STRATIGRAPHY OF THE HITE BED AND THE UPPERMOST
PART OF THE CHINLE FORMATION IN THE RED CANYON-WHITE
CANYON AREA, SOUTHEASTERN UTAH

by

Jeffrey Linwood Dunn

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STATEMENT BY AUTHOR

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This thesis has been approved on the date shown below:

[Signature]  May 25, 1975
R. F. WILSON  Date
Associate Professor of Geosciences
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Strata in the Chinle Formation overlying the Owl Rock Member in the Red Canyon-White Canyon area have been assigned to the Church Rock(?) Member, a designation now in question because of doubtful correlation with type section and problems of priority. Correlation of 25 stratigraphic sections, facilitated by the presence of laterally persistent reddish orange siltstone ledges, has led to the recognition of four sub-units within the Church Rock(?) Member. The uppermost of these units, the Hite Bed, requires detailed study to establish correlation because of its discontinuity, poor exposure, and similarity to adjacent units. The unit overlying the Chinle Formation, forming the basal part of the Wingate Sandstone, is horizontally stratified like the upper portions of the Hite Bed, and contains Chinle-like siltstone and mudstone lentils. This "transitional units" appears to be separated disconformably from the Hite Bed and in one locality fills a channel cut into the Hite Bed. The unit underlying the Hite Bed (Unit L) contains arkosic sandstone lithologically similar to that in the Hite Bed. Paleocurrent studies indicate that this unit was deposited by streams flowing southwest from the Uncompahgre Upland. The Hite Bed, on the other hand, was deposited in the Red Canyon-White Canyon area by currents flowing northward from uplands postulated to the south or west.
INTRODUCTION

The Chinle Formation has attracted many geologically-oriented visitors. Some have come to explain the presence, and many have come to facilitate the absence, by removal, of petrified wood and uranium ore. The occurrence of these commodities in the lower part of the Chinle, however, has resulted in the relative neglect of the upper part, where the presence and absence of an intriguing sandstone and conglomerate, the Hite Bed, prompted recent research.

Purpose and Location

O'Sullivan (1970) and Stewart, Poole, and Wilson (1972) have established the following regarding the Hite Bed:

(1) It is internally complex and displays significant lateral changes in lithology. It has been commonly described as a single unit, but in some places it has been subdivided into two to four units and in other places it has been reported absent.

(2) It is widespread and useful in correlation, particularly as it may overlie an unconformity of regional significance. The tracing of subadjacent contacts casts doubt on the regional equivalence of underlying units.

(3) It may have been deposited by currents originating from a source area west of those contributing to earlier Chinle deposits.

The purpose of this study was to gather information on a local scale which would help verify the above findings. To this end, field
work began in the Red Canyon-White Canyon area (Figs. 1, 2) in the fall of 1973. The study area was selected because (1) it seemed to offer abundant outcrops, (2) it contained the newly defined type section of the Hite Bed, and (3), as surmised from the incongruent descriptions of earlier workers, the area probably included deposits reflecting considerable lateral variation. Field work was essentially completed by January, 1974; laboratory work and writing of the report were completed in May, 1975.

**Methods of Study**

In the field, 17 stratigraphic sections were measured with a Jacob staff or, on vertical exposures, a tape. Three sections measured by earlier workers were reexamined, and one was revised. Between sections, binoculars proved invaluable in the discovery and lateral tracing of outcrops.

Each measured unit was sampled, and the features of each were recorded as indicated in the following classification:

1. **General Lithology.** An estimate of composition was obtained with the aid of a hand lens and dilute hydrochloric acid. Grain sizes in the coarse silt to coarse sand range were estimated by comparison with sediments previously sieved at 1 φ intervals and glued to a card. The color of both fresh and weathered rock surfaces was determined utilizing the Rock Color Chart (Goddard and others, 1948).

2. **Internal Stratigraphy.** Type of stratification was recorded according to the suggestions of McKee and Weir (1953). At ten localities, the abundance of cross-strata made practicable the measurement of dip directions for paleocurrent analysis (Appendix A). Standard deviation, mean
Figure 1: Location map
Figure 2: Index map of Red Canyon-White Canyon area
dip direction, range of mean at 95% confidence, and the consistency ratio was determined from these readings for each site, utilizing statistical methods developed by F. G. Poole (unpublished chart, U.S.G.S., Denver) and others (e.g., Raup and Miesch, 1957).

(3) Contact relationships. The nature of the contact between units was noted. Erosional surfaces were traced laterally to determine relief.

(4) Topographic expression. Resistance to weathering was inferred by recording whether units formed ledges, slopes, or both.

In the laboratory, all samples were examined through a binocular microscope to verify field descriptions. To improve petrologic understanding of the Hite Bed, twelve thin sections were made from representative samples. Three hundred points per slide were counted to estimate percentages of minerals present.

Physiography and Accessibility

The area chosen for this investigation covers 1,200 square kilometers of canyons and buttes drained by ephemeral streams tributary to Lake Powell on the Colorado River. Elevation, which ranges from 1100 to 2400 meters above sea level, induces localized variation in temperature and precipitation, the latter averaging about 25 cm annually. As a result, lower elevations support extremely sparse flora, but buttes are capped with pinon-juniper forests.

Both accessibility and population of the area are relics of uranium mining and exploration. In 1973, the only permanent residents operated a store in the former boomtown of Fry Canyon. Although White Canyon
and the upper reaches of Red Canyon are easily approached by graded dirt roads, all other vehicular navigation is dependent upon a maze of degenerate mining roads (Fig. 3). Until the price of uranium rises again, safest access is on foot.

**General Geology**

Rocks exposed in the Red Canyon-White Canyon area range in age from Permian to Jurassic (Fig. 4). Gross lithology is distinguished by differentially weathering units that form a series of cliffs, slopes, and benches. Distinctive colors have dictated canyon names that taken together verge on the patriotic—red after the Organ Rock Member of the Cutler Formation, the Moenkopi Formation, the Church Rock (?) Member of the Chinle Formation, and the Glen Canyon Group; white (buff) after the Cedar Mesa Member of the Cutler Formation; and blue (gray) after the Monitor Butte, Petrified Forest, and Owl Rock Members of the Chinle Formation. Strata are relatively undeformed and dip in a nearly uniform manner 2° west, forming a flank of the Monument Upwarp. A more detailed discussion of the structure of the Red Canyon-White Canyon area, and descriptions of all exposed units, can be found in the report of Thaden and others (1964).

Most of the slopes in the study area are composed of fine-grained members of the Chinle Formation, which consists of a lower clayey portion, including the Monitor Butte and Petrified Forest Members, and an upper silty portion, comprising the Owl Rock and Church Rock (?) Members. The lower slopes are broken by the bench-forming Mossback Member which, like the basal Shinarump Member, consists of massive but discontinuous sandstones and conglomerates that fill channels.
Figure 3: In-depth assessment of road conditions
Figure 4: Stratigraphic units exposed in study area
The Church Rock(?) Member, distinguished from the underlying Owl Rock Member by its reddish orange color, is queried in this report because of uncertainty regarding continuity with its "typical" section in Monument Valley, and problems with priority of usage (see History of Nomenclature). The Church Rock (?) Member is stratigraphically complex, but can be divided into two portions, one predominantly reddish-orange siltstone, the other predominantly pale red siltstone and sandstone. Ledges within the Church Rock(?) Member aid in the recognition of sub-units (Fig. 5). For the purposes of this investigation, the reddish-orange portion is designated the reddish-orange siltstone unit; it includes an especially persistent ledge herein referred to as the Red Canyon ledge of local usage. The pale red portion is divided into Unit M, Unit L, and the Hite Bed, the focus of this study.

Within the study area, the Hite Bed is present principally in the northwestern part of Red Canyon. It consists of pale red, cross-stratified, very fine-grained sandstone that contains conglomeratic lenses composed of granules and pebbles of siltstone, silty dolomite, silty limestone, and uncommon chert. The Hite Bed fills channels scoured into underlying units, and contains small pale reddish brown siltstone lenses that form one or more slopes where the Hite Bed is not vertically continuous with the overlying Wingate Sandstone.

The Wingate Sandstone forms a prominent cliff above the Chinle Formation about 100 m thick. In most places it lies in sharp disconformable contact with the Church Rock(?) Member, and is composed of fine- to very fine-grained sandstone cross-laminated on a large scale, but commonly horizontally laminated at the base. Mass wasting of the Wingate Sandstone
Figure 5: Schematic diagram of stratigraphic terminology used in this report
and overlying units has covered much of the upper Chinle Formation with sand-sized to house-sized fragments. As a result, complete outcrops of the Church Rock(?) Member are generally found only (1) on promontories where mass wasting of the Wingate is diverted sideward by the topography, or (2) in paths of ephemeral drainage from Wingate buttes, where infrequent floods manage to remove debris. Especially in the White Canyon area, the ongoing destruction of the Wingate Sandstone hampers efforts at correlating beds in the Church Rock(?) Member and rebukes those who theorize that barren areas will necessarily reveal the most outcrops.

Previous Work

The first geologist to undertake a detailed reconnaissance of the Red Canyon-White Canyon area was H. E. Gregory, who made a survey of White Canyon in 1915. C. R. Longwell viewed exposures near the area along the Colorado River in 1921 and published descriptions of them shortly thereafter (Longwell and others, 1923). Gregory revisited the area a few years later, reaching upper Red Canyon in 1925 and lower Red Canyon via the Rasp Trail (now Blue Notch Canyon) in 1927. His report on the San Juan region included descriptions of the rocks exposed in the area, and measurements of stratigraphic sections at Rock Spring and Rasp Trail (Gregory, 1938, p. 71-72).

Before the 1950s, the only other geologic work in the vicinity was that of C. B. Hunt, who measured a section at the mouth of Red Canyon in 1939 in the course of his study of the Henry Mountains (Hunt, 1953, p. 51-52). However, a large number of geologists descended on White Canyon after the first uranium ore was shipped from the Happy Jack Mine in 1949;
by 1954, field work has been completed by more than a dozen investigators. Authors who discussed the general geology of the area include W. E. Bensen, A. F. Trites, Jr., E. P. Beroni, and J. A. Feeger (1952); and R. E. Thaden, A. F. Trites, Jr., and T. L. Finnell (1964). The latter report includes a detailed geologic map of the area and three stratigraphic sections useful for the purposes of this study (Fig. 2, sites 21, 22, and 24). Other workers who measured stratigraphic sections before 1954 include J. H. Stewart, who published two sections of interest (Fig. 1, sites 1 and 19) in a regional study of the Chinle Formation (Stewart and others, 1972, p. 277-286) and T. E. Mullens, who measured a section at Red House in the course of his work in the neighboring Clay Hills area (Mullens, 1960, p. 311-314).

Little geologic activity has taken place in the Red Canyon-White Canyon area since the early years of the uranium boom. The last work relevant to this study was completed in 1958 by M. E. Cooley (Cooley, 1965, p. 85-91), who measured a section near that of Hunt (Fig. 1, site 23).
The history of nomenclature in the upper part of the Chinle Formation (Fig. 6) reflects two points of emphasis: a concern as to the nature of the boundary between the Chinle Formation and the Wingate Sandstone, and an increasing awareness of stratigraphic complexity.

In the 1920s and 1930s, when the boundary between the Wingate and Chinle was thought to be a systemic one, much debate arose as to whether it was unconformable (Gilluly, 1929, p. 94) or conformable (Baker, 1933, p. 41). Disagreement in part centered around the weathering appearance, boundary relationships, and lithology of channel-filling sandstone at the base of the Wingate Formation. Where the channel-filling sandstone formed a continuous cliff with the Wingate, Longwell, et al. (1923, p. 72) and Baker (1933, p. 41-42) placed them with the Wingate, but Baker, noting a lithologic similarity to the Chinle, considered the sandstone transitional in nature, on the basis of his estimation that irregular lower contacts were of local extent and did not represent the major unconformity envisioned by Longwell.

Gregory (1938) considered the Wingate to be unconformable on the Chinle, but it is unclear as to where he placed the channel-filling sandstone. His fourth subdivision of the Chinle Formation (Gregory, 1938, p. 49) consisted of "...red and brown sandstone and sandy shale, weathering as a cliff that, continued upward, includes the Wingate Sandstone.", yet at the mouth of Red Canyon and at the Tables of the Sun, he placed strata similar in character to his fourth subdivision in the Wingate Sandstone.
Figure 6: History of nomenclature in the uppermost part of the Chinle Formation
Northwest of the study area, the channel-filling sandstone was unequivocally, but "arbitrarily", placed in the Chinle by Baker (1946, p. 62) and all subsequent workers except Bensen and others (1952) have done the same near the Red Canyon-White Canyon area.

While there is now a consensus that the Chinle-Wingate contact should be placed above the channel-filling sandstone, the nature of the contact in the vicinity of Red and White Canyons must still be viewed as uncertain. Stewart and others (1972, p. 14) view the contact as disconformable. Thaden and others (1964, p. 69) claim the two formations intertongue in the vicinity of Blue Notch, but are separated by an erosion surface where the channel-filling sandstone is present (p. 59). In this report, the contact is considered disconformable; at one locality, the contact is placed at a channeled surface of erosion (see "Boundary Relations").

In the Red Canyon-White Canyon area, the nomenclature in upper portions of the Chinle has basically followed Gregory's (1938) subdivisions that were based on distinctions recognized in the Navajo Reservation (Gregory, 1917, p. 37-50). The names Church Rock Member and Owl Rock Member were first used in the Red Canyon-White Canyon area by Stewart (1957, p. 459-460). The Owl Rock Member is equivalent to Gregory's third subdivision, and the Church Rock Member as used by Stewart (1957) includes Gregory's fourth subdivision as well as the pesky channel-filling sandstone. This addition to Gregory's fourth subdivision was later referred to as "the so-called Hite bed" by Stewart and others (1959, p. 518), who correlated it with exposures over much of southeastern Utah north of the San Juan River and noted that a similar sandstone occurred
at the top of the Chinle in Monument Valley. Subsequently, the Hite Bed was granted formal status (Stewart and others, 1972, p. 41) when its importance in regional correlation had become apparent.

Doubt has been cast on the use of the term Church Rock Member in southeastern Utah (Stewart and others, 1972, p. 42). In this report, strata in the Red Canyon-White Canyon area are queried as the Church Rock (?) Member for two reasons: (1) the strata may not be correlative with those of the type Church Rock in Monument Valley, and (2) the name, in the author's opinion, is of questionable priority.

The sandstone in Monument Valley noted as similar to the Hite Bed by Stewart and others (1959, p. 518) was assigned to the Hite Bed by Repenning, Cooley and Akers (1969, p. B 26-27). Lateral tracing of the sandstone by O'Sullivan (1970) indicated that strata forming the type Church Rock Member did not extend north of the San Juan River, but pinched out between two tongues of the Hite Bed (Fig. 7), thus demonstrating that the type Church Rock is stratigraphically higher than the Church Rock of Stewart (1957). In addition, O'Sullivan proposed that the two units were separated by a regional unconformity. These relationships prompted a revision of nomenclature in the Monument Valley area which included the reassignment of strata formerly in the Church Rock Member of Stewart (1957) to divisions of the Chinle Formation informally designated the "reddish-orange siltstone member" and the "Mule Ear ledge". O'Sullivan has since modified his views (personal communication) and now feels that the erosion surface at the base of the Hite Bed is of local extent. Stratigraphically, however, the relationship between the "type" Church Rock and the
Figure 7: Schematic diagram of regional relations in the upper part of the Chinle Formation after O'Sullivan (1970)
Church Rock of Stewart (1957) still holds along Comb Ridge; they are not the same unit.

A major problem with the term Church Rock Member is that it was used before it was defined. Stewart (1957, p. 459) claimed that the Church Rock Member would be defined for exposures in Monument Valley "in a report currently being prepared". The report, issued six years later, although including a section of Church Rock "considered typical" (Witkind and Thaden, 1963, p. 33), did not specifically designate a type section (Stewart and others, 1972, p. 41). By that time, Harshbarger, Repenning and Irwin (1957, p. 5-8) had assigned the same strata measured by Witkind and Thaden, in exposures further south, to a newly named Rock Point Member dubiously included in the Wingate Sandstone (Stewart and others, 1972, p. 43-47). Rather than abandon the usage of Church Rock Member by Stewart (1957), officials of the U. S. Geological Survey decided to assign identical rocks on either side of Laguna Creek to different members of different formations (Witkind and Thaden, 1963, p. 34). A better solution, in the author's opinion, would have been to designate the strata north of Laguna Creek the Rock Point Member of the Chinle Formation, as, according to the Stratigraphic Code (American Commission on Stratigraphic Nomenclature, 1961, Art. 7b), "a named member may extend from one formation into another." The result would have retained priority of terms and possibly softened official resistance to an eventual removal of the Rock Point Member from the Wingate Sandstone south of Laguna Creek, a step verged upon by Stewart and others (1972, p. 43-44). As of 1975, however, the nomenclatural situation is still in doubt.
The Owl Rock and Church Rock(?) Members intertongue extensively
(Stewart, 1957, p. 458). The boundary between them was first placed at
the top of the highest limestone or limy siltstone in the Owl Rock
(Stewart and others, 1959, p. 518-519), a policy followed by Thaden and
others (1964, p. 57-58) in separating their "limy unit" from their "silt-
stone-sandstone unit" (Fig. 6). Recently, however, this policy has been
modified: in the study area contact is now placed at a "slight color
change from purplish pale red strata below to reddish brown siltstone
above (Stewart and others, 1972, p. 40).

The Church Rock(?) Member was first subdivided by Stewart and
others (1959) with their introduction of the "Hite Bed of local usage".
Cooley (1965, p. 85-87) recognized a silty and sandy facies within the
Church Rock(?), but O'Sullivan (1970) was the first to designate units
within the Church Rock as used by Stewart (1957) on the scale which has
been followed in this report.

A comparison of the exposures examined by O'Sullivan in Monument
Valley and those of the Red Canyon-White Canyon area shows some similar-
ities: there are one or two sandstone units underlain by an erosion sur-
face, and there is a prominent ledge underlain by reddish-orange siltstone.
However, due to the internal complexity of the units and considerable dis-
tance between the exposures in Monument Valley and those of Red Canyon and
White Canyon, correlation is not attempted, and may indeed be impossible
(O'Sullivan, personal communication). The basal reddish-orange siltstones
appear to be likely equivalents, but the same cannot be said for the Mule
Ear-Red Canyon ledges, or, for that matter, the Hite Bed itself, which,
as this study suggests, is simply too variable to insure long-range correlation without detailed examination.
STRATIGRAPHY OF UNITS BENEATH THE HITE BED

Owl Rock Member

The Owl Rock Member was not measured in its entirety by the author. The upper portion of the Owl Rock generally consists of highly calcareous pale red to grayish siltstone and mudstone with minor amounts of limestone and sandstone. In places, markedly less calcareous beds occur in the Owl Rock Member. In addition, reddish-orange siltstone beds similar to those in the Church Rock(?) Member occur in the upper part of the unit; these are discussed below. As a whole, the Owl Rock Member forms a series of steep slopes broken by small sandstone or limestone ledges and covered with angular to nodular fragments. Limestone is somewhat less common in the Red Canyon-White Canyon area when compared to other areas, but can be of local importance volumetrically: it is estimated from sections of other workers to make up 2 to 16 percent of the total thickness of the Owl Rock Member. Clay content also varies considerably. Although the presence of swelling clays in the Petrified Forest Member generally distinguishes it from the Owl Rock Member (Stewart and others, 1972, p. 40), such clays occur locally in some sections of the Owl Rock.

In the northwestern portion of the study area, the Owl Rock consists mostly of grayish units, but through the rest of the study area, the Owl Rock is roughly divisible into a lower grayish portion and an upper pale reddish portion. The upper part is generally siltier, coarser grained, and more reddish brown than the lower part; this is probably a manifestation of (1) the northward trend toward coarseness and brownness
noted by Stewart and others (1972, p. 39) and (2) the presence of tongues of the Church Rock(?) Member. The Owl Rock Member ranges in thickness from 50 to 75 meters in the Red Canyon-White Canyon area except at site 23, where it has been measured as 12.3 meters thick (Cooley, 1965, p. 87). This section is anomalous in many respects, and probably should be redefined to include in the Owl Rock Member sandstone units Cooley assigned to the Petrified Forest Member.

Contact Between the Owl Rock and Church Rock(?) Members

The Owl Rock and Church Rock(?) Members intertongue extensively in southeastern Utah (Stewart, 1957, 0. 458). As pointed out by Stewart and others (1972, p. 40):

The upper contact of the Owl Rock Member is in most areas placed at the top of the highest limestone bed. Locally, the contact is placed a few feet or a few tens of feet above the highest limestone, where a more significant change in lithology appears to mark a higher contact. In northernmost Arizona and in some parts of southeastern Utah, the contact chosen is a slight color change from purplish pale red strata below to reddish brown siltstone above; the highest limestone is commonly at the color change, but in places some purplish siltstone occurs above the limestone, and here the contact is placed at the color change rather than at the limestone.

In the Red Canyon-White Canyon area, the color change is striking in most places (Fig. 8) because of the grayishness of Owl Rock units. However, the highest limestone in the Owl Rock may be as far as 60 meters below the color change. In addition, reddish-brown and reddish-orange units similar to those in the Church Rock Member occur in the Owl Rock Member below the highest limestone. Where the upper limestone is locally absent, these reddish-brown units could conceivably be included in the Church Rock(?) Member, and thus cast doubt as to which color change should
Figure 8: Units near site 16

View looking northwest. Unit includes:
- W-Wingate Sandstone, trough cross-stratified
- t-Wingate Sandstone, transitional unit,
  horizontally stratified
- L-unit L
- rd-Red Canyon ledge
- ros-reddish-orange siltstone unit
- ou-Owl Rock Member, upper portion (gray and pale red)
- ol-Owl Rock Member, lower portion (gray)
be selected as the contact between members. In the central portion of the study area, an attempt has been made to follow the horizons of locally absent limestones in the Owl Rock Member by placing the Owl Rock-Church Rock(?) contact at or near the top of the highest calcareous pale red siltstone underlying a less calcareous unit of reddish-brown to reddish-orange siltstone averaging 20 meters in thickness. The reddish-orange units below the designated contact may be tongues of the Church Rock(?) Member or unrelated lentils, but intertonguing, if present, is difficult to observe due to (1) the extent of tongues over several miles, and (2) burial of exposure under debris from overlying units.

**Church Rock(?) Member**

As mentioned previously, the Church Rock(?) Member consists of two portions (Fig. 4). The lower part of the member consists of horizontally bedded layers of reddish-brown to reddish-orange, slightly calcareous siltstone; it is here referred to as the "reddish-orange siltstone unit". The upper part generally consists of pale red and pale reddish purple, horizontally bedded to cross-stratified siltstone and sandstone. It is here subdivided (in ascending order) into (1) Unit M, composed of horizontally stratified to rhythmically bedded siltstone, (2) Unit L, composed of structureless to cross-stratified siltstone and one or more trough cross-stratified, channel-filling sandstone units, and (3) the Hite Bed, a channel-filling sandstone similar to the coarse units in Unit L.

The Church Rock(?) Member varies somewhat irregularly in thickness from 30 to 63 meters. (Fig. 9). There are two areas of maximum thickness; one, centered in Rainbow Canyon, is a manifestation of
Figure 9: Isopach map of Church Rock(?) Member
thickening in the upper part of the Member; the other, in Fry Canyon, is the result of the incorporation into the Church Rock(?) Member of tongues included elsewhere in the Owl Rock Member (Fig. 10).

Reddish-Orange Siltstone Unit

The reddish-orange siltstone unit is composed of structureless to horizontally stratified, moderate reddish-orange to pale reddish-brown siltstone beds that include minor pale red and orange pink layers and vary in thickness from 0.3 to 27 meters. Most siltstone layers weather slightly more reddish-orange than the unweathered color, and locally may be altered in streaks and mottles of light greenish gray. The siltstone layers are predominantly coarse-grained (locally with thin sandy to conglomeratic layers) and are slightly calcareous to non-calcareous, in contrast with the finer-grained, highly calcareous Owl Rock Member. Stratification is generally concealed, or vaguely horizontal. Resistant layers commonly preserve mudstone laminae that split to reveal dessication cracks. Micro cross-strata and wavy laminae also occur locally.

The reddish-orange siltstone unit thickens in a southeasterly direction from 6 to 58 meters (Fig. 11). Thickening in the eastern part of the study area is a result of the incorporation into the reddish-orange siltstone unit of tongues that penetrate Unit L laterally (Fig. 10). At sites 8, 19, and 20, where horizontally stratified reddish-orange siltstone makes up more than 50 percent of the thickness of Church Rock(?) strata, the reddish-orange siltstone unit is considered to encompass the entire Member.
Figure 10: Correlations within the Church Rock(?) Member, northwest to southwest.
Figure 11: Isopach map of reddish-orange siltstone unit
The reddish-orange siltstone unit contains prominent ledges, one of which crops out over much of the study area and has proved extremely useful for correlation within the Church Rock(?) Member; it is here referred to as the Red Canyon ledge of local usage. The Red Canyon ledge consists of moderate reddish-orange siltstone which is locally mottled or streaked light greenish gray (Fig. 12). It is composed of well sorted coarse silt-sized and scattered very fine to fine sand-sized grains of quartz. The sand-sized fraction of the Red Canyon ledge is generally less than 5 percent, but may locally be as high as 20 percent. In the northwestern part of the study area, the unit may locally contain basal granules of siltstone in conglomeratic lenses. The coarseness of the siltstone has led some workers to erroneously classify the Red Canyon ledge, and ledges similar to it, as a sandstone; this inaccuracy must be taken into account when interpreting sections measured by early workers.

The Red Canyon ledge generally consists of a single massive bed, but where it is thickest, in Blue Canyon, it consists of two or more massive beds separated by thin to thick siltstone units that weather out to form indentations. The lateral extent of the Red Canyon ledge is shown in Fig. 13. To the west, the Red Canyon ledge has been partially to completely eroded beneath channel-filling units. To the north the ledge splits less massively and is overlain by a slope-forming reddish-orange siltstone from which the Red Canyon ledge laterally becomes indistinguishable. To the east the Red Canyon ledge occurs lower in section (Fig. 10). Farther east, the reddish-orange siltstone unit intertongues with overlying units, and the probable equivalent of the Red Canyon
Figure 12: Streaked and mottled alteration in the Red Canyon ledge
Figure 13: Isopach map of Red Canyon ledge
ledge occurs near the bottom rather than at the top of the reddish-orange siltstone unit.

Below the Red Canyon ledge, the reddish-orange siltstone unit forms steep, rubble-covered slopes commonly broken by thin to (rarely) very thick ledges. Directly beneath the Red Canyon ledge, less resistant siltstone may commonly form a vertical, spheroidally-weathering cliff. Ledges are common in the upper reddish-orange siltstone unit at sites 8, 19, and 20, where as much as half the siltstones may be ledge-forming.

Contact Between the Reddish-Orange and Pale Red Portions of the Church Rock(?) Member

In most localities, contact between the reddish-orange and pale red portions of the Church Rock(?) Member is placed at the top of the Red Canyon ledge. At sites 6 and 24, however, the contact is placed above a 3-meter-thick, slope-forming, reddish-orange siltstone which directly overlies the somewhat less indurated continuation of the Red Canyon ledge. At site 17, the contact is placed above a ledge similar to the Red Canyon ledge, but lower in section. Where Unit M is present above the reddish-orange siltstone unit, the contact is a relatively flat surface with little or no relief. Where Unit L lies directly on the reddish-orange siltstone unit, the contact is a channeled surface of erosion. The contact is intertonguing in a zone west of site 17.

Pale Red Portion of Church Rock(?) Member

The pale red portion of the Church Rock(?) Member predominantly consists of complexly intercalated deposits of horizontal to cross-stratified pale red siltstone, sandstone, and mudstone. Toward the top of unit
L, reddish-orange siltstone ledges similar to those found in the reddish-orange siltstone unit occur. The pale red portion of the Church Rock (?) Member varies in thickness from 12 to 48 meters (Fig. 14). It is exceptionally thick at site 23, which was not visited by the author due to difficulty of access, and thinnest above the southeasternmost extension of the Red Canyon ledge.

**Unit M**

Unit M lies in apparently conformable contact on the reddish-orange siltstone unit. It consists primarily of pale red to moderately reddish-brown, generally calcareous siltstone with lesser amounts of mudstone and lenticular silty limestone (Fig. 15).

The siltstone forms very thin to thick beds with concealed internal stratification and commonly contains light greenish gray alteration colors in mottles, streaks, and nodularly-weathering beds. In places, the siltstone partly consists of rhythmically bedded pale red siltstone alternating with finer-grained reddish-brown siltstone.

The silty limestone is light gray to pale red, and generally altered light greenish gray. It is microcrystalline and contains scattered sand-sized chert and quartz grains. Locally, the limestone may be partially dolomitized and/or silicified. The limestone occurs as lentils intercalated with mudstones near the base of the unit. Some of these lentils form gently dipping trough-shaped bodies. Site 17 is exceptional in that unit M entirely consists of silicified silty limestone that contains a thin pebble conglomerate at the base. No fossils have been found.
Figure 14: Isopach map of pale red portion of the Church Rock (?) Member
Figure 15: Unit M at site 4

Note basal rhythmic bedding.
Unit M is thickest in the eastern half of the study area and is not present in the western half, where it has been eroded by overlying units (Fig. 16). Unit M intertongues with the reddish-orange siltstone unit along most of its margins, and also in the vicinity of site 14.

Contact Between Unit M and Unit L

The contact between unit M and unit L is generally placed at the base of the first sandstone or sandy siltstone above the reddish-orange siltstone unit. At site 9, however, the contact is placed just below a mudstone that has a granularly conglomeratic base (Fig. 17). The contact is generally erosional, with relief averaging about one meter except at site 23, where the contact is placed at an erosion surface with 6 meters relief. The extent and nature of the surface at the base of unit L is not well known. The surface may well be continuous, and hence represent a local unconformity. On the other hand, the lower contact of unit L may be drawn on a series of unrelated scour surfaces and hence artificially link diachronous sandstone lentils. If the latter possibility is true, the contact would therefore be partially intertonguing.

Unit L

Unit L consists of one or more ledges of exclusively trough cross-stratified, slightly calcareous sandstone to sandy siltstone that is generally overlain by pale red, reddish-orange, and reddish-brown noncalcareous siltstones which form slopes and very thin to very thick ledges. All lithologies in unit L are commonly altered in streaks, mottles, and layers of light greenish gray.
Figure 16: Distribution of unit M
Figure 17: Units at site 9

View looking northwest. Note gentle troughs in unit L. Figure in lower right corner for scale.

M-unit M
Lcm-conglomeratic mudstone at base of unit L
Lsd-sandy part of unit L
Lsl-silty part of unit L
hb-Hite Bed
W-Wingate Sandstone
The sandstones occur in lenticular bodies 0.3 to 13 meters thick generally concentrated near the base of unit L. Where they occur higher in section, such as at site 16, they are thin and have a higher fraction of silt-sized grains. The sandstones of unit L are lithologically very similar to the Hite Bed, and conceivably could be included with, or considered a tongue of, the Hite Bed. Both the Hite Bed and the sandy parts or unit L consist of very fine-grained, pale red to purplish, feldspatic units that contain pebble conglomerates composed of siltstone, silty limestone, and silty dolomite clasts as well as disc-shaped siltstone to mudstone intraclasts and lentils that weather out to form indentations. Although a detailed comparison was not undertaken in this study, there are indications that lithologic differences, if any, between the Hite Bed and sandy portions of unit L may lie in the realm of conglomerate studies. Conglomerates in unit L may contain clasts that are more distally derived and less intraformational in character. The sandy portions of unit L contain nearly 10 percent chert at site 3; this is more than twice the maximum amount reported from any Hite Bed locality in the Red Canyon-White Canyon area.

Despite lithologic similarities, separation of the units is warranted for several reasons. Stratigraphically, the sandy portions of unit L are always separated from the Hite Bed by overlying silty units except where the Hite Bed fills channels that cut out the overlying units. The sandy part of unit L is generally thinner than the Hite Bed, more lenticular, and underlies tongues of the reddish-orange siltstone unit while the Hite Bed, if present, is separated from the tongues by a channeled surface of erosion (Fig. 18). The Hite Bed tends to occur as a swale-
Figure 18: Schematic diagram showing intertonguing between unit L and upper portion of reddish-orange siltstone unit.
filling unit, while the sandy part of unit L generally consists of lenticular sandstone bodies that intertongue laterally with siltstones and fill irregular erosion surfaces with less relief than those underlying the Hite Bed. While sedimentary structures found in the two sandstone units predominantly consist of sets of trough cross-laminae, the Hite Bed, unlike the sandy portions of unit L, also contains planar cross-laminae and horizontal laminae in appreciable proportion. As discussed in a later chapter, sedimentary structures may reflect differences in sinuosity of the streams that deposited the two units. In addition, resultant-dip studies (this report) indicate the two units were deposited by current systems emanating from different quadrants.

Fossils are rare in the Church Rock (?) Member. At site 9, the sandy portions of unit L had the distinction of housing the only relatively whole reptile bone found in the course of this study (Fig. 19). The bone is probably a remnant of a phytosaur, a fossil reptile commonly found in lower members of the Chinle Formation. Sand- and granule-sized bone fragments were observed elsewhere in both unit L and the Hite Bed.

The silty portions of unit L generally overlie, and intertongue with, the sandy portions. The lower contact of the silty portions is sharp where directly above sandstone; in places, however, silty ripple-laminated sandstones cap the sandy portions of unit L, and these commonly grade upward into the silty portions.

The silty part of unit L contains three lithologic types: (1) cross-stratified pale red to reddish-brown siltstone to mudstone, (2) structureless reddish-brown siltstone to mudstone, and (3) massive ledge-forming reddish-orange to orange brown coarse-grained siltstone.
Figure 19: Reptile bone in unit L at site 9

Scale is approximately 1:1. Matrix is micro-cross-laminated sandy siltstone.
Most of the silty portions of unit L consist of rocks of the first type. Details of stratification are generally concealed in slope rubble, but where visible, they reveal that this lithologic type, which in places may seem to consist of horizontally laminated to thickly bedded, intercalated siltstone and mudstone, actually consists of strata that form broad troughs (Fig. 17) and are locally deformed (Fig. 20).

The massive reddish-brown siltstone forms thin to very thick tabular beds with sharp to gradational contacts. Internal stratification is concealed. The beds tend to occur in the upper part of unit L, where they form vertical cliffs where protected from erosion by resistant overlying units.

The reddish-orange siltstones are much like the Red Canyon ledge in character, and are in fact tongues which extend from the portion of the study area where the reddish-orange siltstone unit makes up the entire Church Rock(?) Member. They are quartzose, coarse-grained, and, like the Red Canyon ledge, contain mudstone laminae that split to reveal polygonal-shrinkage cracks. They are indistinctly horizontally laminated, and contain rare bioturbations.

Cross-stratified siltstones of unit L commonly overlie the reddish-orange siltstone ledges. Generally the contact is horizontal, but in places the contact is a channeled surface of erosion which cuts into and in places through the reddish-orange ledge, as noticed (1) along the southeast wall of Rainbow Canyon, and (2) on the north wall of Blue Canyon between sites 13 and 14 (Fig. 21).
Figure 20: Deformed bedding in unit L about 500 m northwest of site 13

Deformed layering is located between two sandstone lentils (Lsd) in unit L. Note normal fault zone with downthrown side on left. Wingate Sandstone rests on structureless siltstone in upper part of unit L, as shown by the striped layer (transitional unit, t) that marks the base of the Wingate (upper right corner of photograph). View looking north.
Figure 21: Sketch of channel in unit L
THE HITE BED

The Hite Bed was named by Stewart (1957) for cliffs of cross-stratified sandstone capping the Chinle Formation near the now inundated community of Hite, which was in turn named for Cass Hite, a prospector who ran a placer operation on the site in the 1880s (Hunt, 1953, p. 17). When the name Hite Bed was formalized by Stewart and others (1972), a type section was designated (site 1 in this report). This chapter discusses the lithology, internal stratigraphy, and boundary relations that obtain in the Hite Bed from the type section to the southeast.

Lithology

The Hite Bed consists of three lithologic types: (1) very fine-grained arkosic sandstone, (2) granule to cobble conglomerate grading to conglomeratic sandstone, and (3) siltstone to silty mudstone.

The sandstone is generally pale red and weathers a slightly darker pale red, although some exposures are more purplish, and others weather more reddish-brown. Other surface colors include reddish-orange staining from the overlying Wingate Sandstone. Alteration colors are not as common as in underlying units, but light greenish gray to dusky yellow streaks and mottles occur locally. Site 12 is exceptional in that it displays alteration colors of moderate red, reddish-orange, reddish-brown, reddish-purple, and even dusky blue, giving the Hite Bed an appearance similar to the "Wonderstone" sold in rock shops.
The sandstone is predominantly very fine- to fine-grained and moderately sorted (90 percent of the constituent grains range within three phi classes). Medium to coarse grains are prevalent in poorly sorted sandstone designated as the Hite Bed at sites 4 and 7. Petrographic examination and point counts of thin sections from ten localities indicate that the sandstone is composed of subrounded to subangular grains of (1) quartz (60 percent of sample; includes remarkably clear metaquartz with undulatory extinction), (2) feldspar (25 percent of sample; represented by, in order of prevalence: plagioclase, orthoclase, microcline, sanidine and perthite), and (3) rock fragments (15 percent of sample; including 1 to 2 percent muscovite; rocks represented include, in order of prevalence, volcanics, chert, siltstone and schist). These constituents are moderately well cemented with calcite that appears to have been dolomitized to varying degrees. The presence of dolomite accounts for the only slight effervescence in hydrochloric acid (a fact that may have led some earlier workers into overestimating the importance of the siliceous cement present in the Hite Bed to only a minor degree). Cementing agents fill as little as half the pore spaces, indicating that the Hite Bed has a high permeability.

Conglomeratic sandstones and conglomerates occur throughout the Hite Bed, and locally account for as much as half the thickness of the unit, but they are especially prevalent at and near the base of the Hite Bed. Most of the clasts comprising conglomeratic portions of the Hite Bed are disc-shaped granules to cobbles of siltstone (including sandy and dolomitic varieties) in a matrix of poorly sorted arkosic sandstone. In
addition, the basal conglomerates contain clasts of silty limestone, silty dolomite, and rare chert (Fig. 22).

Siltstone and silty mudstone within the Hite Bed are grayish red to reddish-brown and weather to the latter color. Although clay is locally present to a minor degree, the siltstone tends toward the coarse grain sizes, and commonly contains scattered very fine to fine sand-sized grains. The siltstone is generally well cemented, dolomitic, and commonly feldspathic.

**Internal Stratigraphy**

Internal stratigraphy in the Hite Bed is complex and difficult to trace because outcrops are seldom extensive (Fig. 23). Where present, the Hite Bed commonly forms a flaggy to massively splitting vertical cliff composed of thick to very thick beds of sandstone intercalated with (1) thin to very thick lenses of conglomeratic sandstone and conglomerate, and (2) very thin to thick lenses of siltstone and mudstone which weather out to form indentations.

The sandstone is predominantly composed of small to large scale sets of gently dipping trough cross-laminae with a minor amount of planar cross-stratification. Horizontal laminae and micro-cross-laminae are present especially in the upper part of the unit, and locally appear to form a significant proportion of the Hite Bed (Fig. 24); however, horizontally laminated beds commonly (1) become gently dipping laterally, where they form the edges of very broad troughs, or (2) are actually transverse sections of very gently dipping planar cross-laminae.
Figure 22: Basal conglomerate of Hite Bed at the type section (site 1)

Clasts shown include siltstone, limestone and dolomite.
Figure 23: Type section of the Hite Bed near The Horn

Exposures of the Church Rock(?) Member (cc) seldom extensive. The Hite Bed is a partially buried, darker-weathering ledge at the base of the Wingate Sandstone (w). Note slump blocks that form curved benches in the right-hand portion of the photograph. View looking west.
Figure 24: Pale red portion of Church Rock(?) Member at site 4A
Siltstone and mudstone occur in beds and laminae that are parallel to and weather more readily than adjacent sandstone laminae, forming platy to flaggy indentations. Locally, where siltstone or mudstone occurs in thick lentils, weathering produces steep, indented, fragmental slopes. Mudstone laminae commonly split to reveal dessication structures (Fig. 25).

A characteristic feature of the indented, finer grained strata in the Hite Bed is that, though lenticular, they tend to persist intermittently along certain bedding planes. The original strata appear to have undergone deformation herein ascribed to compaction which has squeezed laminae to form pod trains that give the erroneous impression of being clasts (Fig. 26).

**Boundary Relations**

In the study area, the Hite Bed is thickest near the mouth of Red Canyon, where it is at least 26 meters thick. The Hite Bed thins to the northeast, where it is present intermittently in the south wall of White Canyon. The sporadic occurrence of the Hite Bed in the northeast is well illustrated near sites 6 and 19, where the Hite Bed is reported absent. There, the Hite Bed is represented by pale grayish red siltstone, the base of which becomes a channeled surface of erosion laterally, cutting several meters into underlying units. As the equivalent of the Hite Bed thickens laterally above the correspondingly descending erosion surface, it intertongues with very fine-grained conglomeratic sandstone more typical of the Hite Bed. Because of this intermittency of occurrence, the margins of Hite deposition cannot be placed with certainty in the Red Canyon–White Canyon area, especially where exposures are scarce.
Figure 25: Polygonal-shrinkage cracks in the Hite Bed

View looking upward at underside of splitting planes near site 10. Hammer for scale.
Figure 26: Hite Bed at type section (site 1)

Note indentations where siltstone lenses occur. Differential compaction has given a pod-like configuration to some of the very thin lenses. Other indentations occur where siltstone clasts (as opposed to compacted pods) have weathered out of conglomeratic lenses. View is toward the north.
Where the Hite Bed is recognized at the top of the Church Rock(?) Member, the contact between it and unit L is a channeled surface of erosion; the contact is a sharp, slightly irregular surface below laterally equivalent units. The Hite Bed generally overlies silty portions of unit L, but near the mouth of Red Canyon, where relief on the lower contact of the Hite Bed exceeds 12 meters, the Hite Bed lies directly on sandy portions of unit L. This raises the possibility that where the intervening silty portions of unit L have been eroded away over a large area, the sandy portion of unit L may be included erroneously with the Hite Bed. In such a case, distinction between the two units, if desired, will have to be made on the basis of (1) hitherto undelineated lithologic criteria, (2) studies of sedimentary structures and resultant dip directions (this report), or (3) lateral tracing of a continuous erosion surface where outcrop is extensive. The author views such superposition of sandstones as uncommon, but superposition was verified at site 4 by lateral tracing of the erosion surface between the sandstones. Thus, unit L may constitute the lower part of the Hite Bed at sites 1 and 2, but outcrops are too restricted for confirmation of the possibility.

Contact between the Hite Bed and the Wingate Sandstone is predicated on lithologic differences between the two units. The Wingate Sandstone, like the Hite Bed, is very fine- to fine-grained. It is generally light brown and weathers the same color and moderate reddish-orange in contrast to the pale red to reddish-brown of the Hite Bed. The Wingate is well sorted to moderately well sorted, a greater degree than the Hite, and tends to be more calcareous. While both units are cross-laminated, sets in the Wingate are much thicker and contain larger scale, generally
more planar laminae than the small to medium scale trough cross-laminae found in the Hite. Most visibly, the Wingate Sandstone generally forms a massive cliff bereft of indented siltstone lenses. As can be seen, little difficulty in distinguishing between the two units would be encountered except that in the Red Canyon-White Canyon area the basal few meters of the Wingate Sandstone is commonly transitional in nature.

The transitional unit is horizontally laminated to locally cross-laminated, darker in color than typical sandstone in the Wingate (although the weathering color is commonly the same), and contains horizontal, desiccation-cracked lenses of siltstone. Where the Hite Bed is absent, the slope-forming nature of (1) the silty part of unit L, or (2) the reddish-orange siltstone unit is generally sufficient to locate the contact between the Chinle Formation and the Wingate Sandstone (except at site 25). However, where the Hite Bed is present, and especially where the topmost laminae in the Hite Bed are horizontal, a point of contact is not readily apparent.

The only characteristic of the Wingate Sandstone that has proven reliable in the Red Canyon-White Canyon area to distinguish the Hite Bed from transitional units is the presence of what have been referred to colloquially as "Wingate berries"—coarse rounded to subrounded, clear to amber quartz grains which are scattered in basal portions of the Wingate. This feature of the Wingate was used to define the upper contact of the Hite Bed at its type section (Fig. 27) by Stewart and others (1972). At the type section and elsewhere, the coarse sand grains appear above wavy contacts commonly altered light greenish gray. Although other wavy contacts may occur within a meter or so, the one below the coarse grains is
Contact is at wavy, bleached zone above penny. Coarse sand grains ("Wingate berries") occur especially near the splitting surface 4 cm above the contact.
the one chosen as the contact between the Wingate Sandstone and the Hite Bed.

In the Red Canyon-White Canyon area, the contact between the Hite Bed and the Wingate Sandstone is sharp, but cannot be traced very far laterally because of the cover of debris from the cliff-forming Wingate. At site 7, however, the contact is placed at an erosion surface which truncates the Hite Bed (Fig. 28). The unit overlying the erosion surface, a moderate reddish-brown sandy siltstone (see Appendix B, unit 7.9), is considered to have affinities with the Wingate Sandstone because of the presence within it of very fine- to medium-grained, subrounded to well rounded amber quartz grains.
Figure 28: Sketch of stratigraphic relationships at site 7
PALEOENVIRONMENTAL INTERPRETATIONS

The origin and environment of deposition of the upper Chinle Formation is not well understood. Stewart and others (1972, p. 95-100), in a thoughtful consideration to possible modes of origin for upper Chinle strata, concluded that the Owl Rock and Church Rock (?) Members represented alternating lacustrine and fluvial conditions preceding deposition of the eolian Wingate Sandstone. The findings of this study have not proved inconsistent with the above workers' interpretations: the aim of this chapter is to relate the interpretations in the light of (1) observations made in this study, and (2) sedimentologic concepts prevalent in current literature. In addition, an attempt is made to evaluate some local paleogeographic parameters influencing deposition of fluvial units in the upper Chinle.

Owl Rock Member and Reddish-Orange Siltstone Unit

Over 90 percent of the Owl Rock Member commonly consists of structureless siltstone, the origin of which is uncertain (Stewart and others, 1972, p. 97). That the siltstone is characteristically interstratified with thin but extensive limestone beds containing freshwater palecypods may indicate lacustrine affinities, but the local occurrence of cross-stratified and ripple-laminated siltstones suggests that fluvial conditions may also have played an important role in the deposition of the Owl Rock Member. The overlying reddish-orange siltstone unit, however, offers few genetic clues; it is in part defined by the absence of
limestone, and deposits attributable directly to streams are correspondingly uncommon (but present, just north of site 3, where beds at the base of the Red Canyon ledge are seen to fill a channel cut into underlying structureless siltstone). So the origin of the reddish-orange siltstone unit is as much in doubt as that of the Owl Rock Member. It can be extrapolated that, like the Owl Rock Member, the reddish-orange siltstone unit represents a mixture of fluvial and lacustrine environments—in unknown proportion because of the tabula rosa properties of structures in siltstone, a rock that implies little except deposition in quiet water.

The Red Canyon ledge and others similar to it become more common in the upper part of the reddish-orange siltstone unit. These siltstones contain indistinct horizontal laminations, micro cross-laminae, and mudstone laminae with structures resembling mud curls (Picard and High, 1973, p. 113), thus indicating at least periodic subaerial exposure. Lacustrine, fluvial, or aeolian modes of origin, singly or in combination, seem possible for these massive units.

As pointed out by Stewart and others (1972, p. 97), the siltstones in the upper Chinle "are not...by any means typical lake deposits" because of the coarse constituent grain size (40 to 80 microns) and the oxidized, rather than reduced, state of the iron pigments. However, the indistinct horizontal laminations suggest some kind of subaqueous deposition because aeolian silts are generally structureless (Reineck and Singh, 1973, p. 210). Aeolian winnowing may indeed account for the good sorting of material later reworked during floods or blown into shallow lakes of low organic activity, but in the latter case one would expect an association with evaporites.
Deposition on a floodplain of reworked aeolian deposits seems a reasonable, if somewhat speculative, explanation for these units. While climbing-ripple laminae are commonly associated with modern floodplain deposits (Reineck and Singh, 1973, p. 253), horizontal bedding may form a major portion of some deposits (McKee, Crosby, and Berryhill, 1965). Climbing-ripple laminae are locally abundant in the reddish-orange siltstone unit at sites 14 and 25. Micro cross-stratification is present to some degree in all massive reddish-orange siltstone ledges. Because of the close spacing, in places, of suncracked mudstone laminae, little material seems to have been available per sedimentation unit. In such cases, waning currents may deposit only micro cross-laminae.

Whatever the origin of the reddish-orange siltstone unit in the Red Canyon-White Canyon area, it seems apparent, at least in the massive units, that a large number of depositional events was necessary to accumulate substantial thicknesses of siltstone. X-ray work in the manner of Jones (1972) may well reveal structures in the reddish-orange siltstone unit that cast more light on its history of formation.

**Unit L**

The siltstones in this part of the Church Rock (?) Member can be more readily assigned a fluviatile origin because of association in fining-upwards cyclothems in the manner promulgated by Allen (1965). Unit L can be interpreted as one or more cyclothems with coarse members ranging between 1 and 1.4 meters thick and fine members between 3 and 13 meters thick.
Lithologically, unit L resembles a cyclothem described by Allen (1964, p. 171) in the lower Old Red Sandstone at Ludlow. Coarse members in unit L have an erosion surface below a conglomeratic zone, interpreted as channel lag, and consist predominantly of trough cross-stratified, fine- to very fine-grained sandstone. Very fine-grained silty sandstone locally forms climbing-ripple and micro-cross-laminae above trough sets that commonly decrease in thickness upward—features all consistent with modern deposits in point bars of sinuous streams.

The fine members of unit L, while suggestive of the overbank deposits that commonly overlie point bar sequences, contain several enigmatic features. While in many localities the overlying siltstone is apparently structureless, in others, particularly at a promontory near site 4 (Fig. 24), the siltstone is cross-bedded on a small to large scale. In the upper reaches of Blue Canyon and Rainbow Canyon, where massive tongues of the reddish-orange siltstone unit are interbedded with unit L, channels are observed to have been cut into the reddish-orange siltstone (Fig. 21). At site 17, although mostly obscured by debris, such a channel may entirely cut out a reddish-orange tongue between units 17.5 and 17.6 (see Appendix B). Although the siltstone portions of unit L are commonly buried in slope debris, in some places thin lenses of sandy siltstone form trough-shaped ledges. The origin of these features may be similar to that of features described by Stewart and others (1972, p. 39 and 92) in the Petrified Forest Member—that is, unknown. On the other hand, the presence of a slightly coarser basal unit in these gently dipping channels suggests the beginning of a new, but minor cyclothem, or a
major one that was deposited by an erosive influx possessing little coarse debris. What can generally be said about unit L is that it records one or two major episodes and several minor episodes of fluvial point bar and associated floodplain deposition.

A problem with the fluvial interpretation of silty portions of unit L is the lack of organic remains. Greenish gray mottles in the reddish-orange siltstone unit (Fig. 13) and unit L may represent leached zones of local reduction of organic material in a manner such as that described by Friend (1966). Greenish gray horizontal layers and nodular zones that occur in unit L may represent altered caliche horizons, similar to those found in the Old Red Sandstone (Leeder, 1973, p. 124) or also deposits rich in volcanic ash that were replaced by calcite and dolomite, like layers found elsewhere in the Chinle Formation (Stewart and others, 1972, p. 97).

While criteria for distinguishing ancient deposits of low and high sinuosity streams have not yet become firmly established in the literature, a high sinuosity system for the deposition of unit L seems indicated by (1) the large relative volume of fine-grained units interpreted as overbank deposits, (2) the lack of planar cross-stratification associated with transverse bars common to low sinuosity streams (Smith, 1970), and (3) tentative indications of a wide range in mean paleocurrent directions (Fig. 29).

**Paleogeography Prior to Deposition of the Hite Bed**

Paleocurrent directions measured in unit L and unit M (Fig. 29) indicate a paleoslope to the south or west, directions consistent with
Figure 29: Paleocurrent directions measured in unit L
those measured in equivalent units by Poole (1961, p. 0140). Prior to the deposition of the Hite Bed, sediment entered the Red Canyon-White Canyon area from a probable source in the Uncompahgre Upland (Fig. 30). Circulation of sediment seems to have been sluggish until the advent of the deposition of unit L, when minor high sinuosity streams penetrated the central and northern portions of the Red Canyon-White Canyon area. The streams may have been offshoots of a river system to the north, postulated by Stewart and others (1972, p. 98), a possibility that can be strongly supported if the local concentrations of fish fauna described by Schaeffer (1967) are also discovered in unit L.

**The Hite Bed**

Where present, the Hite Bed caps the Chinle Formation and is directly overlain by the Wingate Sandstone. The Hite Bed, like unit L, is considered to be of fluvial origin, but it differs from the latter unit in several respects. The Hite Bed is composed mostly of medium to large scale trough cross-strata, yet also contains some tabular, inclined and horizontal laminae in its upper portions. The Hite Bed is generally the same grain size as unit L, but contains far more abundant interclasts throughout while those of unit L are generally confined to the base of the unit. Sandy units in the Hite are laterally discontinuous, like those of unit L, but are deposited over a higher percentage of outcrop area.

Although indications are still tenuous, it is possible that the Hite Bed was deposited by a stream system of lower sinuosity than that which deposited unit L, given the reduced amount of overbank deposit and the high amount of intraclasts. In addition, the orientation of
Figure 30: Paleogeography interpreted from upper Chinle strata
paleocurrent indicators (Fig. 31) seems to be more consistent than that of unit L (Fig. 29). What is more important, however, is that the Hite Bed was deposited by streams flowing in nearly the opposite direction of those depositing unit L. This change in paleoslope is interpreted to represent the advent of a new, possibly western source area for Chinle sedimentation, as postulated by Stewart and others (1972, p. 100) and O'Sullivan (1970, p. E 18) on the basis of paleocurrent directions measured elsewhere in the Hite Bed. O'Sullivan noted south-dipping foresets in the Hite Bed on Comb Ridge near the edge of the supposed Rock Point Lagoon, so it is possible, as O'Sullivan indicates, that a separate basin existed north of the Red Canyon-White Canyon area which received sediment from the west and possibly from a divide of local extent south of the study area. That erosion in the upper Chinle Formation south of the area has taken place is indicated by the presence of units correlated with the Hite Bed in unconformable contact directly upon the Owl Rock Member near the San Juan River (Cooley, 1965, p. 51).

Prior to the deposition of the Wingate Sandstone, a period of erosion and/or non-deposition may have occurred in the Red Canyon-White Canyon area, as indicated by (1) an interpreted disconformable contact between the Wingate and the Hite Bed or other units in the Church Rock (?) Member and (2) the presence at one locality (site 7) of a channeled erosion surface at the base of the Wingate (Fig. 29). Deposition in the Wingate of the typical large scale cross-stratification attributed to aeolian dunes was preceded in the study area by a transitional period of sedimentation. During this period, units composed in part of reworked grains from the Chinle Formation were deposited (1) in horizontal laminae
Figure 31: Paleocurrent directions measured in the Hite Bed
interpreted to be products of interdunal sedimentation, and locally (2) as channel-filling strata mostly of fluvial origin.
CONCLUSION

The purpose of this study was to gather information regarding the Hite Bed on a local scale to help verify three general findings of previous workers: (1) that the Hite Bed is internally complex and of discontinuous extent; (2) that it is useful in correlation and may overlie an unconformity of regional significance; and (3) that it may have been deposited from a source area west of those contributing to earlier Chinle deposits.

The first finding was verified again and again during the author's excursions in the Red Canyon-White Canyon area. Not only is the unit discontinuous, but it is more often than not buried in debris from the overlying Wingate Sandstone, a cliff that demands distraught respect from all who seek to work in the upper Chinle in the Red Canyon-White Canyon area. The discontinuity and lithology of the Hite Bed is comparable with characteristics of modern stream-channel deposits; its status as a fluvial unit is confirmed. Tentative indications are that the Hite Bed may have been deposited in a regimen associated with distal low sinuosity streams.

The main value of the Hite Bed as a correlation tool lies in its supposed widespread occurrence and stratigraphic position. The lithologic character of the Hite Bed must be studied more closely to distinguish it from other fine-grained sandstones in the upper Chinle Formation that have nearly the same stratigraphic position but opposite paleocurrent directions. These other sandstones are considered to have been deposited by high sinuosity streams originating from the Uncompahgre Uplift. It is
not certain at this point whether the Hite Bed at its type section in the
Red Canyon-White Canyon area is the same unit as that recognized else­
where. Due to the discontinuous nature of the Hite Bed, it may not be
possible to equate the Hite Bed with similar units on the other side of
the Monument Upwarp; in any case, more lithologic and paleoenvironmental
study needs to be done. If the Hite Bed is ever studied extensively, it
may turn out to be much like the widely recognized Shinarump Member of
the Chinle Formation: the economic importance of that unit quickly led
to (1) a refinement of its extent, (2) the separation from it of unrelated
units (such as the Mossback Member and Monitor Butte Member), and (3) the
onslaught of acupuncture—i.e., hundreds of drill holes to determine the
exact boundaries of channels. All the Hite Bed needs is some gold.

The most reliable unit for correlation on a local scale proved to
be a massive siltstone herein referred to as the Red Canyon ledge. The
unit, however, did not extend beyond the study area and in places is dif­
ficult to distinguish from ledges similar in appearance. Where exposure
is extensive, on the other hand, the tracing of individual ledges may
prove invaluable in establishing separation of diachronous fluvial sand­
stones of a lenticular nature.

The erosional contact at the base of the Hite Bed appears to be
of local extent, but may become of more importance to the south and west.
A hiatus may be indicated between the Hite Bed and the Wingate Sandstone
in the study area: care must be made in locating the contact to recog­
nize a transitional unit at the base of the Wingate that in most locali­
ties is probably of aeolian origin and contains reworked material from
the Chinle Formation. The transitional unit includes mudstone lentils near the base of the Wingate that may give the erroneous impression that the Chinle and Wingate intertongue.

A definite change in conditions of sedimentation is indicated by current directions in the Hite Bed. These directions trend northward and could have been formed from currents emanating from a minor uplift to the south or a major uplift to the west.

The work of many geologists has done much to shed light on the complex interrelationships of the many members of the Chinle Formation. The present study illustrates that the internal stratigraphy of members is equally complex and worthy of further research.
APPENDIX A

PALEOCURRENT DIRECTIONS

Table 1 summarizes the results of a study of paleocurrent directions in the Hite Bed (8 localities), unit L (4 localities), and a unit included in the reddish-orange siltstone unit and located just above the Red Canyon ledge (see Appendix B, Unit 14.2). Trough cross-stratification in unit L and the Hite Bed forms the preponderant indicator of paleocurrent directions. Unfortunately, the inherent preciseness of trough cross-strata cannot be exploited since trough axes, highly reliable paleocurrent indicators (High and Picard, 1974), can seldom be measured due to the lack of exposure with horizontal component. Most indications of paleocurrent direction have been taken from readings of dip direction of trough cross-laminae where cross sections near intersecting planes of vertical exposure enable a three-dimensional orientation to be obtained.

Of 196 readings in the Hite Bed and unit L, six are of trough axes and two are of current lineations, numbers too small to analyze separately from the rest of the data. Measurements in unit 14.2 are more heterogenous, including trends of four trough axes and dip directions of six sets of trough cross-laminae and six truncation surfaces on the stoss side of climbing-ripple marks (the current being taken as traveling opposite the dip direction). Dips of planar cross-strata were not measured because of their paucity and concomitant unreliability (see High and Picard, 1974).
Table 1: Summary of Cross-Stratification Measurements

<table>
<thead>
<tr>
<th>Site no.</th>
<th>No. of readings</th>
<th>Azimuth arithmetic mean</th>
<th>Azimuth trig. mean</th>
<th>Consistency factor</th>
<th>1/2 range of mean 95% confidence</th>
<th>Bimodal resultant vector</th>
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<td>297°</td>
<td>71°</td>
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<td>50°</td>
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<td>4</td>
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<td>314°</td>
<td>36°</td>
<td>315°</td>
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<td>25°</td>
</tr>
<tr>
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<td>347°</td>
<td>75°</td>
<td>342°</td>
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<tr>
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<tr>
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<tr>
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</table>

#Bimodal distribution
+Unimodal distribution extracted by visual examination of bimodal distribution
The average consistency ratio and standard deviation for dips of cross-strata within trough sets (0.63 and 52° respectively) are compatible to those obtained by other workers (Harms, Mackenzie, and McCubbin, 1963, p. 573; Meckel, 1967, p. 85). Bimodal distribution of readings is obtained from the Hite Bed at sites 10 and 15. This probably has resulted from the biased dispersion of dip azimuths obtained from cross-strata that fill troughs so as to have elliptical rather than circular margins (Niehoff, 1958, p. 275): readings cluster around the dip direction of the limbs rather than the axis. The bimodality in each case has been verified using the criterion elucidated by High and Picard (1971, p. 35-36): a number of readings in an interval class is considered modal if it exceeds the average number of readings per class by at least one standard deviation from the average. Note in Table 1 the improved consistency that results if parts of a bimodal distribution are analyzed separately; a resultant vector of the separate modes can be imputed to have a smaller range of 95 percent confidence (computed from unpublished tables by F. G. Poole), depending on the validity of the separation of the distribution into two parts.
Stratigraphic sections have been measured at all sites shown in Figure 2 except 15A, which was used solely for the measurement of paleo-current directions. Site 14A was measured but not described. Other sections not included here have been published elsewhere; they are: site 19 (Stewart and others, 1972, p. 281-286), site 23 (Cooley, 1965, p. 85-91), and sites 21, 22, and 24 (Thaden and others, 1964, p. 60-69). Two sections are included here that were measured by previous workers. Site 1 is located at the type section of the Hite Bed, published in Stewart and others (1972, p. 277-281); the section, in a slightly altered form, is included for the sake of completeness. A section measured at site 20 can be found in Mullens (1960, p. 311-314). The section was revisited and substantially revised; an attempt has been made, however, to retain Mullen's original wording. Sites 2 and 16 were not measured by the author; the descriptions of units have been revised from those made by field assistants.

The remaining sections were measured in feet with a Jacob staff (or tape for thick vertical units) and later converted to meters. Descriptions follow the outline given in "Methods of Study" (this report). Well, moderately, and poorly sorted sediments were considered to have grain size ranges (for 90 percent of constituent grains) within two,
three, and four or more phi classes, respectively. An attempt has been made to conform to the terminology of sedimentary structures preferred by Picard and High (1971).

All sections are located in San Juan County, Utah.
SECTION 1

Measured on promontory across Lake Powell from The Horn, 8.6 km S, 85° E. of Copper Point. (Slightly revised from Stewart and others, 1972, p. 277-278; measured by J. H. Stewart, November 1952.)

Top of section; not top of exposure.

Wingate Sandstone (unmeasured):

1.7 Sandstone, light brown (5YR 6/4), weathering same color, fine- to very fine-grained, well sorted; composed of sub-rounded clear quartz and sparse black accessory minerals; poorly cemented, highly calcareous; composed of thin, small- to medium-scale trough sets of cross-laminae; massive splitting; weathers to form vertical cliff. Only lower 9 m of unit examined. Bottom 4 m contains common to abundant rounded to well rounded coarse grains of clear and amber quartz. From 1.0 to 1.8 m above base of unit sandstone does not contain coarse grains and is horizontally laminated and ripple laminated. Basal contact sharp.

Chinle Formation:

Church Rock(?) Member:

Hite Bed:

1.6 Sandstone and conglomeratic sandstone to cobble conglomerate. Sandstone, pale red (5R 6/2), common pale reddish-brown (10R 5/4) and pale yellowish-orange (10YR 8/6) to dark yellowish-orange (10YR 6/6), weathering pale red (5R 6/2) and light brown (5YR 6/4), fine- to medium-grained, uncommon interstitial green silt, well sorted; composed of subangular clear quartz and uncommon green and orange accessory minerals, common fine-grained white mica; firmly cemented, noncalcareous to moderately calcareous; composed of horizontal laminae and thin small- to medium-scale trough sets of low-angle cross-laminae; platy and blocky to massive splitting. Cobble disk-shaped and have a maximum long dimension of 40 cm. Unit as whole is tabular. Weathers to form
vertical cliff. Basal 0.2 m of unit is cobble conglomerate; 0.2 to 0.5 m pebble conglomerate; 0.5 to 1.2 m sandstone; 1.2 to 2.1 m pebble conglomerate; 2.1 to 3.5 m cobble conglomerate; 2.7 to 8.5 m sandstone; 8.5 to 8.8 m granule conglomerate; 8.8 to 10.4 m sandstone .................................. 10.4

Total of Hite Bed .................................. 10.4

Unit L(?):

1.5 Siltstone, pale reddish-brown (10R 5/4), weathering same color and pale red (10R 6/2); firmly cemented, noncalcareous; contains common thin sets of sandy siltstone in top 1.5 m of unit similar to that in unit 1.4 and grayish orange part of unit 1.3. These thin sets dip at an angle of 30° to the regional dip and are truncated by the overlying unit .............................................. 2.8

1.4 Sandy siltstone (70%) and siltstone (30%). Sandy siltstone, light brown (5YR 6/4) and pale red (10R 6/2), weathering same colors, abundant very fine sand grains; uncommon fine-grained mica, common limonite stains; well-cemented, noncalcareous; composed of thin sets of ripple laminae and horizontal laminae interbedded with siltstone; platy splitting. Siltstone, pale reddish-brown (10R 5/4), weathering same color and pale red (10R 6/2); firmly cemented, noncalcareous; stratification concealed. Entire unit is tabular. Unit weathers to form minor ledge. Poorly exposed granule conglomerate occurs from 0.0 to 0.3 m and 0.4 to 0.6 m above base of unit. Granule conglomerate, pale yellowish-brown (10YR 6/2), weathering same color; composed of granules, abundant medium to very coarse sand grains, and sparse pebbles of siltstone, poorly sorted; firmly cemented, noncalcareous; stratification concealed .............................................. 1.1

Total of Unit L(?) .................................. 3.9

Reddish-orange siltstone unit:

1.3 Sandy siltstone, pale reddish-brown (10R 5/4), abundant grayish-orange (10YR 7/4) from 2.3 to 4.4 m above base of unit and abundant light greenish-gray (5GY 8/1) spots as much as 5 cm in diameter; abundant very fine sand grains; firmly cemented, moderately calcareous; composed of horizontal laminae; unit weathers to form lighter-colored, blocky splitting cliff from 2.3 to 4.4 m above base of unit; rest of unit is steep slope ......... 4.8
1.2 Siltstone, similar to unit 1.5; weathers to form steep rubble-covered slope. Common light greenish-gray (5GY 8/1) spots ............... 3.2

1.1 Sandy siltstone, similar to unit 1.3; platy, blocky and massive splitting; weathers to form vertical cliff in lower 6.1 m and steep loose slope in rest of unit. Bottom 1.0 m of unit contains sandy siltstone that contains abundant light greenish-gray (5GY 8/1) mottles and is well cemented with a calcareous cement. Abundant light greenish-gray (5GY 8/1) mottles about 8 m above base of unit produces a light colored band 1.5 m thick ............... 8.6

Total of reddish-orange siltstone unit ............... 16.6

Total of Church Rock(?) Member ...................... 30.9

Owl Rock Member:

1.0 Siltstone, pale red (5R 6/2) in basal 1.2 m and pale reddish-brown (10R 5/4) in rest of unit, weathering pale red (10R 6/2); firmly cemented, highly calcareous in places, noncalcareous in places; stratification concealed. Basal 1.2 m contains swelling clays ............... 3.2

Total of incomplete Owl Rock Member ............... 3.2

Base of excerpted section, not base of section in Stewart and others (1972, p. 277).
SECTION 2

Measured near southwest corner of butte north of Scorup Canyon, 9.8 km N., 86° W. of Blue Notch, northeastern part of Sec. 6 (unsurveyed, T. 35 S., R. 14 E. (Measured by Rod Stevens, October 13, 1973.)

Top of notch, not top of exposure.

Chinle Formation:

Church Rock(?) Member:

Hite Bed:

2.7 Sandstone, brownish-red to purple, very fine-grained; thin-beded, conglomeratic at bottom; forms slope with thin basal ledge ........................................ 4.0

2.6 Conglomerate, brownish-red, weathering same color; composed of (1) subrounded siltstone pebbles (95%) and (2) granules and cobbles (5%), in a matrix of very fine-grained sandstone; includes some interstitial mudstone; forms indistinct, poorly cemented ledge ........................................ 0.6

Total of Hite Bed .................................... 4.6

Erosion surface: Contact between Hite Bed and unit L(?) is a channel-forming surface of erosion with at least 1.5 m relief.

Unit L(?)

2.5 Siltstone to sandy siltstone (85%) and mudstone (15%). Siltstone, light gray to greenish-gray, weathering reddish-brown; firmly cemented, slightly calcareous; contains polygonal-shrinkage cracks, bioturbations (probably plant roots), and thinly cross-beded trough sets averaging 90 cm in thickness; becomes very sandy at top. Mudstone, dark gray; firmly cemented, noncalcareous; interlayered with siltstone. Unit as whole forms ledge ........................................ 1.5

2.4 Siltstone, grayish-brown to purple; firmly cemented, noncalcareous; poorly exposed, forms slope .............. 4.9
2.3  Siltstone (90%) and mudstone (10%), like unit 2.4; occurs in beds 10 to 60 cm thick interlayered with mudstone; composed of trough cross-strata that are locally deformed; forms cliff ........................................................ 7.1

Total of unit L(?) ........................................... 13.5

Erosion surface: Contact between units 2.2 and 2.3 is a channeled surface of erosion with at least 1.8 m relief.

Reddish-orange siltstone unit:

2.2  Siltstone (50%), mudstone (25%), and conglomerate (25%). Siltstone, grayish-pink, commonly altered light greenish-gray; firmly cemented, slightly calcareous; contains wavy laminae and local climbing-ripple laminae; forms very thin to thick beds. Mudstone, grayish-red, occurs interbedded with siltstone. Granule to pebble conglomerate, composed of (1) disc-shaped siltstone clasts, and (2) sparse chert pebbles in very fine-grained sandstone matrix; forms lenses as thick as 0.5 m. Unit is entirely composed of low angle trough cross-strata; flaggy splitting; forms vertical cliff in line of section, laterally forms steep slope ......................... 1.8

Contact: The boundary between units 2.2 and 2.1 is an irregular surface of about 30 cm relief, probably representing minor erosion.

2.1  Siltstone, reddish-orange, altered yellowish coloration at top of unit; firmly cemented, slightly calcareous; contains scattered granules of quartz; forms ledge with concealed base ............................................ 2.7

Total of incomplete reddish-range siltstone unit ........ 4.5

Total of incomplete Church Rock(?) Member ................. 22.6

Base of section; base of exposure.
SECTION 3

Measured up the southeast side of the promontory that forms the southwestern half of a pass between Blue Notch and Scorup Canyons, 6.2 km S. 55° E. of Copper Point, Sec. 4 (unsurveyed), T. 35 S., R. 14 E. (Measured by J. Dunn and R. Stevens, October 15, 1973.)

Top of section; not top of exposure.

Wingate Sandstone (unmeasured):

3.10 Sandstone, light brown (5YR 6/4), weathering same color, fine- to very fine-grained, well sorted; composed of subrounded quartz grains; moderately well cemented, highly calcareous; composed of small- to large-scale trough and wedge-planar cross-laminae; massive splitting; weathers to form vertical cliff.

Contact: Wingate-Chinle contact is covered, but may be placed near change from vertical cliff to steep slope.

Chinle Formation:

Church Rock(?) Member:

Unit L:

3.9 Siltstone, pale red (10R 6/2), weathering same color to pale reddish-brown (10R 6/4); moderately well cemented, noncalcareous; most of unit is covered with debris from overlying units; forms steep slope .................................. 3.7

3.8 Sandstone, silty sandstone, siltstone, and conglomerate. Sandstone and silty sandstone, moderate dusky red (5R 4/4), weathering same color or altered with streaks and mottles of light greenish-gray (5GY 8/1), very fine- to fine-grained, moderately sorted to well sorted; composed of (1) subangular to angular clear to dark gray quartz, and (2) uncommon feldspar, chert, muscovite, biotite, and dark accessory minerals; firmly cemented, moderately calcareous; composed of indistinct small-scale sets of trough cross-laminae. Siltstone, medium gray (N5) and light gray (N7), weathering same colors; composed of
quartz and as much as 5% dark accessory mineral grains; firmly cemented, noncalcareous; occurs as small-scale pods to lentils that weather out as recesses when enclosed in sandstone; largest lentil is 50 cm thick and contains deformed micro-cross-laminae. Conglomerate is composed of coarse sand-sized grains to cobbles of disc-shaped to spherical limestone, siltstone, mudstone, and local chert in a matrix of fine- to medium-grained sandstone; forms basal 0.6 to 1.0 m of unit. Unit as whole weathers as slope with a basal ledge 0.5 to 1.8 m thick. 

Total of unit L ................................. 6.9

Erosion surface: Contact between unit L and reddish-orange siltstone unit is a channel-forming surface of erosion with at least 1.3 m relief.

Reddish-orange siltstone unit:

3.7 Siltstone, pale orange pink (10R 7/2), weathering same color to light brown (5YR 6/4); moderately calcareous; composed of indistinct horizontal to wavy laminae; forms a slope containing slabby-splitting ledges .......................... 1.5

3.6 Siltstone, moderate orange pink (10R 7/4) and moderate reddish-orange (10R 6/6), weathering light brown (5YR 6/4) and altered in streaks and mottles of (1) grayish-red (10R 4/2) to moderate reddish-brown (10R 4/6), and (2) light greenish-gray (5GY 8/1); firmly cemented, slightly calcareous; contains laminae and very thin beds of mudstone, especially in basal 1.5 m of unit. Mudstone beds and laminae commonly form dessication structures and in places beds are micro-cross-laminated. Rest of unit is structureless to horizontally laminated; splitting is massive to blocky. Unit as whole forms part of vertical cliff ........................................ 4.4

3.5 Sandstone, light brown (5YR 6/4) and moderate reddish-brown (10R 4/6), weathering same colors, very fine- to fine-grained; composed of subangular grains of quartz; poorly to moderately well cemented, noncalcareous to slightly calcareous; stratification concealed. Unit is lenticular, forms part of cliff ...................................... 0.3

3.4 Siltstone, light brown (5YR 5/4) and pale reddish-brown (10R 5/4), weathering same colors, basal 0.3 m altered yellowish-gray (5Y 6/1), light brown (5YR 6/4), and yellowish-gray (5Y 7/2); firmly cemented, moderately calcareous; composed of indistinct horizontal laminae along which coarse sand grains and granules are sparsely
disseminated. Unit weathers as follows: basal part of unit forms a ledge 2.4 to 3.1 m thick, contains several indentations of finer grained, locally micro-cross-laminated siltstone; middle part of unit forms a steep slope 1.5 to 2.2 m thick; upper part of unit is 2.1 m thick and contains mudstone laminae that commonly form polygonal-shrinkage cracks in plan view; mudstone laminae weather out to form slits 1 to 8 mm deep. Unit as whole forms cliff with central slope ............... 6.6

Contact: Contact between units 3.4 and 3.3 near line of section is flat with no apparent relief; however, 200 m to the northeast, the same surface is channeled with 3 m relief.

3.3 Siltstone, moderate orange pink (10R 7/4) to pale red (10R 6/2), weathering same colors, contains common light greenish-gray (5GY 8/1) mottling; moderately well to poorly cemented, highly calcareous; contains micro-cross-stratification; weathers to form rubble-covered slope with a few thin ledges. Uppermost 0.6 m of unit forms a vertical ledge capped by fine-grained recessed siltstone 0 to 6 cm thick ............... 2.4

3.2 Siltstone, pale reddish-brown (10R 5/4), weathering moderate reddish-orange (10R 6/6), altered very pale green (10G 8/2) in mottles 1 to 20 cm in diameter; firmly cemented, moderately calcareous; appears structureless. Basal 0.3 m of unit contains as much as 3% coarse sand grains and scattered granules. Unit forms vertical ledge; spheroidal weathering common in uppermost 0.9 m . . . . . . . 3.0

3.1 Sandstone, light greenish-gray (5GY 8/1), weathering light brown (5YR 6/4) to moderate reddish-orange (10R 6/6), very coarse-grained to conglomeratic, poorly sorted, locally contains laminae and very thin beds of very fine- to fine-grained sandstone; composed of subangular to subrounded quartz with minor amounts of chert, siltstone, and dark accessory mineral grains; firmly cemented, highly calcareous; contains very indistinct cross-laminae; blocky splitting; forms base of vertical ledge ......................... 1.2

Total reddish-orange siltstone unit .................. 19.4

Total Church Rock(?) Member .......................... 30.0

Contact: Contact between the Church Rock(?) and Owl Rock Members is an irregular surface of less than 15 cm relief. Unit 3.1 truncates underlying cross-strata. Contact is
placed near color change from grayish Owl Rock units to more reddish Church Rock(?) units.

Owl Rock Member (unmeasured):

3.0 Sandstone, moderate orange pink (10R 7/4), weathering same color, mottled very pale green (10G 8/2), fine-grained, well sorted; composed of subangular to sub-rounded quartz grains and sparse dark accessory mineral grains; moderately well cemented, slightly to moderately calcareous; forms steep rubble-covered slope. Only top of unit examined.

Base of section; not base of exposure.
SECTION 4

Measured on the southern rim of Blue Notch Canyon, 6.2 km
due east of Castle Butte. Section is located 700 m east
of the promontory that terminates the southern rim of
Blue Notch Canyon and 160 m west of where the rim angles
abruptly northward; section is in the southwestern quar­
ter of sec. 16 (unsurveyed), T. 35 S., R. 14 E.

Top of section; not top of exposure.

Wingate Sandstone (unmeasured):

4.8 Sandstone, light brown (5YR 6/4), weathering moderate
reddish-orange (10R 6/6), fine- to medium-grained, well
sorted; composed of subrounded to subangular clear quartz
grains with uncommon coarse-grained clear and amber
quartz distributed along laminae or in small aggregates;
moderately well cemented, highly calcareous; contains
indistinct medium- to large-scale wedge-planar cross­
laminae; massive splitting; forms vertical cliff. Only
base of formation examined.

Contact: Wingate-Chinle contact is a wavy surface of 2
to 3 cm amplitude. The surface appears flat, but it
slopes 3.4 m vertically over 150 m horizontally relative
to the Red Canyon ledge.

Chinle Formation:

Church Rock(?) Member:

Hite Bed:

4.7 Sandstone, conglomeratic sandstone, and siltstone to mud­
stone. Sandstone and conglomeratic sandstone, pale red
(10R 7/2), weathering moderate reddish-orange (10R 6/6),
generally medium-grained, poorly sorted; composed of (1)
subangular very fine to coarse grains of clear to pale
red (10R 6/2) quartz, (2) disc-shaped grains, granules,
and uncommon pebbles to cobbles of grayish-red (10R 4/2)
to dark reddish-brown (10R 3/4) siltstone to mudstone,
and (3) minor amounts of dark accessory mineral grains;
moderately well cemented, moderately calcareous; composed
of small- to large-scale sets of trough cross-laminae; laterally contains numerous conglomeratic zones above intrastratal diastems; in line of section forms a vertical ledge continuous with the cliff of the overlying Wingate Sandstone. Siltstone, grayish-red (10R 5/2) to moderate reddish-brown (10R 5/4); firmly cemented, noncalcareous, forms slopes and indentations; not present in line of section. About 100 m to the east, a 5 by 15 m siltstone lense intertongues with thin sandstone at its margins. About 20 to the west, the extremity of a thick siltstone lentil is brecciated into boulder-sized fragments.

Total of Hite Bed

Erosion surface: Contact between the Hite Bed and unit L is a channeled surface of erosion. Over a distance of 500 m west of the line of section, relief of the surface totals 12.7 m.

Unit L:

4.6 Siltstone, grayish-orange pink (5YR 7/2), weathering same color; firmly cemented, noncalcareous; composed of a single set of concave-upward, tabular-planar cross-laminae dipping 21°, N. 80° W. Unit forms vertical ledge continuous with that of overlying unit.

Erosion surface: Contact between units 4.6 and 4.5 is an irregular surface of erosion with about 1 m relief.

4.5 Siltstone and mudstone, pale red (5R 6/2), weathering same color; slightly calcareous; predominantly microcross-stratified. Mudstone is concentrated in very thin beds and laminae that weather out to form indentations. Unit forms vertical ledge.

Total of unit L

Contact: Contact between unit L and unit M is an irregular surface of minor erosion with relief less than 10 cm.

Unit M:

4.4 Sandstone and siltstone, pale red (10R 6/2), weathering same color. Sandstone, generally medium-grained, moderately to poorly sorted; well cemented, noncalcareous; forms very thin, indistinctly cross-laminated beds with coarse-grained to granular and pebbly basal surfaces;
occurs intercalated with siltstone in upper 1.8 m of unit. Siltstone, well cemented, noncalcareous, is indistinctly stratified. Unit weathers as a vertical ledge to steep slope broken by a small ledge of altered, light greenish-gray (5GY 8/1) siltstone that occurs 0.8 m from base of unit and is 0.7 m thick.

Contact: Contact between units 4.4 and 4.3 is gradational, and is placed above the last strongly apparent very thin grayish-orange pink siltstone bed in unit 4.3.

4.3 Siltstone and mudstone. Siltstone, grayish-orange pink (5YR 7/2); siltstone and mudstone, pale red (5R 6/2) with pale reddish-brown (10R 5/4) to moderate reddish-brown (10R 4/6) streaks, weathering same colors; firmly cemented, noncalcareous to slightly calcareous. Unit is characterized by very thin siltstone beds separated by darker, finer-grained beds that are 1 to 8 cm (and in one case, 1.3 m) thick. Beds are commonly laminated and are horizontal. Basal 1.2 m is more orange pink (10R 7/4) and is mostly altered light greenish-gray (5GY 8/1) or moderate reddish-brown (10R 4/6). Basal part of unit is more silicified and is laterally conglomeratic. Unit as whole fractures to form a steep slope of angular fragments.

Total of unit M

Reddish-orange siltstone unit:

Red Canyon ledge:

4.2 Siltstone to sandy siltstone, moderate reddish-orange (10R 6/6), weathering same, coated in places with manganese staining; composed of coarse silt-sized and scattered very fine sand-sized grains; firmly cemented, slightly calcareous; composed of horizontal to wavy laminae and also contains micro-cross-stratification. Mudstone laminae are common in basal 0.3 m; many of these are bent upward in cross section because they form polygonal-shrinkage cracks in plan view. Unit displays common light greenish-gray (5GY 8/1) alteration in streaks and mottles. Unit splits massively; forms vertical cliff.

Total of Red Canyon ledge

4.1 Siltstone and conglomeratic siltstone. Siltstone, reddish-brown (10R 5/6) and moderate orange pink (10R 7/4), weathering same colors; firmly cemented, slightly
calcareous to noncalcareous. Conglomeratic siltstone, reddish-brown (10R 5/6), but predominantly altered light greenish-gray (5GY 8/1); moderately to highly calcareous; composed of horizontal laminae and zones of subrounded to subangular granules to pebbles of siltstone, silty limestone, and sparse quartz and chert; quartz clasts predominate in basal 6 cm of unit; conglomeratic portion occurs in basal 0.5 m of unit. Polygonal-shrinkage cracks occur in uppermost 6 cm of conglomeratic portion. Unit as whole forms steep slope covered with angular fragments.

Total of reddish-orange siltstone unit ..................... 19.3

Total of Church Rock(?) Member ............................. 39.2

Contact: Contact between the Church Rock(?) and Owl Rock Members is placed at color change from grayish and pale reddish units in the Owl Rock Member to brownish-red and reddish-orange units in the Church Rock(?) Member.

Owl Rock Member (unmeasured):

4.0 Siltstone, pale red (5R 6/2), weathering pale reddish-brown (10R 5/4) and moderate reddish-brown (10R 4/6), weathering colors in part due to staining from overlying units; moderately well cemented, slightly to moderately calcareous; appears structureless. Yellowish-gray (5Y 8/1) mottling common; iron oxide penetrate fractures. Unit contains local concentrations of siltstone pebbles like those in unit 4.1; forms slope. Only top of unit examined.

Base of section; not base of exposure.
SECTION 5

Measured up promontory that separates Blue Notch Canyon from a southern fork, 6.4 km due west of Ducket Crossing; section crosses the southern boundary of sec. 11 (unsurveyed), T. 35 S., R. 14 E. (Measured by J. Dunn and R. Stevens, October 18, 1973.)

Top of section; not top of exposure.

Wingate Sandstone (unmeasured):

5.5 Sandstone, conglomeratic sandstone, and dolomite. Sandstone, moderate reddish-orange (10R 6/6), weathering same color, fine- to very fine-grained; well sorted, but contains numerous subrounded amber coarse grains along laminae and in aggregates; composed of subrounded quartz grains and sparse dark accessory mineral grains; contains large-scale cross-laminae; forms 95% or more of unit. Sandstone to conglomeratic sandstone, pale reddish-brown (10R 5/4), generally fine-grained, ranges in places from very fine- to coarse-grained, moderately to poorly sorted; composed of clear to dark amber subangular to well rounded quartz grains and scattered granules to pebbles of pale red siltstone; moderately well cemented, slightly calcareous; composed of micro-cross-laminae; forms basal 0.7 m of unit. Dolomite, light olive gray (5Y 6/1), exposed surface light brown (5YR 6/4 to 5/6) or coated with white carbonate crust; microcrystalline; forms inaccessible bed about 1 m thick located about 7 m from base of unit; dolomite splits into tongues laterally and pinches out. Unit as whole splits massively and forms vertical cliff. Only basal part examined.

Contact: Contact between the Wingate Sandstone and the Chinle Formation is a wavy surface of 1 to 2 cm amplitude. Contact is placed just below color change and presence of coarse amber quartz grains in the Wingate.

Chinle Formation:

Church Rock(?) Member:
Hite Bed and unit L undifferentiated:

5.7 Sandstone, siltstone, conglomeratic sandstone, and conglomerate, light dusky red (5R 4/4) overall, weathering moderate red (5R 5/4). Sandstone to arkosic sandstone and conglomeratic sandstone, pale red (5R 6/2 to 10R 6/2), weathering pale reddish-brown (10R 6/4), fine-grained, moderately to poorly sorted; composed of subrounded to subangular quartz grains, as much as 10% subangular feldspar grains, and sparse dark accessory minerals and muscovite flakes; conglomeratic portions composed of less than 30% granules to pebbles of slightly darker-colored siltstone and mudstone weathering out to form recesses in the sandstone matrix; moderately well-cemented, noncalcareous to slightly calcareous; sandstone in upper part of unit (Hite Bed) contains medium- to large-scale trough cross-laminae, horizontal laminae, and micro-cross-stratification; sandstone in lower part of unit (unit L) is composed of small- to medium-scale trough cross-laminae that grade into micro-cross-laminae with decreasing set height. Siltstone, grayish-red (10R 4/2), weathering same color; composed of quartz and accessory muscovite grains; firmly cemented, noncalcareous; forms very thin to very thick beds, many of which are lenticular; also occurs as laminae within sandstone. Siltstone to very fine-grained sandstone, pale red (5R 6/2), weathering grayish-red (5R 4/2), finely laminated; firmly cemented, slightly calcareous; occurs in uppermost 0.5 m of unit. Conglomerate, composed of subrounded granules to cobbles of light olive gray (5Y 5/1) dolomite, pale red (10R 6/2) limestone, grayish-red (5R 4/2) siltstone, and rare chert, in a matrix of poorly sorted sand-sized quartz grains including sparse grains of chert and mica; occurs in basal 0.6 m of unit and is thickest at base of paleochannels. Unit as whole is a series of platy to massively splitting ledges .... 20.1

Total of Hite Bed and unit L undifferentiated .... 20.1

Erosion surface: Contact between unit 5.7 and unit M is a channeled surface of erosion with at least 1 m relief.

Unit M:

5.6 Siltstone, pale orange brown (10R 6/4) and light brown (5YR 6/4), weathering same colors, altered light greenish-gray (5G 8/1) in streaks and mottles; firmly cemented, noncalcareous. Unit weathers as follows: 0.0 to 2.1 m, rhythmically bedded, alternately colored, slope-forming siltstones 1 to 10 cm thick; 2.1 to 2.6 m, partially
silicified, micro cross-stratified, flaggy-splitting ledge; 2.6 to 3.9 m, slope covered with pebble-sized angular fragments; 3.9 to 4.6 m, spheroidally-weathering ledge with an altered zone 25 cm thick at base of ledge ...................................................... 4.6

Total of unit M ........................................... 4.6

Contact: Contact between unit M and reddish-orange siltstone unit is placed at change in color and weathering characteristics; surface of contact is flat and appears to have little relief.

Reddish-orange siltstone unit:

Red Canyon ledge:

5.5 Siltstone, moderate reddish-orange (10R 6/6) to pale reddish-brown (10R 5/4), weathering same, contains yellowish-gray (5Y 8/1) alteration in mottles 1 to 15 mm in diameter; firmly cemented, slightly calcareous; contains faint horizontal and micro cross-laminae; massive splitting; forms vertical, overhanging ledge .......................... 4.2

5.4 Siltstone, like unit 5.5; forms cliff composed of four very thick beds that alternately protrude and recess; other minor indentations occur locally .......................... 5.1

Total of Red Canyon ledge .................................. 9.3

5.3 Siltstone, pale red (10R 6/2), weathering same color; firmly cemented, noncalcareous; forms ledge below overhang . 1.0

5.2 Siltstone, grayish-orange pink (5YR 7/2), weathering pale reddish-brown (10R 5/4); firmly cemented, noncalcareous; forms slope . 0.7

5.1 Siltstone, like unit 5.5; forms small poorly defined ledges and steep slope covered with angular pebble- to cobble-sized fragments .......................... 8.9

Total reddish-orange siltstone unit .......................... 19.9

Total of Church Rock(?) Member .......................... 44.6

Contact: Contact between the Owl Rock and Church Rock(?) Members is placed at color change from grayish units in the Owl Rock Member to more reddish-orange, markedly less calcareous units in the Church Rock(?) Member.
Owl Rock Member:

5.02 Limy siltstone, grayish-orange pink (5YR 7/2), weathering same color, stained reddish-brown (10R 4/4 to 10R 6/4); contains uncommon subangular to subrounded sand-sized quartz grains; firmly cemented, highly calcareous; forms a slope capped by a weakly defined nodular ledge and covered by angular to rounded, pebble-to cobble-sized fragments ........................................... 2.1

5.01 Limestone, bluish-white (5B 9/1), weathering grayish-orange (10YR 7/4), moderate reddish-orange (10R 6/6), and light greenish-gray (5G 8/1); microcrystalline; appears partially silicified; forms ledge .................. 0.4

Total of incomplete Owl Rock Member .................. 2.5

Base of section; not base of outcrop.
SECTION 6

Measured up the promontory that forms the southern half of Blue Notch, 1.6 km N. 40° W. of the Happy Jack Mine, sec. 6 (unsurveyed), T. 35 S., R. 15 E. (Measured by J. Dunn and R. Stevens, October 19, 1973.)

Top of section; not top of exposure.

Wingate Sandstone (unmeasured):

6.12 Sandstone, siltstone and mudstone. Sandstone, pale reddish-orange (10R 5/6), very fine- to coarse-grained, poorly sorted; composed of subangular to subrounded quartz grains and minor amounts of dark accessory minerals; moderately well cemented, moderately calcareous; contains medium- to large-scale wedge-planar cross-laminae and horizontal laminae near base of unit. Siltstone and thinly interbedded mudstone, grayish red (10R 4/2), occur 2.0 m from base of unit in a bed 1.1 m thick. Siltstone is horizontally laminated; mudstone commonly forms polygonal-shrinkage cracks. Unit as whole forms vertical cliff; only base of unit examined.

Contact: Wingate-Chinle contact is sharp and wavy; it is marked in the lowermost Wingate by a thin bleached zone containing coarse amber sand-sized quartz grains.

Chinle Formation:

Church Rock(?) Member:

Hite Bed:

6.11 Siltstone, pale grayish-red (5R 5/2), weathering pale reddish-brown (10R 5/4); firmly cemented, noncalcareous; stratification concealed; lower portion weathers out more easily than upper portion. Unit intertongues with very fine-grained, thinly bedded sandstones 400 m to the southwest .................................................. 1.6

Total of Hite Bed .............................................. 1.6
Erosion surface: Contact between the Hite Bed and unit L is an irregular erosion surface with less than 0.3 m relief; laterally, however, the surface forms the base of a channel that cuts more than 4.5 m into underlying units.

Unit L:

6.10 Siltstone, moderate reddish-orange to moderate orange pink (10R 6/6 to 10R 7/4), altered with mottles of light greenish-gray (5GY 8/1) in upper portion; firmly cemented, noncalcareous; iron oxide prevalent along fractures. Lower portion weathers as ledge; upper portion splits into platy and flaggy fragments and forms a slope. Laterally, a unit in the same stratigraphic position as unit 6.10 is more pale reddish-purple (5RP 6/2), weathering pale reddish-brown (10R 5/4) with altered dusky yellow (5Y 6/4) blotches that weather light brown (5YR 6/4)... 1.6

6.9 Siltstone, moderate reddish-orange (10R 6/6), weathering same color; firmly cemented, noncalcareous; micro-cross-stratification prevalent in basal 1.2 m; forms thin basal ledge grading upward into a slope covered with angular fragments... 3.4

6.8 Siltstone, grayish-red (10R 4/2), weathering same color; noncalcareous; has blotchy appearance; forms a slope covered with angular, granule-sized fragments... 0.6

6.7 Siltstone, light brown (5YR 5/6), weathering pale reddish-brown (10R 5/4); moderately well cemented, slightly calcareous; composed of horizontal, wavy, and micro-cross-stratified laminae; massive splitting; forms ledge... 3.1

6.6 Siltstone to mudstone, moderate orange pink (10R 7/4), weathering same color to moderate reddish-orange (10R 6/6); well cemented, noncalcareous to slightly calcareous; composed of horizontal laminae, climbing-ripple laminae, and micro-cross-laminae. Local concentrations of dark accessory mineral grains occur along laminae. Unit forms a steep slope with a basal ledge 1.2 m thick. Lower contact is sharp and irregular... 2.8

6.5 Siltstone, mudstone, and minor conglomerate. Siltstone moderate orange pink (10R 7/2), weathering same color; siltstone and mudstone, pale red (10R 6/2) to pale reddish-brown (10R 5/4), weathering the same to slightly darker colors, also altered light greenish-gray (5GY 8/1)
toward top of unit; firmly cemented, slightly to moderately calcareous; forms steep slope with minor thin ledges that contain locally abundant mudstone intraclasts. Granule to pebble conglomerate, light bluish-gray (5B 7/1) to light greenish-gray (5G 8/1), weathering light greenish-gray (5G 8/1) with minor iron oxide staining; poorly to moderately well cemented; composed of coarse sand-sized grains to small pebbles of limestone, silty limestone, and siltstone, with sparse quartz and feldspar grains; forms thin basal ledge. Unit weathers as follows: 0.0 to 0.2 m, ledge; 0.2 to 6.7 m, steep slope; 6.7 to 7.4 m, laminated, platy-splitting ledge; 7.4 to 9.6 m, steep slope; 9.6 to 10.1 m, ledge of wavy-laminated siltstone in 1 to 2 cm beds separated by mudstone seams commonly 2 to 5 cm thick; platy to flaggy splitting; 10.1 to 10.9 m, steep slope .......... 10.9

Total of unit L ....................................... 22.4

Contact: Contact between unit L and unit M is an irregular surface of about 5 cm relief, probably representing minor erosion.

Unit M:

6.4 Siltstone and silty limestone. Siltstone, pale red (10R 6/2), weathering same color; firmly cemented, slightly to moderately calcareous. Silty limestone, light greenish-gray (5G 8/1) with iron oxide staining; microcrystalline; most common toward base of unit. As a whole, unit weathers to form steep slope ............ 4.7

Total of unit M ....................................... 4.7

Reddish-orange siltstone unit:

6.3 Siltstone, moderate reddish-brown (10R 5/6), weathering same color, altered light greenish-gray (5GY 8/1) in circular mottles; firmly cemented, slightly calcareous; weathers to form steep slope with a central, blocky-splitting, spheroidally-weathering ledge ............ 3.1

6.2 Siltstone, moderate orange pink (10R 7/4), weathering moderate reddish-orange (10R 6/6); firmly cemented, slightly calcareous; contains biogenic (?) sole marks; forms ledge ............... 1.1

6.1 Siltstone, pale reddish-brown (10R 5/4) and moderate reddish-brown (10R 4/6), weathering moderate reddish-brown (10R 4/6), contains moderate orange pink nodules
and blotches at upper and lower contacts; firmly cemented, slightly calcareous; contains scattered subangular fine-grained sand in central band 0.4 m thick; forms steep slope or, where unit underlies ledge, a vertical slope .......................... 1.9

Total of reddish-orange siltstone unit .......................... 6.1

Total of Church Rock(?) Member .............................. 34.8

Contact: Contact between the Church Rock(?) and Owl Rock Members is placed at color change from predominantly light greenish-gray, calcareous siltstones in the Owl Rock Member to less calcareous, reddish-brown siltstones in the Church Rock(?) Member.

Owl Rock Member:

6.05 Silty limestone and limy siltstone, light gray (n 7) and pale red (10R 6/2); predominantly altered light greenish-gray (5GY 8/1) or stained reddish-brown (10R 5/4). Silty limestone is microcrystalline and occurs in three ledges varying in thickness from 15 to 90 cm; silty limestone forms two slopes between ledges. Basal 2 cm of unit contains numerous subangular to subrounded coarse sand grains and granules .......................... 2.4

Contact: Contact between units 6.05 and 6.04 is irregular and probably represents minor local erosion.

6.04 Limy siltstone, yellowish-gray (5Y 8/1), weathering light brown (5YR 6/4) to moderate orange pink (5YR 8/4); firmly cemented; contains as much as 4% medium to coarse subrounded sand-sized grains, especially toward base of unit. Mudstone laminae with polygonal-shrinkage cracks occur in basal 2.4 m of unit. Unit weathers as follows: 0.0 to 0.2 m, ledge; 0.2 to 1.8 m, slope; 1.8 to 2.4 m, slope or ledge; 2.4 to 2.7 m, ledge; 2.7 to 10.4 m, steep slope .......................... 10.4

6.03 Siltstone, moderate reddish-orange (10R 6/6); contains scattered well rounded coarse sand-sized grains; forms slope. Unit is probably a tongue of the Church Rock(?) Member .......................... 2.4

6.02 Conglomeratic siltstone, grayish-orange pink (5YR 6/2); contains pebbles and indistinct cross-strata .......................... 0.3

6.01 Siltstone, pale reddish-brown (10R 5/4); forms slope capped by rounded ledge .......................... 5.1
6.00 Limy siltstone, light greenish-gray (5GY 8/1); forms cross-stratified cliff ................. 1.8

Total incomplete Owl Rock Member ..................... 22.4

Base of section; not base of exposure.
Measured up steep slopes and ledges that form the eastern side of the first reentrant west of a minor tributary that flows south to enter Red Canyon Wash 1.3 km upstream from where Red Canyon Wash is joined by a major southern tributary paralleling the graded road into the canyon. Section is located 12.1 km S. 37° W. of Fry Canyon Store and 7.4 km S. 33° E. of Chocolate Drop, sec. 16 (unsurveyed), T. 36 S., R. 15 E. (Measured by J. Dunn and R. Stevens, October 21, 1973.)

Top of section; not top of exposure.

Wingate Sandstone (unmeasured):

7.10 Sandstone, light brown (5YR 6/4), weathering same color, very fine- to fine-grained, well sorted; moderately well cemented, moderately calcareous; composed of subrounded to subangular clear and amber quartz grains and rare dark accessory-minerals; contains minor amounts of anomalously coarse-grained quartz sand in lower part of unit, either randomly scattered throughout, disseminated along laminae, or clumped in lenticular aggregates; composed predominantly of small- to large-scale wedge-planar cross-laminae, but also contains faint horizontal laminae; massive splitting; forms vertical cliff. Only base of unit examined.

Contact: Contact between units 7.10 and 7.9 is a wavy surface of 2 to 3 cm amplitude.

Wingate transitional unit:

7.9 Siltstone and mudstone. Siltstone, grayish-orange pink (5YR 6/2) to pale red (10R 6/2), weathering same colors; firmly cemented, slightly calcareous; composed of very thin to thick beds containing horizontal laminae and micro-cross-strata. Mudstone, pale reddish-purple (RP 6/2) to pale reddish-brown (10R 5/4); forms laminae between siltstone beds; commonly contains polygonal-shrinkage cracks. Unit as whole forms series of ledges and indentations. Layers are horizontal to very gently cross-stratified; upper 1.5 m of unit is an asymmetrical trough cut into lower part of unit in line of section, or
cut into equivalent unit described below. Unit pinches out about 100 m to the southwest above unit 7.8. Lower part of unit pinches out above, or partially intertongues with, a unit 150 m to the northeast described as follows:

Siltstone, moderate reddish-brown (10R 5/6), slightly darker in uppermost 0.6 m, weathering same color, generally coarse-grained with 5% or more very fine to medium sand-sized grains; firmly cemented, slightly calcareous; composed of subangular to subrounded quartz grains and sparse dark accessory minerals, locally contains (1) subrounded to well rounded dark amber quartz grains, and (2) fine-grained siltstone and mudstone clasts that form weathered-out cavities and zones of granule conglomerate. Stratification is very indistinct, but appears to consist of small- to large-scale trough cross-laminae, horizontal laminae, and micro-cross-strata. This siltstone does not occur in line of section, but is approximately 8 m thick 200 m to the northeast.

Total Wingate transitional unit ................. 3.6

Erosion surface: Contact between Wingate transitional unit and Chinle Formation is an irregular surface of erosion obscured by debris in line of section, but lateral relationships suggest that relief on this surface may be 1/4 m.

Chinle Formation:

Church Rock(?) Member:

Hite Bed:

7.8 Sandstone and siltstone. Arkosic sandstone, pale red purple (5RP 6/2), weathering grayish-red (5R 4/2) and stained moderate reddish-brown (10R 4/6), very fine- to coarse-grained, moderately well to poorly sorted; composed of subangular quartz, feldspar, and scattered muscovite, biotite, and dark accessory mineral grains; firmly cemented, noncalcareous to slightly calcareous; contains small- to medium-scale trough cross-laminae, otherwise is horizontally laminated. Siltstone, pale to grayish-red (10R 4/2 to 6/2), occurs as discontinuous laminae, granules to pebbles, or small weathered-out pods. Unit as whole forms a vertical ledge ........... 4.4

Total of Hite Bed ........................................ 4.4

Erosion surface: Contact between the Hite Bed and unit L is an irregular surface of erosion with little relief in
line of section, but about 1.5 m relief laterally to the southwest.

Unit L:

7.7 Siltstone, limy siltstone, silty limestone, and mudstone. Siltstone and limy siltstone, pale reddish-brown (10R 5/4) to moderate reddish-brown (10R 4/6), and pale red (5R 6/2), weathering same colors with light greenish-gray (5G 8/1) alteration in streaks and mottles; slightly to highly calcareous; stratification obscured in basal part of unit, but toward the top of unit, very thin to thin pale red beds alternate with finer-grained, darker pale red beds. Silty limestone, light olive gray (5Y 6/1), stained pale reddish-brown (10R 5/4), microcrystalline, forms discontinuous laminae in limy siltstone. Mudstone, moderate yellowish-brown (10YR 5/4); firmly cemented, noncalcareous; contains scattered tabular chert fragments; forms central altered (?) zone 0.5 m thick. Unit as whole forms slope or indentation ........................................... 1.1

7.6 Siltstone, pale reddish-brown (10R 4/6), weathering moderate reddish-brown (10R 5/4) or altered in mottles of light greenish-gray (5GY 8/1); firmly cemented, noncalcareous; indistinctly laminated, contains small trough at top of unit; massive splitting; forms indented spheroidal ledge .................................................... 1.7

7.5 Sandstone to granule conglomerate, light greenish-gray (5G 8/1), weathering grayish-orange (10YR 7/4), moderate orange pink (10R 7/4) and moderate reddish-orange (10R 6/6); moderately well to poorly sorted; composed of sand-sized quartz grains and granules to pebbles of moderate reddish-brown (10R 4/6) siltstone, moderate orange pink (10YR 8/4) limestone, and sparse very light gray (N 8) chert; well cemented, highly calcareous; contains faint horizontal bedding. Unit is generally fine- to coarse-grained, but silty very fine-grained sandstone occurs in uppermost 0.5 m of unit and in 1 to 2 cm zones throughout. Unit forms massively splitting ledge that thins to the west and pinches out under rubble to the east .................................................... 1.3

Total of unit L ........................................ 4.1

Contact: Contact between unit L and unit M is an irregular surface of erosion with little relief in vicinity of line of section.
Unit M:

7.4 Siltstone, pale reddish-brown (10R 6/4), weathering same color, altered in mottles of light greenish-gray (5GY 8/1) toward the top of unit; firmly cemented, noncalcareous; forms slope, lower contact gradational. Lateral equivalents include silty limestone, claystone with polygonal-shrinkage cracks, and siltstone; these lateral units form gentle trough-shaped ledges and indentations ............ 1.3

7.3 Siltstone, moderate reddish-brown (10R 4/4), weathering same color; firmly cemented, noncalcareous; forms a small spheroidally-weathering ledge that breaks into pebblesized fragments, or laterally, a slope ................. 0.9

Total of unit M ......................................................... 2.2

Reddish-orange siltstone unit:

Red Canyon ledge:

7.2 Siltstone, reddish-brown (10R 5/6), weathering moderate reddish-orange (10R 6/6), contains uncommon mottles altered light greenish-gray (5GY 8/1); firmly cemented, slightly calcareous; contains very faint horizontal laminae; massive splitting; forms vertical cliff .......... 6.3

Total of Red Canyon ledge .............................. 6.3

7.1 Siltstone, like unit 7.2; forms series of ledges and steep slopes .............................................. 15.6

Total of reddish-orange siltstone unit ............... 21.9

Total of Church Rock(?) Member .......................... 36.2

Contact: Contact between the Church Rock(?) and Owl Rock Members is placed at color change from pale red siltstone in the Owl Rock to reddish-orange siltstone in the Church Rock(?)

Owl Rock Member:

7.06 Siltstone, pale red (10R 6/2), weathering same color; firmly cemented, slightly to moderately calcareous; contains coarse sand-sized limestone clasts; forms steep slope. Lower contact approximated .............. 2.6
<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.05</td>
<td>Siltstone, pale reddish-brown (10R 4/5), weathering same color and mottled yellowish-gray (5Y 7/2); firmly cemented, moderately calcareous; lower contact difficult to place in rubble-covered slope; may be a tongue of the Church Rock(?) Member</td>
<td>4.7</td>
</tr>
<tr>
<td>7.04</td>
<td>Siltstone, pale reddish-brown (10R 5/4), contains uncommon mottles altered light greenish-gray (5GY 8/1); firmly cemented, highly calcareous; forms steep slope with basal ledge 1.0 m thick</td>
<td>5.5</td>
</tr>
<tr>
<td>7.03</td>
<td>Mudstone, reddish-brown (10R 4/4), like unit 7.04; siltier toward top of unit; contains scattered chert grains; forms steep slope with minor ledges</td>
<td>10.4</td>
</tr>
<tr>
<td>7.02</td>
<td>Siltstone, light brown (5YR 6/4), weathering same color; like unit 7.03; forms slope</td>
<td>4.0</td>
</tr>
<tr>
<td>7.01</td>
<td>Silty limestone, pale reddish-brown (10R 5/3), weathering moderate orange pink (10R 7/4); iron oxide penetrates fractures; massive splitting; forms ledge. Unit not measured.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Total of incomplete Owl Rock Member</strong></td>
<td><strong>27.2</strong></td>
</tr>
</tbody>
</table>

Base of section; not base of exposure.
SECTION 8

Measured up the southwest corner of Moss Back Butte (formerly called The Sundial), 10.8 km S. 38° E. of Fry Canyon Store. Section is in the northwest quarter of sec. 29 (unsurveyed), T. 37 S., R. 17 E. (Measured by J. Dunn and R. Stevens, October 26, 1973.)

Top of section; not top of exposure.

Wingate Sandstone (unmeasured):

8.15 Sandstone, light brown (5YR 6/4), weathering moderate reddish-brown (10 4/6 to 10 R 5/6), very fine- to coarse-grained, predominantly fine-grained, moderately sorted; composed of clear to amber subangular to subrounded quartz grains and sparse dark accessory minerals; moderately well cemented, slightly calcareous; composed of faint small- to large-scale wedge-planar cross-laminae and, in basal few meters of unit, horizontal laminae. Unit splits massively; forms vertical cliff. Only base of unit examined.

Contact: Contact between the Wingate Sandstone and the Chinle Formation is a wavy surface of 2 to 4 cm amplitude. Contact is determined by weathering characteristics and amber quartz content of the overlying Wingate Sandstone.

Chinle Formation:

Church Rock(?) Member:

Reddish-orange siltstone unit:

8.14 Siltstone, moderate reddish-brown (10R 5/5), weathering same color; firmly cemented, noncalcareous; appears structureless, may contain horizontal laminae; forms steep slope covered with angular pebble-sized fragments at base, grades to a spheroidally-weathering vertical ledge indented beneath the Wingate Sandstone; ledge forms uppermost 2 m of unit . . . . . . . . . . . . . . . . 4.6

8.13 Siltstone, moderate reddish-orange (10R 5/6 to 10R 6/6), weathering same colors, altered light greenish-gray
8.12 Siltstone, pale reddish-brown (10R 4/4), weathering same color; firmly cemented, slightly calcareous; stratification concealed; fractures along irregular grayish-red (10 4/2) surfaces; forms steep slope covered with angular, pebble-sized fragments .................. 3.1

8.11 Siltstone, like unit 8.13; forms ledge .................. 1.5

8.10 Siltstone, like unit 8.12; forms steep slope .......... 2.6

8.9 Granule conglomerate, grayish-red (10R 4/2), weathering same color; composed of subangular granules (26 to 30%), very fine to coarse sand-sized grains (10%) and local pebbles (0 to 4%) as long as 8 mm, in a siltstone matrix (60%); clasts include (1) pinkish-gray (5YR 8/1) and very light gray (N 8) to white (N 9) chert and quartzite, (2) pale red purple (5RP 6/2) siltstone and dolomitic siltstone, and (3) light gray (N 7) to white (N 9) limestone. Unit is weakly to firmly cemented with dolomite; calcite coats clasts and fills pores formerly occupied by clasts; calcite and clay occur along fractures. Unit forms slope ........................................ 0.3

8.8 Siltstone, like unit 8.12; platy to flaggy splitting; forms ledge ................................. 1.8

8.7 Siltstone, like unit 8.13. Alteration has produced light greenish-gray (5GY 8/1) blotchy mottles as large as 25 cm in diameter. Unit forms a ledge that can be subdivided as follows: 0.0 to 0.2 m, finer-grained siltstone with faint horizontal laminae; 0.2 to 0.8 m, sandy siltstone; 0.8 to 2.1 m, siltstone with biogenic (?) structures .... 2.1

8.6 Siltstone, pale red (5R 6/2), altered light greenish-gray in uncommon mottles as large as 2 cm in diameter; firmly cemented, slightly calcareous; forms steep slope ........................................ 1.5

8.5 Siltstone, pale reddish-brown (10R 6/4), weathering moderate reddish-brown (10R 4/6) to moderate reddish-orange (10R 6/6); firmly cemented, slightly calcareous; contains faint horizontal laminae and possible biogenic structures; forms prominent ledge .................. 1.2

8.4 Siltstone, pale red (10R 6/2), weathering same color; firmly cemented, moderately calcareous; contains
horizontal laminae composed of finer-grained siltstone; forms steep slope covered with angular fragments  

8.3 Siltstone and microcystalline, silty limestone; pale reddish-brown (10R 5/4), weathering a slightly lighter color (10R 6/4); firmly cemented, moderately to highly calcareous; contains horizontal laminae with polygonal-shrinkage cracks; contains silty limestone nodules to layers weathering very pale orange (10YR 8/2); forms steep slope with basal ledge; ledge splits in a platy to flaggy manner and is 1.0 m thick  

8.2 Siltstone and silty limestone. Siltstone, like unit 8.4; forms slope. Silty limestone, altered light greenish-gray (5G 8/1), microcystalline; forms very thin bed at top of slope  

8.1 Siltstone and silty limestone, like unit 8.3; nodules more prevalent; forms slope with basal ledge 3.1 m thick  

Total of reddish-orange siltstone unit  

Total of Church Rock(?) Member  

Contact: Contact between the Church Rock(?) and Owl Rock Members is placed at color change from more grayish to more brownish units.

Owl Rock Member:

8.04 Siltstone and silty limestone, pale reddish-brown (10R 5/4), pale red (5R 6/2) and grayish orange pink (5YR 7/2), commonly altered in streaks of light greenish-gray (5GY 8/1); firmly cemented, moderately to highly calcareous; forms steep slope with numerous very thin to thin ledges. Highest limestone bed is 6.8 m below the base of the Church Rock(?) Member  

8.03 Silty limestone, pale red (5R 6/2), weathering moderate orange pink (10R 6/4 to 10R 7/4) and mottled light greenish-gray (5GY 8/1); microcystalline; contains numerous silt-sized and medium to coarse sand-sized grains at base of unit; structures include ripple laminae, climbing-ripple laminae, and indistinct parting lineation; unit forms overhanging ledge  

8.02 Siltstone, moderate orange pink (10R 6/4), weathering grayish-orange pink (10R 8/2), altered in mottles of
light greenish-gray (5GY 8/1); firmly cemented, moderately to highly calcareous; forms indentation below ledge. Contacts are gradational ....... 0.3

8.01 Siltstone, moderate reddish-orange (10R 5/6 to 10R 6/6), weathering same colors; firmly cemented, moderately calcareous. Unit weathers as follows: 0.0 to 0.6 m, ledge; 0.6 to 5.5 m, steep slope; 5.5 to 8.2 m, steep slope with several very thin ledges; 8.2 to 8.9 m, ledge ... 8.9

Total of incomplete Owl Rock Member ............... 22.3

Base of section; not base of exposure.
SECTION 9

Measured 150 m southeast of the small northern fork at the head of Rainbow Canyon, 5.2 km due south of Blue Notch and 12.4 km S. 83° E. of Castle Butte. Section is in the southwestern quarter of sec. 19 (unsurveyed), T. 35 S., R. 15 E. (Measured by J. Dunn and D. McKee, November 4, 1973.)

Top of section; not top of exposure. Meters

Wingate Sandstone (unmeasured):

9.15 Sandstone, light brown (5YR 6/4), weathering same color to moderate reddish-orange (10R 6/6), fine- to very fine-grained, moderately well sorted; composed of sub-rounded to subangular grains of quartz and sparse, dark accessory minerals; firmly cemented, slightly calcareous; composed of indistinct medium- to large-scale wedge-planar cross-laminae; massive splitting; forms vertical cliff. Only basal part of unit examined.

Contact: Contact between units 9.15 and 9.14 is an undulating surface with little relief.

Wingate transitional unit:

9.14 Silty, arkosic sandstone, pale red (5R 6/2) and pale red purple to grayish-red purpl (5RP 7/2 to 5RP 4/2), exposed surface pale reddish-brown (10R 5/4) to grayish-red (10R 4/2), very fine- to fine-grained, contains 5 to 20% coarse silt-sized grains; composed of subangular to sub-rounded clear and amber quartz (75%), angular to subangular white feldspar (25%), and sparse biotite, muscovite, and dark accessory mineral grains (less than 1%); firmly cemented, noncalcareous; horizontally laminated and uncommonly micro cross-stratified; splits along laminae; forms part of vertical cliff .......................... 0.9

Total of Wingate transitional unit .................. 0.9
Chinle Formation:

Church Rock(? Member):

Hite Bed:

9.13 Sandstone, arkosic sandstone, siltstone and mudstone. Sandstone and arkosic sandstone, pale red purple (5RP 6/2), weathering pale reddish-brown (10R 5/4), very fine- to medium-grained, moderately sorted; composed of subangular quartz, angular white feldspar (0 to 10%) and sparse muscovite, biotite, and dark accessory mineral grains; firmly cemented, slightly friable, slightly calcareous; horizontally laminated and gently cross-laminated. Siltstone, pale grayish-red (10R 5/2), weathering pale reddish-brown (10R 5/4), coarse-grained, well sorted; firmly cemented, noncalcareous; occurs as lenticular granules, pebbles, laminae and beds throughout sandstone, commonly weathers out to form indentations or cavities. Unit as whole contains thin to very thick sets of small- to large-scale trough cross-stratification; forms cliff containing numerous ledges. Base of unit is locally conglomeratic ... 7.5

Total of Hite Bed ..................................... 7.5

Erosion surface: Contact between Hite Bed and unit L is a broadly channeled surface of erosion with at least 0.6 m relief.

Unit L:

9.12 Siltstone, moderate reddish-orange (10R 6/6), firmly cemented, slightly calcareous; contains faint horizontal to wavy laminae; massive splitting; forms ledge .... 1.9

9.11 Siltstone, mudstone and limestone, light red (5R 6/4) and pale reddish-brown (10R 5/4), with yellowish-gray (5Y 8/1) alteration in streaks and mottles; firmly cemented, slightly to highly calcareous; composed of beds 1 to 90 cm thick that form gentle, very large-scale troughs. Microcrystalline limestones are concentrated in basal 1.8 m of unit; siltstones alternate with mudstones in beds that progressively thicken upward and become slightly coarser-grained. Unit as whole forms steep slope; immediately to the west, unit forms a cliff with slabby splitting ................. 11.2

9.10 Limy sandstone, siltstone, mudstone, conglomeratic sandstone, and limestone conglomerate, weathering moderate
reddish-orange (10R 6/6). Sandstone and conglomeratic sandstone, light brownish-gray (5YR 6/1), poorly sorted, composed of very fine to coarse grains of subangular to subrounded quartz and dark accessory minerals, contains enticular accumulations of granule-sized siltstone, mudstone, limestone, and chert clasts (probably bone fragments); moderately well cemented, highly calcareous; occurs in beds 1 to 20 cm thick. Siltstone and mudstone, pale reddish-brown (10R 5/4), firmly cemented, moderately calcareous, occur in beds respectively 10 to 15 cm thick, and 1 to 2 cm thick. Limestone pebble conglomerate, occurs in uppermost 0.4 m of unit, also contains clasts of siltstone and dolomite. From a distance, unit as whole appears to consist of a single set of southwesterly-dipping tabular-planar cross-strata; actually, unit is composed of an intricate combination of very thin to thick sets of small- to large-scale wedge-planar and trough cross-strata. Unit forms a vertical ledge with slabby to massive splitting.

<table>
<thead>
<tr>
<th>9.9</th>
<th>Mudstone, pale reddish-brown (10R 5/4), weathering same color, altered very pale green (10G 8/2) at base; firmly cemented, slightly to moderately calcareous; contains faint horizontal laminae; contains abundant limestone, siltstone and chert granules, also uncommon bone fragments; forms niche; intertongues with overlying unit</th>
<th>0.9</th>
</tr>
</thead>
</table>

Total of unit L: 14.3

Erosion surface: Contact between unit L and unit M is a gently channeled erosion surface with 0.6 m relief.

Unit M:

| 9.8 | Siltstone and mudstone, pale reddish-brown (10R 5/4), weathering same color, contains altered light greenish-gray (5GY 8/1) mottling; firmly cemented, moderately calcareous; contains horizontal laminae and micro-cross-stratification. Abundant fragments of siltstone, silt dolomite, limestone, and chert occur in basal 10 cm of unit. Unit forms steep slope in line of section; laterally forms spheroidally-weathering cliff with irregular indentations and cavities | 4.2 |
| 9.7 | Mudstone, grayish-red (10R 5/2) to pale reddish-brown (10R 5/4), weathering same colors; firmly cemented, slightly calcareous; has brecciated appearance due to penetration of iron oxide along fractures; contains rare bone fragments; contains abundant silt-sized | 4.2 |
grains in basal portion; forms slope. Laterally, unit forms indentation in cliff......................... 0.4

9.6 Silty limestone, light gray (N 7) to pale red (5R 5/5), weathering same colors and light greenish-gray (5GY 8/1); microcystalline, faintly laminated; contains grayish-yellow green (5GY 7/2) chert nodules and uncommon very fine to coarse sand-sized grains in uppermost 0.4 m of unit; silt-sized grains increase in abundance in top 15 cm of unit. Unit forms prominent ledge ......................... 0.7

Total of unit M ......................................... 5.3

Reddish-orange siltstone unit:

Red Canyon ledge:

9.5 Siltstone, moderate orange pink (10R 7/4), weathering moderate reddish-orange (10R 6/6) to pale reddish-brown (10R 5/4), altered in streaks and blotches to light greenish-gray (5GY 8/1); firmly cemented, slightly to moderately calcareous; generally forms massively-splitting ledge; forms steep slope in direct line of section .............. 5.6

9.4 Siltstone, like unit 9.5; contains mudstone laminae with polygonal-shrinkage cracks; contains horizontal lamina, micro cross-stratification, and biogenic (?) structures; massive to blocky splitting in lower portion; platy to flaggy splitting in upper portion; forms slope with thick, basal, spheroidally-weathering ledge ............... 5.4

Total of Red Canyon ledge ................................ 11.0

9.3 Siltstone, moderate orange pink (10R 7/4) and pale red (10R 6/2), weathering same colors and pale reddish-brown (10R 7/4); forms series of small ledges and slopes. Very fine sand-sized grains occur in uppermost slope ........ 1.9

9.2 Siltstone, like unit 9.5, but more calcareous; forms ledge ..................................................... 0.7

9.1 Siltstone, like unit 9.5, uppermost 1.0 m of unit more pale reddish-brown (10R 5/4); moderately calcareous; contains prominent light greenish-gray (5GY 8/1) altered zone just above small ledge 7.6 m from base of unit; unit weathers prominently to form steep slopes, but also contains minor lenticular ledges .................. 10.7
Total of reddish-orange siltstone unit ............... 24.3
Total of Church Rock(?) Member ..................... 53.4

Contact: Contact between the Church Rock(?) and Owl Rock Members is placed just above a series of thinly bedded limestones that are somewhat above upward color change from grayish and pale red siltstones to reddish-orange and brown siltstones.

Owl Rock Member:

9.04 Silty limestone, moderate orange pink (10R 7/4), weathering moderate reddish-orange (10R 6/6), commonly altered light greenish-gray (5GY 8/1); microcrystalline; forms small ledge ...................... 0.4

9.03 Siltstone, pale reddish-brown (10R 5/4), weathering moderate reddish-orange (10R 6/6); firmly cemented, moderately calcareous; forms slope ..................... 0.8

9.02 Silty limestone, like unit 9.04; forms minor ledge .... 0.2

9.01 Siltstone, grayish-orange pink (10YR 7/2), weathering moderate reddish-orange (10R 6/6), altered in mottles of very pale orange (10YR 8/2); firmly cemented, highly calcareous; forms slope above grayish units ................. 1.5

Total of incomplete Owl Rock Member .................. 2.9

Base of section; not base of exposure.
SECTION 10

Measured above half way down the north rim of Rainbow Canyon, 400 m S. 82° E. of spot elevation 5760 on the Mancos Mesa 15 minute quadrangle, 10.1 km S. 69° E. of Castle Butte, and 7.4 km S. 45° W. of Ducket Crossing. Section is located near the boundary between secs. 35 and 36 (unsurveyed), T. 35 S., R. 14 E. (Measured by J. Dunn and D. McKee, November 5, 1973.)

Top of section; not top of exposure.

Wingate Sandstone (Only base of unit examined):

Wingate transitional unit:

10.3 Sandstone and mudstone granule conglomerate, like unit 10.2; horizontally laminated; contains coarse sand-sized grains of amber quartz in upper part of unit; lower part of unit contains abundant mudstone clasts . . 1.4

Total of Wingate transitional unit . . . . . . . . . . 1.4

Chinle Formation:

Church Rock(?) Member:

Hite Bed, unit L, and unit M(?) undifferentiated:

10.2 Sandstone, siltstone, mudstone, and limestone. Sandstone, very pale orange (10YR 8/2) to pale red (5R 6/2), weathering pale reddish-brown (10R 5/4), very fine- to medium-grained, moderately sorted; composed of subrounded to subangular quartz, angular to subangular feldspar (5 to 10%), and sparse mica and dark accessory mineral grains; firmly cemented, moderately calcareous; contains thin to very thick sets of small- to large-scale trough cross-laminae. Siltstone, pale reddish-brown (10R 5/4) to dark reddish-brown (10R 3/4), weathering same colors; firmly cemented, predominantly noncalcareous to slightly calcareous, moderately calcareous in places; stratification obscure. Limestone, orange brown (10R 6/4), microcrystalline.
Most of unit is slope-forming, and buried under debris from overlying units; presence of mudstone is inferred from float. The Hite Bed forms ledges in uppermost 10 m of unit; base of the Hite Bed is obscured .............. 23.9

Total of Hite Bed, unit L, and unit M(?) undifferentiated 23.9

Reddish-orange siltstone unit:

Red Canyon ledge (not measured):

10.1 Siltstone, moderate reddish-orange (10R 6/6), weathering same color to slightly darker, predominantly coarse-grained; firmly cemented, slightly calcareous; horizontally laminated; massive splitting; forms mostly buried ledge.

Total of incomplete Church Rock(?) Member .............. 23.9

Base of section; not base of exposure.
SECTION 11

Measured up slopes and ledges overlying the top of a small gully about 250 m around the northwest side of a promontory that marks the southern end of the northwestern wall of Rainbow Canyon, sec. 9 (unsurveyed), T. 36 S., R. 14 E. Section is 12.9 km S. 46° W. of Ducket Crossing. (Measured by J. Dunn and D. McKee, November 6, 1973.)

Top of section; not top of exposure.  

Wingate Sandstone (unmeasured):

11.6 Sandstone, light brown (5YR 6/4), weathering same color to moderate reddish-orange (10R 6/6), very fine- to medium-grained, well sorted to moderately sorted; composed of subrounded to subangular quartz and sparse, dark accessory mineral grains; firmly cemented, moderately calcareous; contains indistinct laminae that form medium- to large-scale sets of wedge-planar cross-strata; contains subrounded coarse amber quartz grains; massive splitting; forms vertical cliff. Only base of unit examined.

Contact: Contact between the Chinle Formation and Wingate Sandstone is placed at color change from reddish-brown to light brown sandstones. Contact is defined by the diastem immediately beneath sandstone containing coarse sand-sized grains of amber quartz.

Chinle Formation:

Church Rock(?) Member:

Hite Bed:

11.5 Sandstone and conglomerate. Sandstone, pale red (10R 6/2) to pale red purple (5RP 7/2), weathering pale red (5R 6/2) to grayish-red (5R 4/2) and pale brown (5YR 5/2) to grayish brown (5YR 3/2), very fine- to coarse-grained, predominantly fine-grained, moderately to poorly sorted; composed of subrounded to subangular quartz, angular to subangular feldspar (in amounts of 5 to 10%), and uncommon dark
accessory mineral grains; firmly cemented, slightly to moderately calcareous; composed of thin to very thick sets of small- to medium-scale trough cross-laminae. Conglomerate; composed of granules to pebbles of microcrystalline dolomite and limestone; also contains intraclasts of siltstone and mudstone; occurs in lentils at base of unit and elsewhere in unit. Unit forms a series of rounded ledges that laterally form a vertical cliff.

Total of Hite Bed ........................................... 19.9

Erosion surface: Contact between Hite Bed and unit L is a channeled surface of erosion. Contact is obscured in line of section.

Unit L:

11.4 Siltstone and mudstone, pale reddish-brown (10R 5/4) to dark reddish-brown (10R 3/4); firmly cemented, noncalcareous; forms slope or indentation in lateral cliff ........................................... 3.1

11.3 Sandstone and conglomerate, like unit 11.5. Conglomerate contains uncommon clasts of chert and granite. Unit forms one or more ledges ........................................... 6.3

Total of unit L ........................................... 9.4

Erosion surface: Contact between unit L and reddish-orange siltstone is a channeled surface of erosion with little relief in line of section, but more than 1 m relief laterally toward point of promontory.

Reddish-orange siltstone unit:

Red Canyon ledge:

11.2 Siltstone and granule conglomerate, pale orange pink (10R 7/2) to pale red (10R 6/2), weathering moderate reddish-orange (10R 6/6). Siltstone composed of horizontal laminae, wavy laminae, and mudstone laminae containing polygonal-shrinkage cracks; micro-cross-stratification also present. Siltstone is firmly cemented and noncalcareous. Granule conglomerate composed of subrounded, disc-shaped fine to coarse sand-sized clasts (50%) and granules (50%) of siltstone (90%) and dark reddish-brown mudstone (10%); matrix contains extensive iron oxide cement that forms irregularly subhorizontal stringers between granules; conglomerate
occurs in basal 5 cm of unit. Unit as whole splits massively and forms overhanging ledge.

Total of Red Canyon ledge.

11.1 Siltstone, sandy siltstone and sandstone. Siltstone and sandy siltstone, pale orange pink (10R 7/2) to pale reddish brown (10R 5/4), weathering moderate orange (10R 6/6), altered in mottles of yellowish-gray (5Y 6/1); firmly cemented, slightly calcareous to noncalcareous; contains as much as 25% very fine to coarse sand-sized grains and sparse granules of subrounded siltstone, limestone, granite, and quartz in a zone 5 to 90 cm from base of unit. Sandstone, pale greenish-gray (5G 8/1), medium- to coarse-grained, moderately sorted; composed of subangular to subrounded quartz grains (90%) and rock fragments (10%); forms basal 5 cm of unit. Unit weathers as follows: 0 to 3.1 m, ledge, platy to blocky splitting, irregularly defined in upper portion; 3.1 to 6.1 m, slope, rubble-covered, poorly exposed; 6.1 to 11.9 m, ledges and slopes, flaggy splitting, or laterally a spheroidally-weathering cliff with massive splitting; 11.9 to 13.3 m, ledge, contains iron oxide along fractures and granule-sized silicious nodules.

Total of reddish-orange siltstone unit.

Total of Church Rock(?) Member.

Contact: Contact between the Church Rock(?) and the Owl Rock Members is an irregular surface of minor erosion and presumably little relief (contact is covered laterally). The contact is placed at a color change from grayish units in the Owl Rock Member to brownish- and reddish-orange units in the Church Rock(?) Member.

Owl Rock Member (unmeasured):

11.0 Limy siltstone to silty limestone, yellowish-gray (5Y 7/1) to pale reddish-brown (10R 5/4), commonly altered light greenish-gray (5G 8/1). Limestone occurs in thin beds that laterally form gently dipping troughs. Unit poorly exposed; forms steep debris-covered slope. Only top of unit examined.

Base of section; not base of exposure.
SECTION 12

Measured up the steep slope at the base of the southwest wall of Red Canyon, 5.3 km southeast of the promontory just west of Warm Spring. Section is located 14.6 km S. 49° W. of Ducket Crossing and 8.3 km N. 50° W. of Chocolate Drop, in sec. 18 (unsurveyed), T. 36 S., R. 14 E. (Measured by J. Dunn and D. McKee, November 7, 1973.)

Top of section; not top of exposure. Meters

Wingate Sandstone (unmeasured):

12.7 Sandstone, light brown (5YR 6/4) to moderate orange pink (10R 7/4), weathering same colors to pale reddish-brown (10R 5/4), fine- to medium-grained, well to moderately sorted; composed of subrounded to subangular quartz grains and sparse, dark accessory minerals; firmly cemented, moderately calcareous; contains thin to very thick sets of medium- to large-scale wedge-planar cross-laminae; massive splitting; forms cliff. Only base of unit examined.

Contact: Contact between the Wingate Sandstone and the Chinle Formation is a flat, sharply defined surface that in most places is covered with debris.

Chinle Formation:

Church Rock(?) Member:

Hite Bed:

12.6 Sandstone and conglomerate. Sandstone, pale red (5R 6/2), altered shades of dark reddish-brown (10R 3/4), moderate red (5R 5/4), moderate reddish-orange (10R 6/6), grayish-red purple (5RP 4/2), pale red purple (5RP 6/2) and dusky blue (5PB 3/2), weathering pale reddish-brown (10R 5/4), very fine-grained, well sorted, contains sparse silt-sized grains; composed of subangular clear, white, and darkly stained quartz grains with uncommon feldspar and sparse, dark accessory mineral grains; slightly friable, slightly
calcareous, highly porous; composed of thick to very thin sets of small- to large-scale trough cross-laminae. Alteration colors in sandstone occur in laminar streaks that do not necessarily follow bedding planes; alteration is most apparent in upper portion of unit. Conglomerate is composed of limestone and siltstone clasts and forms thin to thick beds in the lower half of unit. Unit as a whole forms a series of rounded ledges with flaggy to blocky splitting ........................................ 19.1

Total of Hite Bed ........................................ 19.1

Erosion surface: Contact between the Hite Bed and unit L is a channeled surface of erosion of uncertain relief due to the poor exposure of the contact.

Unit L:

12.5 Siltstone, pale red (5R 6/2) to moderate reddish-brown (10R 5/4), weathering same colors; firmly cemented, noncalcareous; forms slope and is poorly exposed ........ 7.1

12.4 Sandstone and conglomerate, like unit 12.6, poorly exposed; contains clasts of siltstone, limestone and chert ................................................ 1.5

Total of unit L ........................................ 8.6

Erosion surface: Contact between unit L and reddish-orange siltstone unit is a channeled surface of erosion with approximately 1.5 m relief in the vicinity of the line of section.

Reddish-orange siltstone unit:

Red Canyon ledge:

12.3 Siltstone, pale reddish-brown (10R 6/4), in upper portion pale pink (10R 8/2) to pale reddish-purple (10R 6/2), weathering pale reddish-brown (10R 5/4), locally altered like unit 12.6; well indurated with siliceous cement, especially in upper portion of unit, noncalcareous; contains thin sets of indistinct trough cross-laminae near top of unit, otherwise composed of horizontal to micro cross-stratified laminae; contains mudstone laminae with polygonal-shrinkage cracks; massive splitting; forms ledge ........................................ 4.6
12.2 Mudstone and limy siltstone, mostly altered pale greenish-gray (5GY 8/1). Mudstone, pale reddish-brown (10R 5/4), weathering same color; firmly cemented, slightly calcareous; forms two beds, each approximately 12 cm thick and bounded by irregular upper and lower contacts. LImy siltstone, pale red (10R 6/4), 45 cm thick, is sandwiched between mudstone layers. Unit as a whole forms steep slope .......... 0.7

12.1 Siltstone, moderate reddish-orange (10R 6/6) to reddish-brown (10R 5/6) and moderate orange pink (10R 7/4), weathering same colors and altered in mottles of light greenish-gray (5GY 8/1); firmly cemented, slightly calcareous; forms steep slope capped by a rounded ledge with flaggy splitting; ledge is 3.2 m thick .......... 7.2

Total of reddish-orange siltstone unit ............ 13.1

Total of Church Rock(?) Member ................. 40.8

Contact: Contact between the Church Rock(?) and Owl Rock Members is obscured beneath slope debris. The contact, approximately placed, marks color change grayish and pale red units in the Owl Rock Member to reddish-brown units in the Church Rock(?) Member.

Owl Rock Member (not examined in detail):

12.04 Siltstone and nodular limestone, pale red (10R 6/2), commonly altered light greenish-gray (5GY 8/1); concealed in steep slope ............ 3.5

12.03 Siltstone, pale reddish-brown (10R 5/4), weathering same color; laterally, unit is grayish-orange pink (5YR 7/2), weathering moderate orange pink (10R 7/4); forms ledge .................... 0.5

12.02 Siltstone, moderate reddish-orange (10R 6/6), in top 60 cm pale red (10R 5/2), weathering same colors to pale reddish-brown (10R 5/4); firmly cemented, highly calcareous; forms steep slope. May be a tongue of the Church Rock(?) Member ............ 3.2

12.01 Sandstone, siltstone, and limestone, weathering pale red (10R 6/2), streaked and mottled light greenish-gray (5GY 8/1). Sandstone, medium-grained to conglomeratic at base of unit, otherwise medium-grained;
firmly cemented, highly calcareous; forms ledge. Siltstone, firmly cemented; contains limestone, siltstone and chert clasts; forms slope in upper part of unit. Limestone, very light gray (N 8), slightly greenish; microcrystalline; horizontally laminated. Lithologies occur as follows: 0 to 0.6 m, sandstone; 0.6 to 0.7 m, limestone and siltstone; 0.7 to 2.1 m, siltstone. Unit generally forms slope. Basal contact laterally forms gentle swales ............................................ 2.1

Total of incomplete Owl Rock Member ................ 9.3

Base of section; not base of exposure.
SECTION 13

Measured up the central promontory of three promontories that form the north rim along the uppermost 6.5 km of Blue Canyon. Section is located 6.9 km N. 59° E. of Chocolate Drop, 10.1 km, N. 85° W. of Fry Canyon Store, sec. 21 (unsurveyed), T. 36 S., R. 15 E. (Measured by J. Dunn and D. McKee, November 8, 1973.)

Top of section; not top of exposure.

Wingate Sandstone (unmeasured):

13.7 Sandstone, pale brown (10R 6/4), weathering moderate reddish-orange (10R 6/6), very fine- to medium-grained, moderately sorted; composed of subrounded to subangular quartz and sparse, dark accessory mineral grains; contains scattered coarse-grained amber quartz; moderately well cemented, slightly to moderately calcareous; composed of thin to very thick sets of trough and wedge-planar cross-laminae; massive splitting; forms cliff. Only base of unit examined.

Contact: Contact between the Wingate Sandstone and the Chinle Formation is a level wavy surface of less than 2 cm amplitude. Contact marks sharp change in color and grain size, and is placed beneath lowermost unit typical of the Wingate Sandstone that contains coarse amber quartz grains.

Chinle Formation:

Church Rock (?) Member:

Unit L:

13.6 Siltstone, pale red (5R 6/2) to greyish-red (10R 4/2), weathering same colors; firmly cemented, noncalcareous; contains very faint horizontal laminae and micro-cross-stratification; forms indented ledge . . . . . . . . . . . . . . 0.1

Contact: Contact between units 13.6 and 13.5, while apparently conformable in line of section, may be a
channeled surface of erosion laterally, where unit 13.5 is absent, and has possibly been removed by erosion. However, overlying debris obscures lateral relationships.

13.5 Siltstone, moderate orange brown (10R 5/6), weathering same color; firmly cemented, noncalcareous; stratification concealed; forms a flaggy to massively splitting ledge ..................................... 4.0

13.4 Siltstone, pale red (5R 6/2), like unit 13.6; contains local granule-sized mudstone intraclasts; structures obscured, appears to contain thin trough crossbeds . . . 5.2

13.3 Silty sandstone, very pale red purple (5RP 6/2), weathering grayish-orange pink (5YR 7/2) and pale yellowish-brown (10YR 6/2), altered light greenish-gray (5G 8/1) in circular mottles, very fine- to fine-grained, contains 5 to 20% silt-sized grains; composed of subangular to subrounded quartz grains, and scattered grains of kaolinitized feldspar, very fine-grained micas, and dark accessory minerals; firmly cemented, noncalcareous to moderately calcareous. Basal 4.6 m contains faint laminae and a thin zone of scattered chert fragments. Upper 2.2 m of unit is separated from the lower part of unit by a channeled surface of erosion, and contains a basal conglomeratic zone 0.6 m thick composed of pebbles of reworked sandstone and uncommon siltstone, mudstone, and chert; upper part of unit also contains very thin to thin sets of small- to medium-scale trough cross-laminae. Unit as whole forms a series of flaggy to massively splitting ledges. Laterally, unit thins into discrete sandstone tongues .... 6.8

Total of unit L ......................................... 16.1

Erosion surface: Contact between unit L and reddish-orange siltstone unit is a channeled surface of erosion. Relief on the surface cannot be measured because of the presence of overlying debris; relief is estimated, however, to be greater than 1 m, based on lateral relationships.

Reddish-orange siltstone unit:

Red Canyon ledge:

13.2 Siltstone, orange brown (10R 5/6), weathering moderate reddish-orange (10R 6/6); firmly cemented, slightly calcareous; faintly laminated; massive splitting; forms cliff composed of three sub-units ................. 8.5
Contact: Contact between units 13.2 and 13.1 appears conformable in line of section, but laterally is an erosion surface with about 60 cm relief.

13.1 Siltstone, orange brown (10R 5/6), weathering moderate reddish-orange (10R 6/6) to moderate reddish-brown (10R 5/4); firmly cemented, slightly calcareous; forms steep slope covered angular pebble-sized fragments  ... 13.8

Total of reddish-orange siltstone unit  ......... 22.3

Total of Church Rock(?) Member  .............. 38.4

Contact: Contact between the Church Rock(?) and Owl Rock Members is obscured by debris and is approximately placed to correspond to a color change between pale red and grayish units in the Owl Rock Member, and reddish-brown to reddish-orange units in the Church Rock(?) Member.

Owl Rock Member:

13.06 Siltstone, pale red (10R 6/2), in upper 6 m more reddish-brown (10R 4/4); firmly cemented, moderately calcareous; forms slope  ......... 20.8

13.05 Limestone and siltstone, pale red (10R 6/2); forms prominent ledge; grades into overlying unit  ......... 2.1

13.04 Siltstone to mudstone, moderate orange pink (5YR 8/4), altered light greenish-gray (5GY 8/1); contains some mudstone and limy zones; forms slope  ......... 5.2

13.03 Siltstone, like unit 13.06, mottled light greenish-gray (5GY 8/1); forms slope  ......... 5.5

13.02 Siltstone, like unit 13.04; forms slope  ......... 5.5

13.01 Siltstone, like unit 13.06; forms slope. Very fine-grained to fine-grained sandstone forms basal ledge; flaggy to slabby splitting  ......... 14.4

13.00 Limestone, light gray (N 7), microcrystalline; not measured  ......... 0.0

Total of incomplete Owl Rock Member  ......... 53.5

Base of section; not base of exposure.
SECTION 14

Measured above a small bench on the southeast wall of Blue Canyon, 5.8 km S. 88° E. of Fry Canyon Store, and 11.3 km S. 12° E. of Jacob's Chair, on or near the boundary of secs. 25 and 26 (unsurveyed), T. 36 S., R. 15 E. (Measured by J. Dunn and D. McKee, November 10, 1973.)

Top of section; not top of exposure.  

Wingate Sandstone (unmeasured):

14.4 Sandstone, pale brown (10R 6/4), weathering same color, fine-grained, well sorted; composed of subangular to subrounded quartz grains and sparse, dark accessory mineral grains; firmly cemented, moderately calcareous; cross-laminated; massive splitting; forms vertical cliff. Only base of unit examined.

Contact: Contact between the Chinle Formation and Wingate Sandstone is sharp, wavy and bleached light greenish-gray (GY 8/1).

Chinle Formation:

Church Rock(?) Member:

Hite Bed:

14.3 Sandstone, conglomeratic sandstone, and conglomerate. Sandstone, grayish-pink (5R 8/2) to pale red (5R 6/2), weathering grayish-red (10R 4/2) to very dusky red (10R 2/2), generally fine-grained, well sorted to poorly sorted; composed of clear, white, and stained subrounded to subangular quartz grains with as much as 5% feldspar and dark accessory mineral grains; firmly cemented, slightly calcareous; contains thin to thick sets of small- to large-scale trough cross-laminae; massive to blocky splitting; forms vertical ledges. Conglomeratic sandstone and conglomerate; composed of disc-shaped granules to cobbles of siltstone, mudstone, and limestone; occurs at base of unit. Unit as a whole fills a swale extending 1500 m along canyon wall. ........................................ 15.0
Total of Hite Bed ........................................ 15.0

Erosion surface: Contact between Hite Bed and reddish-orange siltstone unit is a channeled surface of erosion. Relief of swale is in excess of 10 m.

Reddish-orange siltstone unit:

14.2 Siltstone, moderate orange pink (10R 7/4), weathering pale reddish-brown (10R 5/4), altered very pale orange (10YR 8/2) in circular mottles 2 to 5 cm in diameter; coarse-grained; composed of subangular quartz grains with about 2% feldspar, biotite, muscovite, and dark accessory mineral grains; firmly cemented, noncalcareous; upper portion composed of climbing-ripple laminae displaying considerable stoss-side erosion; platy to slabby splitting; forms vertical ledge. Laterally, unit becomes more finely-grained, and forms a slope with minor ledges ........................................ 6.7

14.1 Siltstone, pale reddish-brown (10R 5/4), weathering same color and moderate reddish-orange (10R 6/6); firmly cemented, slightly calcareous; forms partially exposed ledge ........................................ 0.0

Total of incomplete reddish-orange siltstone unit .... 6.7

Total of incomplete Church Rock(?) Member .......... 21.7

Base of section; base of exposure.
SECTION 15

Measured up the south side of Chocolate Drop, 16.8 km S. 37° E. of Castle Butte and 18.4 km S. 42.5° W. of Jacob's Chair, sec. 35 (unsurveyed), T. 36 S., R. 14 E. (Measured by J. Dunn, November 11, 1973.)

Note: Units 15.04 through 15.4 (and part of 15.5) occur on a slump block; thickness is measured perpendicular to bedding planes.

Top of section and top of exposure.  

**Wingate Sandstone:**

15.6 Sandstone, light brown (10YR 6/4), weathering moderate reddish-orange (10R 6/6), fine- to medium-grained, moderately sorted; composed of subrounded to subangular quartz and sparse, dark accessory mineral grains; firmly cemented, slightly calcareous; contains indistinct medium- to large-scale wedge-planar cross-laminae. Only base of unit remains as a vertically-edged cap to a house-sized outlier of Hite Bed, which surmounts Chocolate Drop .................................................. 4.2

Total of incomplete Wingate Sandstone ..................... 4.2

Contact: Contact between the Chinle Formation and Wingate Sandstone is a wavy surface of about 2 cm amplitude.

**Chinle Formation:**

**Church Rock(?) Member:**

**Hite Bed:**

15.5 Sandstone and conglomerate. Sandstone, pale red (10R 6/2) to grayish-orange pink (10R 8/2), weathering grayish-red (10R 4/2) to pale reddish-brown (10R 5/4), altered bluish-white (5B 9/1), light greenish-gray (5G 8/1), and locally, dusky yellow (5Y 6/4); very fine- to coarse-grained, generally very fine- to fine-grained, moderately sorted; composed of subangular to subrounded quartz grains with sparse
muscovite, biotite, feldspar, and dark accessory mineral grains; slightly friable, slightly calcareous. Conglomerate to conglomeratic sandstone; composed of disc-shaped granules to cobbles of siltstone, mudstone, and dolomite; occurs at base of unit and in lenticular beds. Unit as a whole is indistinctly trough cross-stratified and forms a series of thin to very thick, fractured ledges. Total of Hite Bed: 14.9

Erosion surface: Contact between Hite Bed and unit L is a channeled surface of erosion with less than 1 m relief.

Unit L:

15.4 Siltstone, pale reddish-purple (5RP 6/2), weathering same color; firmly cemented, noncalcareous; forms steep slope. Total of unit L: 4.6

15.3 Sandstone and conglomerate, like unit 15.5; composed of horizontal laminae and thin to thick sets of small- to medium-scale trough cross-laminae; massive splitting; forms ledge. Conglomerate occurs at base of unit. Total of unit L: 4.6

Erosion surface: Contact between unit L and reddish-orange siltstone unit is a channeled surface of erosion with about 1.5 m relief.

Reddish-orange siltstone unit:

Red Canyon ledge:

15.2 Siltstone, moderate reddish-orange (10R 6/6), weathering same color, altered dark yellowish-orange (10YR 6/6) in transverse streaks; firmly cemented, noncalcareous to slightly calcareous; massive splitting; forms ledge. Total of Red Canyon ledge: 4.6

15.1 Siltstone, moderate reddish-orange (10R 6/6) and pale red (10R 6/2), weathering same colors; firmly cemented, noncalcareous to slightly calcareous; forms steep slope covered with pebble-sized angular fragments. Total of reddish-orange siltstone unit: 12.9

Total of Church Rock(?) Member: 41.6
Contact: Contact between the Church Rock(?) Member and Owl Rock Member is obscured in debris; it is approximately placed to coincide with color change from grayish units in the Owl Rock Member to reddish-orange units in the Church Rock(?) Member.

Owl Rock Member:

15.07 Mudstone, grayish-red purple (5R 5/2), weathering same color; firmly cemented, highly calcareous; contains swelling clays; forms steep slope ................. 6.0

15.06 Siltstone, pale reddish-brown (10R 5/4) to moderate reddish-orange (10R 6/6), weathering same colors; firmly cemented, slightly calcareous; composed of faint, wavy laminae and micro cross-laminae; massive splitting; forms ledge; may be a tongue of the Church Rock(?) Member .................. 2.4

15.05 Siltstone, pale reddish-brown (10R 5/4) and, in upper portion, grayish-orange pink (10YR 7/2); firmly cemented, moderately calcareous; forms slope ............. 5.7

15.04 Limy siltstone and silty limestone. Limy siltstone, moderate orange pink (10R 7/4) and, in upper portion, grayish-orange pink (5YR 7/2), weathering same colors, streaking common as a result of alteration; firmly cemented, highly calcareous. Silty limestone, pale red (5R 6/2), weathering same color; microcrystalline. Unit as whole forms a series of steep slopes and thin ledges ......................... 2.4

15.03 Silty limestone, like limestone in unit 15.04; forms prominent ledge ......................... 1.1

15.02 Siltstone, moderate reddish-orange (10R 6/6) (slightly yellowish), moderate reddish-brown (10R 5/4), and light moderate brown (5YR 5/4), weathering same colors; firmly cemented, moderately calcareous; forms slope .... 4.4

15.01 Siltstone and sandstone, light red (5R 6/4), and in upper portion, pale reddish-brown (10R 6/4); not closely examined ..................... 23.3

Total of incomplete Owl Rock Member ..................... 45.3

Base of section; not base of exposure.
SECTION 16

Measured along roadcut of jeep trail that crosses a narrow pass between White Canyon and the longest tributary of Blue Canyon, 11.9 km N. 52° W. of Fry Canyon Store and 6.9 km S. 57° W. of Jacob's Chair, in the northwestern quarter of sec. 34 (unsurveyed), T. 35 S., R. 15 E. (Measured by D. McKee, November 15, 1973.)

Top of section; not top of exposure.

Chinle Formation:

Church Rock(?) Member:

16.5 Siltstone and mudstone, pale red (5R 6/2), weathering same color and grayish-pink (5R 8/2), altered light greenish-gray (5G 8/1) in circular mottles; moderately well cemented, slightly calcareous. Very thin to thin beds of siltstone predominate, alternating with very thin beds and laminae of slightly darker colored mudstone. Units occupying the interval laterally include very thin to thin beds of channel-filling, clay-rich sandstones and siltstones (possibly an equivalent of the Hite Bed), and, on the Blue Canyon side of the pass, rhythmically laminated claystones. Unit in line of section forms a steep slope to an indented cliff below the Wingate Sandstone .......................... 10.1

16.4 Sandstone and conglomeratic sandstone, pale red (5R 6/2), weathering same color, generally medium- to coarse-grained, ranges from very fine- to coarse-grained, moderately to poorly sorted; composed of subrounded, medium sand-sized to pebble-sized (at base of unit) clasts of mudstone, siltstone, limestone, quartz, and rare chert; clasts are disc-shaped and well compacted in a very fine- to medium-grained sandstone matrix composed of quartz and sparse, dark accessory mineral grains; firmly cemented, moderately calcareous; contains faint horizontal and trough shaped laminae; forms small ledge or part of slope ................................. 0.6

Erosion surface: Contact between units 16.4 and 16.3 is a channeled surface of erosion of uncertain relief due to poor exposure.
16.3 Siltstone and sandstone (?), like unit 16.5; unit concealed in rubble-covered slope .......................... 16.5

Reddish-orange siltstone unit:

Red Canyon ledge:

16.2 Siltstone, moderate reddish-orange (10R 6/6), weathering same color; firmly cemented, slightly calcareous; massive splitting; forms vertical ledge .......................... 7.9

Total of Red Canyon ledge ........................................ 7.9

16.1 Siltstone, pale red (5R 6/2); forms steep slope ............... 3.7

Total of reddish-orange siltstone unit .......................... 11.6

Total of Church Rock(?) Member ................................. 38.8

Contact: Contact between Church Rock(?) Member and Owl Rock Member is approximately placed due to slope rubble.

Base of section; not base of exposure.
SECTION 17

Measured about 250 m north of the promontory directly north-northwest of the northwesternmost Table of the Sun. Section is located 4.2 km S. 11° E. of Fry Canyon Store and 14.8 km S. 73° W. of The Needle (formerly The Gismo), sec. 3 (unsurveyed), T. 37 S., R. 16 E. (Measured by J. Dunn and J. Lyle, December 21, 1973.)

Top of section, not top of exposure.

Wingate Sandstone (unmeasured):

17.9 Sandstone, light brown (5YR 6/4) to grayish-orange pink (5YR 7/2), weathering pale reddish-brown (10R 5/4) to moderate reddish-orange (10R 6/6), fine- to medium-grained, moderately sorted, contains scattered coarse amber quartz grains; composed of subrounded to subangular quartz and sparse, dark accessory mineral grains; slightly friable, moderately calcareous; contains thin to very thick sets of medium- to large-scale trough cross-laminae; massive splitting; forms vertical cliff. Only base of unit examined.

Contact: Contact between the Wingate Sandstone and the Chinle Formation is sharp and horizontal. Basal Wingate is defined by the presence of coarse amber quartz grains.

Chinle Formation:

Church Rock(?) Member:

Unit L:

17.8 Siltstone, reddish-brown (10R 4/4), weathering same color to moderate reddish-orange (10R 6/6); firmly cemented, slightly calcareous; contains very faint horizontal laminae; massive splitting; forms vertical ledge; thins to northwest .............. 3.1

17.7 Siltstone and mudstone, pale orange brown (10R 6/4) to reddish-brown (10R 4/4), weathering same colors; firmly cemented, noncalcareous to moderately calcareous;
very thinly to thickly (?) bedded; forms slope. Unit is poorly exposed.  

**17.6** Siltstone and sandstone to granule conglomerate. Siltstone, like unit 17.7, but finer-grained. Sandstone to granule conglomerate, pale red (10R 6/2), weathering same color, altered in mottles of light greenish-gray (5GY 8/1); composed of fine sand-sized to small pebble sized clasts of mudstone, siltstone, quartz, feldspar, chert, and quartzite (?); weakly to firmly cemented, noncalcareous to slightly calcareous. Details of unit are buried in rubble-covered slope; unit appears to contain trough cross-stratification and is probably coarser toward base. Unit apparently fills a channel cut through a reddish-orange siltstone ledge that is absent in line of section, but present laterally to the southeast.  

Contact: Contact between units 17.6 and 17.5 is obscured in debris, but is probably a channeled surface of erosion. Contact is approximately placed in slope.  

**17.5** Sandy siltstone to conglomeratic sandstone, pale red (10R 6/2), weathering moderate reddish-orange (10R 6/6), pale reddish-brown (10R 5/4), and grayish-red (10R 4/2) to dusky red (10R 3/2); composed of subangular to well rounded granules, pebbles and cobbles of siltstone, mudstone, limestone, and sparse chert in a matrix of silt-sized to medium sand-sized quartz grains; grades upward into a flaggy splitting ledge composed of silty sandstone to sandy siltstone; firmly cemented, moderately calcareous; composed of small- to medium-scale trough cross-laminae in lower portion, and horizontal laminae climbing-ripple laminae, and micro-cross-laminae in upper portion; flaggy to slabby splitting; forms vertical cliff, laterally forms series of ledges and slopes and apparently pinches out.  

Total of unit L:  

**10.5**  

Erosion surface: Contact between unit L and unit M is a channeled surface of erosion with at least 1.5 m relief.  

Unit M:  

**17.4** Limestone, silty limestone, and pebbly sandstone. Limestone and silty limestone, pinkish-gray (5YR 7/1), weathering same color, predominantly altered light greenish-gray (5GY 8/1); microcrystalline; contains
coarser-grained calcite in void fillings of recrystallized zones. Pebbly sandstone, coarse-grained, occurs in one bed 15 cm thick. Entire unit has been subjected to siliceous alteration: microcrystalline quartz (1) has replaced many limestone and silty limestone layers, and (2) occurs in ferruginous coloration as dike-like bodies and abundant cylindrical nodules. Unit as whole forms series of ledges .......... 6.1

17.3 Pebble conglomerate, light bluish-gray (5B 7/1) to light greenish-gray (5G 8/1), weathering light olive gray (5Y 6/1), bimodally sorted; composed of subangular to subrounded granules and pebbles of gray siltstone, white chert, and igneous (?) rock, in a moderately calcareous, well sorted to moderately sorted, very fine-grained matrix of sand-sized subangular to well rounded quartz grains with sparse, subrounded, dark accessory minerals and angular chert; forms part of ledge ................. 0.2

Total of unit M .................. 6.3

Reddish-orange siltstone unit:

17.2 Siltstone, light brown (5YR 6/4), weathering pale reddish-brown (10R 5/4), altered light greenish-gray 5GY 8/1) in uppermost portion; firmly cemented, slightly calcareous; composed of horizontal laminae and microcross-laminae; contains mudstone laminae with polygonal-shrinkage cracks; muscovite flakes occur along mudstone laminae in basal 1.5 m of unit. Unit as whole forms ledge that laterally grades into slope ................. 6.9

17.1 Siltstone, moderate reddish-orange (10R 6/6), weathering same color to moderate reddish-brown (10R 5/4); firmly cemented, slightly calcareous; forms steep slope capped by spheroidally-weathering ledge 2.8 m thick ................. 20.8

Total of reddish-orange siltstone unit ........ 27.7

Total of Church Rock(?) Member ............. 62.8

Contact: Contact between the Church Rock(?) and Owl Rock Members is placed within 1 m of a color change laterally prominent but obscured beneath debris in line of section. Change is from grayish units in the Owl Rock Member to reddish units in the Church Rock(?) Member.

Base of section; not base of exposure.
SECTION 18

Measured 150 m north of a reentrant caused by a series of joints and faults in the southwest wall of the southern fork of Red Canyon, 12.7 km S. 33° E. of Chocolate Drop and 16.3 km S. 34° W. of Fry Canyon Store, on or near the boundary of secs. 3 and 4 (unsurveyed), T. 37 S., R. 15 E. (Measured by J. Dunn and J. Lyle, December 25, 1973.)

Top of section; not top of exposure.

Wingate Sandstone:

18.10 Sandstone, light brown (5YR 6/4) to pale reddish-brown (10R 5/4), weathering same color to moderate orange brown (10R 4/5), fine-grained, moderately sorted; composed of subangular to subrounded grains of quartz and sparse, dark accessory minerals; slightly friable, slightly to moderately calcareous; contains faint large-scale trough cross-laminae; massive splitting; forms vertical cliff. Only base of unit examined; unit not measured ....................... 0.0

Transitional unit:

18.9 Siltstone, orange brown (10R 5/6), weathering same color; contains very fine sand-sized grains of amber quartz; firmly cemented, noncalcareous; composed of horizontal laminae and gently dipping trough cross-laminae; forms basal part of vertical cliff ............ 3.5

Total of transitional unit ......................... 3.5

Total of incomplete Wingate Sandstone ................... 3.5

Chinle Formation:

Church Rock(?) Member:

Hite Bed:

18.8 Dolomitic siltstone to silty dolomite, pale red purple
(5RP 5/2), weathering pale red (5R 5/2). Silty dolomite; microcrystalline; contains coarser-grained recrystallized zones. Where not covered with rubble from overlying units, unit forms a series of very thin, rounded, nodular ledges .............................. 1.5

18.7 Sandy siltstone to very fine-grained silty sandstone, pale red (5R 6/2), weathering same color to grayish-orange pink (5YR 7/2); poorly cemented with small amounts of interstitial clay; highly porous; composed of subangular grains of clear and stained quartz with sparse micas, dark accessory minerals, and feldspar; forms steep, poorly exposed slope ............................... 5.3

18.6 Sandstone and conglomerate, pale red (5R 6/2), weathering same color to grayish-red (5R 4/2), altered (like unit 12.6) shades of purple, gray, and whitish-pink in streaks not necessarily parallel to laminae. Sandstone, fine-grained, moderately sorted; composed of subangular to subrounded grains of quartz, mica, and dark accessory minerals. Conglomerate and conglomeratic sandstone contains granules to cobbles of disc-shaped siltstone and limestone. Unit as whole weathers as follows: 0 to 3.7 m, ledge or series of ledges composed of very thin to thick sets of trough cross-laminae with lenses of conglomerate; 3.7 to 5.7 m, steep slope, flaggy splitting, grades into overlying unit ................................. 5.7

Total of Hite Bed ........................................ 12.5

Erosion surface: Contact between Hite Bed and unit M is a channeled surface of erosion with gentle relief of 1 m.

Unit M:

18.5 Silty limestone, light greenish-gray (5GY 8/1); microcrystalline; contains (1) scattered sand-sized chert grains, (2) probably more than 30% coarse silt-sized and very fine sand-sized subrounded quartz grains, and (3) disseminated along laminae, disc-shaped coarse sand-sized to granule-sized, grayish-green (10GY 5/2) mudstone clasts; forms small ledge ............................ 0.9

18.4 Limy siltstone, light brown (5YR 6/4); firmly cemented, highly calcareous; alternates with very thin beds of slightly darker sandy siltstone containing angular to subrounded, very fine- to fine-grained clasts of sand-sized quartz and feldspar; forms slope with minor ledges ................................. 1.9
Reddish-orange siltstone unit:

Red Canyon ledge:

18.3 Siltstone, pale reddish-brown (10R 5/4); firmly cemented, slightly calcareous; composed of horizontal laminae, wavy laminae, and micro-cross-laminae; contains mudstone laminae with polygonal-shrinkage cracks in lower portion; massive to flaggy splitting; forms ledge with rounded top .............................................. 6.5

Total of Red Canyon ledge .................................. 6.5

18.2 Siltstone, moderate reddish-orange (10R 6/6), weathering same color; firmly cemented, slightly calcareous; forms slope with series of spheroidally-weathering ledges .................................................. 13.8

18.1 Siltstone, like unit 18.2; contains pale red (5R 5/2) beds; forms slope. Unit mostly obscured by rubble ... 12.8

Total of reddish-orange siltstone unit ................... 33.1

Total of Church Rock(?) Member ............................ 48.4

Contact: Contact between the Church Rock(?) and Owl Rock Members is placed at color change, partially obscured in slope, from purplish-gray siltstone in the Owl Rock Member to reddish-brown units in the Church Rock(?) Member.

Base of section; not base of outcrop.
SECTION 20

Measured on the north face of the southeasternmost end of the cliff that forms the southern rim of the south fork of Red Canyon. Section is located 20.1 km S. 16° W. of Fry Canyon Store, on or near the boundary of secs. 24 and 25 (unsurveyed), T. 38 S., R. 15 E. (Based on descriptions and measurements of T. Mullens and H. Hubbard (Mullens, 1960, p. 311); revisited and revised by J. Dunn and J. Lyle, December 27, 1973.)

Top of section; not top of exposure.

Wingate Sandstone:

20.10 Sandstone, moderate reddish-brown, very fine-grained, many to scarce red and black accessory minerals; well indurated; only slightly calcareous; not measured .......... 0.0

Transitional unit:

20.9 Siltstone, pale orange brown (10R 6/4) to pale reddish-brown (10R 5/4), coarse-grained; firmly cemented, slightly calcareous; contains white mica along sparse mudstone laminae; basal surfaces display polygonal-shrinkage cracks and asymmetrical ripple marks. Axes of the ripple marks trend N. 60° W.; ripples are asymmetrical to the south. Unit as whole forms massively splitting ledge ........................................ 7.3

Total of transitional unit ................................ 7.3
Total of incomplete Wingate Sandstone .................. 7.3

Chinle Formation:

Church Rock(?) Member:

Reddish-orange siltstone unit:

20.8 Siltstone, dark reddish-brown (10R 4/4), sandy; well indurated; noncalcareous cement; hackly to concretionary
weathering; undulating lower contact; forms slight undercut below unit 20.9 ............... 0.5

20.7 Siltstone, orange brown (10R 5/6), weathering moderate reddish-orange (10R 6/6); well indurated, calcareous cement; bedding structures not exposed, but probably horizontal, as horizontal ledges, 45 to 60 cm thick, occur in upper part of steep slope ......... 7.2

20.6 Silty sandstone, pinkish-gray (5YR 8/1), stained moderate reddish-orange (10R 6/6), very fine-grained, well sorted; composed of subrounded to well rounded quartz grains firmly cemented with carbonate; forms nodular ledge and small overlying slope .......... 0.6

20.5 Siltstone, like unit 20.7; forms slope ............ 12.7

20.4 Limestone, greenish-gray (5GY 8/1), dense, noncrystalline; relatively pure; lenticular bed; contains scattered chert concretions. Unit may be equivalent to units 18.5 and 18.4, which were assigned to unit M .... 0.3

20.3 Siltstone, like unit 20.7; forms slope ............ 4.7

20.2 Siltstone, pale reddish-brown (10R 5/4), weathering moderate reddish-orange (10R 6/6); firm calcareous cement; one massive bed with horizontal laminations; forms distinctive ledge at base, platy slope at top ... 5.4

20.1 Siltstone, like unit 20.7; forms slope ............ 26.1

Total of reddish-orange siltstone unit ............... 57.5

Total of Church Rock(?) Member ...................... 57.5

Contact: Contact between the Church Rock(?) and Owl Rock Members is placed at color change from pale red and grayish-green siltstones and sandstones in the Owl Rock Member to moderate reddish-orange siltstones in the Church Rock(?) Member.

Owl Rock Member:

20.0 Sandstone and siltstone, pale red, very fine-grained, poorly sorted; composed of clear quartz with abundant black and dark green accessory minerals, many green and white mica flakes, and abundant interstitial clay; weak calcareous cement; bedding structures masked; forms steep slope ................. 7.3
Total of incomplete Owl Rock Member ........... 7.3

Base of revised section; not base of original section of Mullens (1960).
SECTION 25

Measured near a bend of the southwestern rim of White Canyon, 350 m due east of spot elevation 6844 on the Natural Bridges 15 minute quadrangle. Section is located 3.1 km N. 63° W. of Fry Canyon Store and 9.4 km S. 6° E. of Jacob's Chair, on or near the boundary of secs. 19 and 20 (unsurveyed), T. 36 S., R. 16 E. (Measured by J. Dunn and L. McFadden, March 25, 1975.)

Top of section; not top of exposure.

Wingate Sandstone:

Transitional unit:

25.10 Sandstone, moderate reddish-orange (10R 6/6) to moderate orange pink (10R 7/4), weathering moderate reddish-orange (10R 6/6), generally very fine- to fine-grained with uncommon medium-sized grains scattered along laminae, moderately sorted; composed of subrounded to subangular quartz grains, and uncommon feldspar and dark accessory mineral grains; well indurated, moderately calcareous; contains predominantly horizontal laminae with some small-scale, low angle trough cross-laminae; massive to blocky splitting; forms ledge at base of cliff ................... 2.9

Total of transitional unit ......................... 2.9

Total of incomplete Wingate Sandstone ........... 2.9

Chinle Formation(?):

Church Rock(?) Member(?):

Unit L(?):

25.9 Sandy siltstone (?), moderate reddish-orange (10R 6/6)(?), and mudstone (?), pale red (10R 6/2) to grayish-red (10R 4/2), slightly (?) calcareous. Unit is buried under sand and rubble derived from overlying units; unit is tentatively placed in the Chinle Formation because it forms a slope. Lower boundary is somewhat arbitrarily placed ........................................... 5.2
Chinle Formation:

Church Rock (?) Member:

Unit L:

25.8 Siltstone, moderate reddish-orange (10R 6/6), weathering same color; contains rare, very fine sand-sized grains and rare, dark accessory mineral grains; well indurated with dolomitic cement; horizontally laminated; contains mudstone laminae occurring at intervals of 5 to 50 mm over zones 5 to 20 cm thick; some mudstone laminae contain polygonal-shrinkage cracks. Splitting is generally blocky to massive; platy splitting occurs in some of the zones containing mudstone laminae. Unit forms vertical ledge in basal 2.8 m; upper portion of unit forms slope and is concealed in debris ......... 4.1

25.7 Siltstone, pale reddish-brown (10R 5/4), weathering same color and moderate reddish-orange (10R 6/6); noncalcareous; appears structureless; forms covered slope .. 0.4

25.6 Siltstone, pale reddish-brown (10R 5/4), weathering same color and moderate reddish-orange (10R 6/6); firmly cemented, slightly calcareous; contains indistinct wavy laminae throughout that are composed of fine-grained siltstone; platy to flaggy splitting occurs along these laminae in the uppermost 0.3 m of unit. Unit forms ledge .. 0.6

25.5 Mudstone, pale reddish-brown (10R 5/4), weathering same color; firmly cemented, noncalcareous; composed of finely interlaminated siltstone and claystone; forms slope covered with angular fragments .......... 0.7

Contact: Contact between units 25.5 and 25.4 is gradational.

25.4 Siltstone and mudstone. Siltstone, pale red (5R 6/2), weathering moderate reddish-orange (10R 6/6) to moderate orange pink (10R 7/4); firmly cemented, slightly calcareous. Mudstone, moderate red (5R 5/4), weathering same color to pale reddish-brown (10R 5/4); noncalcareous; occurs as thin laminae spaced at 1 to 20 mm intervals. Entire unit composed of micro cross-laminae; forms a ledge with platy to slabby splitting ....... 1.2

25.3 Sandstone, siltstone, mudstone, and, laterally, conglomerate. Sandstone to silty sandstone, pale grayish-red (10R 5/2), weathering same color, commonly stained
moderate reddish-orange (10R 6/6), and altered in mottles of light greenish-gray (5G 8/1); fine- to medium-grained, moderately to poorly sorted; composed of (1) coarse, silt-sized and very fine to medium sand-sized grains of well rounded to subangular clear quartz uncommonly stained with iron oxide, (2) dark accessory mineral and muscovite grains in amounts as great as 1 to 2 percent, and (3) locally abundant medium to coarse sand-sized grains and granules of silty dolomite, siltstone, mudstone, and chert disseminated along laminae; firmly cemented, highly calcareous; contains indistinct horizontal laminae, micro-cross-laminae, and uncommon parting lineations; occurs (1) concealed in basal portion of unit, and (2) buried in float-covered slope in upper 2.3 m of unit. Presence of siltstone and mudstone in line of section is inferred from exposures 100 m to the northwest, where pale red (5R 6/2) and pale reddish-brown (10R 5/4) structureless and micro-cross-laminated siltstones and mudstones comprise the entire unit. Unit in line of section forms covered slope. 60 m to the southwest, base of unit is composed of a channel-filling conglomerate described as follows: Cobble to granule conglomerate, pale grayish-red purple (10R 5/2) and pale blue green (5BG 7/2) overall, weathering same or slightly darker colors, locally altered moderate reddish-orange (10R 6/6); firmly cemented, highly calcareous; composed of well rounded to subangular clasts of (1) light gray (N 7) microcrystalline limestone and dolomite; (2) altered light olive gray (5Y 5/2) limestone; (3) white (N 9), moderate red (5R 4/6), and grayish-orange (10YR 7/4) chert, much of which may be fragments of petrified wood and bone; and (4) uncommon reddish-brown (10R 5/4) siltstone; in a matrix of fine- to medium-grained arkosic sandstone. Some limestone clasts appear to have been recrystallized and are encrusted with carbonate overgrowths; when removed from matrix, the clasts have a pitted appearance caused by the impressions of neighboring clasts in the overgrowth. Conglomerate unit contains uncommon siltstone lentils less than 0.3 m thick and forms a series of blocky to massive splitting ledges in a paleochannel about 90 m wide ... 11.9

Total of unit L ........................................ 24.1

Erosion surface: Contact between unit L and reddish-orange siltstone is a channeled surface of erosion with little relief in line of section, but as many as 6 m relief in paleochannel to the southwest.
Reddish-orange siltstone unit:

25.2 Siltstone and mudstone. Siltstone, moderate reddish-orange (10R 6/6), weathering same color in lower part of unit, grading upward to grayish-pink (5R 8/2) and, in uppermost 2.2 m of unit, moderate orange pink (5YR 8/4); well indurated with dolomitic cement, slightly calcareous; composed of horizontal laminae, wavy laminae, and micro-cross-laminae; contains uncommon worm borings (?) and rare carbonized plant (?) fragments; occurs inter-stratified with mudstone, comprising 95% of unit thickness. Mudstone to claystone, pale reddish-brown (10R 5/4), weathering same color, commonly stained moderate reddish-orange (10R 6/6); firmly cemented, noncalcareous; occurs in laminae 0.1 to 1 mm thick separated by siltstone laminae 3 to 20 mm thick in lower and upper portions of unit, and as many as 75 mm thick in central portion of unit. Unit as whole weathers as follows: 0 to 4.9 m, vertical cliff, platy to blocky splitting; 4.9 to 7.1 m, series of ledges, flaggy splitting ............... 7.1

25.1 Siltstone. Unit is concealed except in upper portion, which is orange brown (10R 5/5), weathering same color to moderate reddish-orange (10R 6/6); firmly cemented, slightly calcareous; composed of horizontal laminae and micro-cross-laminae; forms steep slope ............... 11.4

Total of reddish-orange siltstone unit ............... 18.5

Total of Church Rock (?) Member ............... 42.6

Contact: Contact between the Church Rock (?) Member and Owl Rock Member is buried in slope; it is approximately placed to coincide with laterally exposed color change from pale red units in the Owl Rock Member to reddish-orange units in the Church Rock (?) Member.

Owl Rock Member (unmeasured):

25.0 Siltstone and mudstone, generally pale red (5R 6/2); firmly cemented, slightly to moderately calcareous. Unit is buried in rubble-covered slope.

Base of section; base of exposed Upper Chinle units.
REFERENCES CITED


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