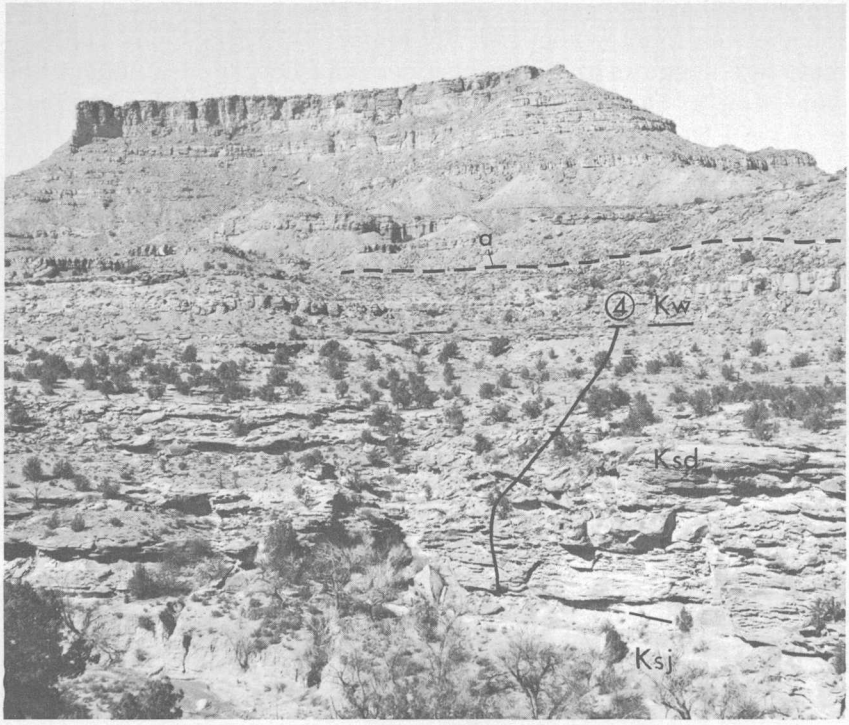

FIGURE 9. — Type locality of Drip Tank Member. View is toward the north across Drip Tank Canyon. 4, Type measured section; member is 141 feet thick. *a*, Dirt road that leads to Glen Canyon City, Utah (about 32 miles). Ksj, John Henry Member; Ksd, Drip Tank Member; Kw, Wahweap Formation.

contact is placed at the base of the lowest mudstone bed overlying the Drip Tank Member. Where exposures are poor, the contacts can be placed at the top or the bottom (whichever is appropriate) of prominent and laterally continuous sandstone beds that occur at or near the sandstone-mudstone contact and that can be traced laterally as key beds.

The Drip Tank Member contains abundant low- and high-angle medium-scale trough cross-stratification, fluvial channels in which the crossbedding dips down the axis of the channels, and cut-and-fill structures; but the member lacks marine fossils or bedding structures typical of marine beds. These features suggest that the member was deposited in fluvial environments. Fossils diagnostic of an age more restricted than Late Cretaceous have not been found in either the Drip Tank Member or the overlying Wahweap Formation. The Drip Tank Member is probably only slightly younger than the upper beds of the John Henry Member because

these members apparently interfinger; therefore, the Drip Tank Member is probably about early Campanian in age. This approximate age suggests that the member was deposited at about the same time as the Emery Sandstone Member of the Mancos Shale in central Utah and the Point Lookout Sandstone in the San Juan Basin of northwestern New Mexico.

TYPE SECTIONS OF MEMBERS IN THE STRAIGHT CLIFFS FORMATION

Colors in the following descriptions follow the nomenclature of the "Rock-Color Chart" (Goddard and others, 1963), and bedding classification generally follows that of McKee and Weir (1953). Partings in coal beds are not thicker than the adjacent coal seams, and a parting 1 foot or more thick is considered to divide the coal into two separate beds. Very thin coal beds are those less than 1 foot thick, and they are not listed.

Type section of Drip Tank Member

[Section 4 (fig. 1) measured up east side of small tributary canyon on north side of Drip Tank Canyon in the NE¼NE¼ sec. 24, T. 40 S., R. 3 E., Kane County, Utah]

	Thickness (feet)
Wahweap Formation (part):	
81. Sandstone, grayish-orange (weathers very pale orange), fine-grained, crossbedded; forms prominent cliff	32.0
80. Mudstone, dusky-yellow, very thin bedded to thin-bedded; forms slope	29.0
79. Sandstone, pale-yellowish-brown (weathers grayish brown), fine-grained, ripple cross-laminated; forms small ledge	1.0
78. Mudstone; same as unit 80	3.0
Total measured Wahweap Formation	65.0
Straight Cliffs Formation:	
Drip Tank Member:	
77. Sandstone, pale-yellowish-brown (weathers grayish brown), fine-grained, crossbedded; upper 2 ft is ripple cross-laminated; forms small cliff	7.0
76. Sandstone, medium-light-gray, fine-grained, very thin bedded to thin-bedded and crossbedded; upper 1 ft is mudstone (same as unit 80) that grades down into siltstone and mudstone; forms cliff	18.0
75. Sandstone, grayish-orange (weathers very pale orange), medium-grained, very thin bedded to thin-bedded and crossbedded; forms slope	32.0
74. Sandstone, pale-yellowish-brown to grayish-orange, fine- to coarse-grained, crossbedded; locally contains granule and pebble conglomerate lenses; forms prominent cliff	84.0
Total Drip Tank Member	141.0

Type section of Drip Tank Member — Continued

Straight Cliffs Formation — Continued

John Henry Member (part):	Thickness (feet)
73. Mudstone, medium-light-gray; forms slope	4.5
72. Sandstone, light-gray (weathers grayish orange), medium- to coarse-grained, crossbedded; forms cliff	25.0
71. Mudstone; same as unit 73; forms slope, base concealed	3.0
Total measured John Henry Member	32.5

Type section of John Henry Member

[Section 3 (fig. 1) measured westward up small tributary canyon on west side of Smoky Hollow. Measurements made on north side of tributary canyon offsetting westward on various prominent sandstone and coal beds. Progressing westward, tributary canyon divides at about unit 19, and section goes up north branch; unit 20 is measured on north side, and higher units are measured on south side. North branch of tributary canyon divides again at about unit 27, and section goes up northwest side of southwest-heading branch and up prominent bluffs to flat top of ridge. Section measured in the SE¼NW¼ and W½NW¼ sec. 32 and N½NE¼ sec 31, T. 41 S., R. 4 E., Kane County, Utah]

Straight Cliffs Formation: Drip Tank Member (part):	Thickness (feet)
70. Sandstone, grayish-orange, medium-grained, crossbedded; basal 2 ft contains scattered pebbles, bone fragments, and small petrified logs; forms cliff	32.0
Total measured Drip Tank Member	32.0

John Henry Member: Upper barren zone:	
69. Mudstone, dusky-yellow to light-olive-gray, very thin bedded to thin-bedded; contains several thin beds of very fine grained sandstone; forms slope	19.0
68. Sandstone, grayish-orange, medium-grained, crossbedded; contains scattered granules and pebbles; forms cliff	39.5
67. Mudstone, dusky-yellow to light-olive-gray, very thin bedded to thin-bedded; forms slope	9.0
66. Sandstone, grayish-orange, fine-grained, massive; rare crossbedding; forms cliff	19.0
65. Mudstone; same as unit 69	19.0
64. Sandstone, grayish-orange, fine-grained, crossbedded; forms cliff	7.0
63. Mudstone; same as unit 69	16.0
62. Sandstone; same as unit 64; bedding is slumped near top; contains 1-ft-thick mudchip conglomerate lens 5 ft above base	16.0
61. Mudstone; same as unit 69; contains small gray limestone lenses; upper 5 ft has bedding that dips about 15°	45.0
60. Sandstone; same as unit 64	6.0
59. Mudstone; same as unit 67	17.0

Type section of John Henry Member — Continued

Straight Cliffs Formation — Continued
John Henry Member — Continued
Upper barren zone — Continued

	Thickness (feet)
58. Sandstone; same as unit 64; includes some slumped bedding	21.0
57. Mudstone, carbonaceous, dark-gray to black; contains a very thin coal bed in middle; forms slope	2.0
56. Sandstone; same as unit 58 but medium grained	8.0
55. Mudstone; same as unit 69	14.5
54. Sandstone; same as unit 64; ripple cross-laminated at top; contains 2-ft bed of mudstone (same as unit 67) 2 ft below top	16.5
53. Mudstone; same as unit 67; contains minor beds of carbonaceous mudstone and a few very thin coal beds; forms slope	18.5
52. Sandstone; same as unit 64 but fine to medium grained; contains a 4-ft mudstone bed 25 ft above base and a 2-ft mudstone bed (same as unit 67) 17 ft above base; forms cliff with minor bench on top	38.0
51. Mudstone, same as unit 67; contains a 5-ft sandstone bed (same as unit 64) 25 ft above base and a 4-ft sandstone bed (same as unit 64) 4 ft above base	35.0
Total upper barren zone	366.0

Rees coal zone:

50. Mudstone, carbonaceous, dark-gray to black; 1.17 ft thick, underlain by coal 1.83 ft thick; forms slope	3.0
49. Mudstone, carbonaceous, dark-gray to black, very thin bedded; forms slope	3.0
Total Rees coal zone	6.0

Middle barren zone:

48. Mudstone, dusky-yellow to light-olive-gray, very thin bedded to thin-bedded; includes carbonized plant twigs and a few thin gray limestone lenses; two beds of pale-yellowish-brown fine-grained ripple cross-laminated sandstone 3 ft thick occur at top and 5 ft above base; forms slope	31.5
47. Sandstone; same as unit 58; top 3 ft is very thin bedded	12.0
46. Mudstone; same as unit 67; interbedded with about 15 percent each of carbonaceous mudstone, sandstone, and very thin coal beds	5.5
45. Sandstone; same as unit 58	14.0
44. Mudstone, same as unit 67; interbedded with about 30 percent pale-yellowish-brown fine-grained sandstone, 10 percent carbonaceous mudstone, and 10 percent very thin coal beds	18.5

Type section of John Henry Member — Continued

Straight Cliffs Formation — Continued

John Henry Member — Continued

	Thickness (feet)
Middle barren zone — Continued	
43. Sandstone, pale-yellowish-brown, very fine grained to fine-grained, crossbedded; top 3 ft is ripple cross-laminated; contains thin beds of mudstone (same as unit 67) in lower 10 ft; forms cliff at top to slope at base	16.5
42. Mudstone; same as unit 67	6.0
Total middle barren zone	104.0
Christensen coal zone:	
41. Coal, black; forms slope	7.5
40. Mudstone, carbonaceous, dark-gray to black, very thin bedded to thin-bedded; forms slope	3.0
39. Sandstone; same as unit 43 but medium-grained grading to fine-grained at top; forms cliff	13.5
38. Mudstone, carbonaceous; same as unit 40; contains thick coal beds listed below, several other very thin coal beds, and a few gray limestone lenses.	

Height above base (ft)	*Thickness of coal (ft)*
61.7	2.17
56.0	4.58
37.5	1.67
19.5	3.75
10.0	6.33 (excluding 0.50-ft parting)
1.0	2.42

Thickness of mudstone unit	73.5
37. Sandstone, pale-yellowish-brown, very fine grained, laminated; forms cliff	7.0
36. Mudstone, carbonaceous; same as unit 40; contains thick coal beds listed below and several other very thin coal beds.	

Height above base (ft)	*Thickness of coal (ft)*
31.0	6.25 (excluding 0.04-ft parting)
16.0	2.0
13.5	1.08

Thickness of mudstone unit	39.0
Total Christensen coal zone	143.5
Lower barren zone:	
35. Sandstone, pale-yellowish-brown, very fine grained, crossbedded, grading to ripple cross-laminated at top; forms cliff	12.0
34. Mudstone, carbonaceous; same as unit 40; contains a very thin coal bed near middle	17.0
33. Sandstone; same as unit 35; includes some slumped bedding	8.0
Total lower barren zone	37.0

Type section of John Henry Member — Continued

Straight Cliffs Formation — Continued
John Henry Member — Continued
Lower coal zone:

	Thickness (feet)
32. Mudstone, carbonaceous; same as unit 40; contains coal beds listed below and several other very thin coal beds, several thin mudstone beds (same as unit 67) scattered throughout, and several laminated sandstone beds (same as unit 37) in lower 20 ft.	

Height above base (ft)	Thickness of coal (ft)
73.5	2.17
64.5	1.42
47.5	1.00
43.5	1.25
5.5	1.33 (excluding 0.25-ft parting)

Thickness of mudstone unit	83.0
31. Sandstone, pale-yellowish-brown (weathers moderate brown), fine-grained, irregularly very thin bedded; contains finely disseminated carbonaceous material; top is well cemented; forms small cliff	1.5
Total lower coal zone	84.5
Total John Henry Member	741.0

Unconformity.
Smoky Hollow Member (part):
Calico bed (part):

30. Sandstone, white to very light gray, medium-grained, crossbedded; contains granules and pebbles scattered throughout and small conglomerate lenses; cross-stratification at top is truncated by overlying unit 31, but there is no relief at the contact; forms cliff; only upper part measured	5.0
Total measured Calico bed	5.0
Total measured Smoky Hollow Member	5.0

Type section of Smoky Hollow Member

[Section 2 (fig. 1) measured up the east side of a southeast-trending spur on west side of Smoky Hollow in the NE¼NE¼SW¼ sec. 5, T. 42 S., R. 4 E., Kane County, Utah]

Straight Cliffs Formation:
John Henry Member (part):

	Thickness (feet)
29. Sandstone, grayish-orange, medium- to coarse-grained, crossbedded; upper 5 ft is very fine grained and ripple cross-laminated; contains scattered pebbles and small conglomerate lenses near base; this unit is a local fluvial channel sandstone bed; forms slope at top to cliff at base	15.0
Total measured John Henry Member	15.0

Type section of Smoky Hollow Member — Continued

	Thickness (feet)
Straight Cliffs Formation — Continued	
Smoky Hollow Member:	
Calico bed:	
28. Sandstone, white, coarse-grained, crossbedded; contains scattered pebbles and small conglomerate lenses near base; forms cliff	5.0
27. Sandstone, white, crossbedded; upper 3 ft is very fine grained, grading to siltstone and weathers to a slight notch; middle 2 ft is medium grained; basal 3 ft is mainly a pebble conglomerate; forms cliff	8.0
26. Sandstone, white, medium-grained, crossbedded; contains irregular lenses of granule and pebble conglomerate; grades south into dark-gray mudstone; forms cliff	7.0
Total Calico bed	20.0
Barren zone:	
25. Interbedded mudstone, dark-gray, and light-gray siltstone; very thin bedded to thin bedded; forms slope	5.5
24. Mudstone, dark-gray; forms slope	2.0
23. Sandstone, very pale orange, fine-grained, crossbedded and ripple cross-laminated; forms small cliff	1.5
22. Mudstone, medium-gray; forms slope	2.0
21. Mudstone, dusky-yellow; forms slope	8.5
20. Sandstone, pale-yellowish-brown (weathers pale orange), medium-grained, crossbedded; contains scattered granules and pebbles; upper 5 ft is moderate brown and very coarse grained or locally dusky yellow green and very fine grained, forms a conspicuous dark caprock; unit forms cliff	22.0
19. Mudstone, medium-gray to dusky-yellow; contains small ironstone concretions; forms slope	21.0
18. Sandstone, pale-yellowish-brown (weathers pale orange), fine-grained, crossbedded and ripple cross-laminated; contains a 1-ft bed of medium-gray mudstone in middle; forms irregular ledge	7.0
17. Mudstone, dusky-yellow; forms slope	1.0
16. Sandstone, pale-yellowish-brown (weathers very pale orange), fine-grained, crossbedded; upper 1 ft is very fine grained; forms cliff	7.5
15. Mudstone, dusky-yellow, very thin bedded to thin-bedded; forms cliff	4.0
14. Sandstone, grayish-orange, very fine grained, very thin bedded and ripple cross-laminated; forms ledge	2.5
Total barren zone	84.5
Coal zone:	
13. Mudstone, carbonaceous, pale-brown to black; contains several very thin coal beds; forms slope	6.0
12. Coal, black; forms slope	1.5

Type section of Smoky Hollow Member — Continued

Straight Cliffs Formation — Continued Coal zone — Continued	Thickness (feet)
11. Mudstone, carbonaceous, pale-brown, brownish-black, and grayish-black; forms slope	4.0
Total coal zone	11.5
Total Smoky Hollow Member	116.0
Tibbet Canyon Member (part):	
10. Sandstone, very pale orange, medium-grained, thin-bedded to crossbedded; forms slope	20.0
Total measured Tibbet Canyon Member	20.0

Type section of Tibbet Canyon Member

[Section 1 (fig. 1) measured on east side of southeast-trending spur on north side of Tibbet Canyon in the N½NE¼NE¼ sec. 14, T. 42 S., R. 3 E., Kane County, Utah]

Straight Cliffs Formation: Smoky Hollow Member (part):	Thickness (feet)
9. Mudstone, carbonaceous, medium-light-gray and brownish-black; contains several very thin coal beds; forms slope	4.0
Total measured Smoky Hollow Member	4.0
Tibbet Canyon Member:	
8. Sandstone, grayish-orange to dark-yellowish-orange, very fine grained to medium-grained; irregularly laminated to very thin bedded; forms slope	1.0
7. Sandstone, grayish-orange (weathers moderate brown), medium-grained, crossbedded; basal 0–3 ft is coarse grained; forms prominent cliff	21.0
6. Sandstone, grayish-orange (weathers moderate brown), very fine grained to medium-grained, crossbedded; contains minor amounts of dusky-yellow mudstone laminae and very thin beds; forms blocky cliff	28.0
5. Sandstone, grayish-orange (weathers moderate brown); very fine grained but grades to fine grained in upper 1 ft; crossbedded; forms prominent cliff	14.0
4. Sandstone; same as unit 6 but very fine grained; very thin bedded to thick bedded and crossbedded; forms slabby cliff	20.0
3. Mudstone, dusky-yellow, very thin bedded to thin-bedded; interbedded with about 30 percent sandstone (same as unit 4); forms slight notch in cliff	10.0
2. Sandstone; same as unit 4; interbedded with about 30 percent mudstone (same as unit 3); forms slabby cliff	10.0
Total Tibbet Canyon Member	104.0
Total of the four members of the Straight Cliffs Formation	1,102.0

Type section of Tibbet Canyon Member — Continued

Tropic Shale (part):	Thickness (feet)
1. Mudstone, dusky-yellow, very thin bedded; includes several siltstone beds; forms slope	50.0
Total measured Tropic Shale	50.0

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