Stratigraphy of the Lower Tertiary and Upper Cretaceous (?) Continental Strata in the Canyon Range, Juab County, Utah

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ABSTRACT.—The Canyon Range Formation (informal new name), formerly mapped as the Indianola Group within the Canyon Range, is divisible into two distinct, mappable units, A and B.

Unit A is nearly all conglomeratic strata, and conglomerate texture and sedimentary structures suggest an alluvial fan depositional environment. Precambrian and basal Cambrian quartzite classes represent the erosional debris from the allochthonous Canyon Range thrust. Unit B is composed of interbedded fluvial sandstone and conglomerates with lacustrine limestones, commonly micritic and/or oolitic. Conglomerate classes indicate a Paleozoic carbonate provenance.

Unit A, previously mapped as the Indianola, underlies Unit B and correlates with the Price River-Lower North Horn Formations of the Pavant Range and Long Ridge. Marginal paleontologic and stratigraphic indicators suggest Unit B to be equivalent to the Paleocene-Eocene North Horn and Flagstaff Formations rather than the Cretaceous Indianola Group. Stratigraphic and structural relationships indicate the last major phase of "Sevier" thrusting ended by Price River (?) time.

INTRODUCTION

Within the Canyon Range of central Utah is an exceptionally thick sequence of Sevier syn-to-postorogenic conglomeratic strata commonly (though questionably) referred to as the Indianola Group and North Horn Formation. This study examines a part of the so-called "Indianola" in an attempt to verify or change the present stratigraphic assignment.

The Canyon Range is situated along the eastern margin of the Sevier orogenic belt which roughly coincides with the Paleozoic miogeosynclinal hinge line. Structurally and stratigraphically, the Canyon Range consists of folded autochthonous and allochthonous plates composed of Precambrian and basal Cambrian quartzite and Lower Paleozoic carbonates. A much younger sequence, heretofore suggested as Late Cretaceous (?) to Lower Tertiary (?) and locally overridden by the older sequence, is composed of conglomerates, sandstones, and freshwater limestones.

Many of the conglomeratic formations associated with the Sevier and more recent tectonic events have the potential to produce stratigraphic information which would help decipher the timing of structural development. To date, most of the conglomeratic strata have either been ignored in research or have resisted precise dating. When they are studied, the lack of precision is seen to be due primarily to an absence of fossil forms in strata bounding critical unconformities or faults. Further complications to the stratigraphy are caused by rapid facies changes, numerous unconformities, a great variance in stratigraphic thickness, and a general similarity among many Upper Cretaceous and Lower Tertiary formations.

This study examines a well-exposed portion of the younger sequence. Described herein are two stratigraphic sections totaling 1,036 m with associated documentation of lithologies, sedimentary structures, paleontology, and stratigraphic relationships. From this and a regional evaluation of the Upper Cretaceous and Lower Tertiary stratigraphy is determined the proper stratigraphic position for the sequence. Also developed are an interpretation of the sedimentary environments and a reconstruction of the structural development of the Canyon Range.

Location

The study area is located 15 km southwest of Mills, Juab County, Utah, and 8 km west of U.S. 91 (fig. 1). The area of study is situated in the southeast 1/4, T.16S, R.3W. Access is provided by a graded dirt road which extends southwest from Mills, Utah, to about 3 km east of the area. A few unimproved jeep roads extend westward from the graded road to the base of the range and provide the only access to mountains characterized by rugged topography.

Exposures of the east-dipping Canyon Range fanglomerate (Armstrong 1968, p. 448) are essentially restricted to the east flank of the range. In the vicinity of Cow Canyon, stratigraphic sections, though incomplete, are well exposed.

Previous Work

Early research dealing with the Canyon Range was cursory in nature, but nevertheless important in the recognizing of critical stratigraphic relationships. Gilbert first studied in the Canyon Range in 1890 but restricted his attention to geomorphic features resulting from the Pleistocene Lake Bonneville. Tower and Smith (1899, p. 617) recognized an unconformity in Leamington Canyon between folded Paleozoic strata and conglomerates they considered to be Eocene. They noted the ab-
sence of volcanic material in the conglomerates, the presence of volcanics in Pleistocene and Recent alluvial deposits, and concluded the volcanics were post-Eocene. Davis (1905, p. 32-33) presented a cross-section depicting a "sharp shear or fault on the steep eastern slope of the range" with quartzite faulted over conglomerates (the Canyon Range thrust). Davis also observed that conglomerates comprised much of Fool Peak, and though discordant with the underlying quartzite, both dip in a westerly direction. Loughlin (1912, p. 448) visited the unconformity in Sevier (Leamington) Canyon and noted the presence of a bed of dark-colored volcanic rock, "presumably andesite or latite," resting on the conglomerates. He noticed (1914, p. 56-57) the relationship of gently east-dipping conglomerates in contact with a "steep erosion surface of quartzite" north of Oak Creek summit (Canyon Range thrust). This he inferred was sedimentary and "indicated a very uneven pre-Eocene topography." He concluded (1914, p. 57) the conglomerates in the Canyon Range were Eocene by correlation with similar strata in the southern Wasatch Mountains.

Christiansen (1952) performed the only major study to date and measured some 5,245 m of conglomerates, sandstones, shales, and limestones. Lacking paleontologic evidence, Christiansen (1952, p. 725-28) suggested that 3,810 m of the conglomeratic strata are equivalent to the Cretaceous Indianola Group; 1,067 m, a probable Cretaceous-Paleocene North Horn or Flagstaff Formation equivalent, and 366 m, the Oligocene (?) Fool Creek Conglomerate.

Armstrong (1968, p. 448), in his research on the Sevier orogenic belt, suggests a discordant stratigraphic relationship seems to exist in the Canyon Range with the assignment of the conglomeratic strata to the Indianola group. Regional stratigraphic relations of the oldest strata found unconformably overlying major thrusts and the first major occurrence of distinct, Precambrian quartzite clasts in conglomerates would suggest that the "Indianola" in the Canyon Range is Price River or younger (Armstrong 1968, p. 448). Rather than Cretaceous Indianola Formation, Armstrong suggests the Canyon Range "fanglomerate" is possibly a Paleocene-Eocene Flagstaff Formation equivalent.

Numerous other important works, dealing with the stratigraphy of nearby ranges, are too numerous to mention at this time. They will be referred to throughout the text.

Methods of Study

Two stratigraphic sections totaling 1,036 m were measured using a Jacob's staff and an Abney level hand in the spring and summer of 1974 and spring and fall of 1975. Measurements of bed attitude and rare paleocurrent directions were made with a Brunton compass. Standard field procedures, plus the use of Skylab and low- and high-altitude aerial photographs, were used to help in correlations and in formulating structural-stratigraphic ideas.

Thin sections were made of major lithologic types (excepting conglomerates) to aid in the investigation. They were studied under a petrographic microscope for composition, texture, sedimentary and biogenic structures, and classification. Samples were mounted with epoxy and stained for identification of calcite and/or dolomite. Quantitative measurement of clast size and composition was accomplished through measurement of outcrops, scaled color slides, and samples brought back from the field.

During 1975-1976 approximately 12 samples were processed for palynological age determination by Mr. Mark Nations and Mr. G. Fournier of Gulf Research and Development Company.

Terminology used in this paper for description of stratification and cross-stratification will follow Hays and Kana (1976, p. 1-8). Color descriptions will correspond to the standardized color chart published by the Geological Society of America (Goddard 1970). Descriptive grain-size terminology used is the Modified Wentworth Scale proposed by Dunbar and Rogers (1957, p. 161).

Acknowledgements

The author would like to express his thanks to the members of the thesis committee, Dr. H. J. Bissell (chairman), Dr. J. R. Bushman, and Dr. W. K. Hamblin, for their time and expertise in assisting in this study. Special thanks go to Dr. Bushman for his interest and original thesis suggestions regarding stratigraphic problems with unfossiliferous conglomeratic strata. Sincere gratitude is extended to Mr. Mark Nations and Mr. G. Fournier of Gulf Research and Development Company for their efforts in processing and evaluating palynological samples for age determination. Special recognition is given to my wife, Linda, for her support of a research project that seemingly took as long as the deposition of the Canyon Range Formation itself. To the many others who willingly provided materials, time, and expertise the writer's thanks are extended.
through boulder-sized clasts of orthoquartzite. The upper unit was void of limestone clasts, consisting only of orthoquartzite pebbles, cobbles, and boulders. From the clast descriptions, the provenance of the orthoquartzites was probably a terrain composed of Upper Precambrian through Lower Cambrian strata. Thomas (1960, p. 46), however, suggests a northern source area on the basis of southward thinning of units and a northward coarsening of conglomerate units. The southern Wasatch area some 16 km to the north was suggested as a possible source for the Indianola of the Gunnison Plateau.

Thin-bedded limestone beds are found in most Indianola localities in rare to occasional occurrences. Lithologically, the limestones are generally finely crystalline, silty to arenaceous, with colors ranging through grays, light to dark brown, and black, occasionally being carbonaceous.

Spieker (1949, p. 60) considered the lithologies of the Indianola to be indicative of a piedmont or highland depositional area.

**South Flat Formation**

The South Flat Formation was originally defined by Hunt (1950, p. 55-62) and later formally proposed as a formation (Hunt 1954) for an 870-m sequence of conglomerate and sandstone overlying the Indianola in the Gunnison Plateau. Thomas (1960, p. 47) redefined the South Flat making most of the basal conglomerates of Hunt (1950) the upper member of the Indianola. The redefined South Flat is 290 m thick and consists predominantly of gray-to-buff sandstone with subordinate shale and occasional flaggy-beded limestone. Lithologically, the limestones are similar to those in the underlying Indianola Group. The age of the redefined South Flat Formation is thought to be Cretaceous middle Montanan (Thomas 1960, p. 54). Hays (1960, p. 44) indicates the South Flat to be non-marine, and most probably fluviatile in origin.

**Price River–Castlegate Formations Undifferentiated**

The Price River Formation was defined by Spieker and Reeside (1925, p. 445) for sandstone outcrops in Price River Canyon near Castle Gate, Utah. Clark (1928) later divided the Price River into two members at the type location and named the lower member the Castlegate Sandstone. The age of the Price River Formation is probably Cretaceous late Montanan. In general, west of the type section it is not possible to differentiate the Castlegate Sandstone from the overlying Price River. In regions to the west of the type section, the Price River commonly connotes massively bedded conglomeratic sequences, although at the type section conglomerate is a minor rock type.

Spieker (1951, p. 67) assumed the Price River to be present beneath younger formations in the Long Ridge, but none is exposed. Gilliland (1951, p. 17) reported only post-Price River strata in the Valley Mountains. Lautenschlager (1952, p. 38) reported a conglomeratic sequence which he assigned to the Price River Formation. It consisted of conglomerate and sandstone which, when viewed from a distance, appear dark-purplish red. Clast diameters range from 30 cm near the base to 2.5 to 15 cm in the upper part of the section. Most of the clasts are derived from the Precambrian of Tintic Formations. Lautenschlager (1952, p. 39) notes that where present, the Price River overlies the Sevier postorogenic erosion surface and that usually the underlying formations are Cambrian or Ordovician. Relief on the erosional surface is as much as 150 m. Lautenschlager (p. 40) comments that no fossils have been found in the Price River Formation in the Pavant Range, and the age is not well established. Conformably overlying the Price River Formation are sandstones of the North Horn Formation. Although the North Horn Formation also lacks paleontological control, it is overlain by the fossiliferous Flagstaff Formation. In the Pavant Range, the Price River Formation appears to have been deposited in an alluvial fan depositional system, whereas the overlying North Horn was fluvial and lacustrine.

**North Horn Formation**

The North Horn Formation was defined by Spieker (1949, p. 132) as the former lower member of the Wasatch Formation. At the type locality on North Horn Mountain, the section is typically made up of shales, limestones, and sandstone. The North Horn is known to bridge the Cretaceous-Tertiary boundary, with the majority of the section being Paleocene in age. In the Long Ridge area, Muesig (1951, p. 72) described the North Horn as flaming red beds with essentially all clastic types and terrigenous limestone present. He noted that individual beds are extremely variable, and that units cannot be traced for any considerable distance vertically or laterally. A conglomerate approximately 137 m thick is present at the base of one section and represents the lowest North Horn exposed in the Long Ridge. Clasts from this conglomerate are very well-rounded purple and lemon-colored quartzite boulders, 30 to 60 cm in diameter, with no limestone clasts. Lambert (1976) noted dark and light-colored quartzite cobbles, which are 60 to 90 cm in diameter, to be present within conglomerate lenses within the formation. He noted that red, sandy oncolites up to 2.5 cm in diameter are the distinguishing feature of this formation in Long Ridge. Tucker (1951) mapped the Scipio quadrangle and found oncites in the uppermost North Horn Formation. Gilliland (1951, p. 20) found the North Horn in the Valley Mountains to be atypical of the formation in most localities as it consisted chiefly of sandstone with smaller amounts of limestone. Gilliland also noted that grayish-brown algal nodules up to 15 cm in diameter are abundant throughout the North Horn Formation in the Valley Mountains. Lautenschlager (1952, p. 41) measured the North Horn Formation in the central Pavant Range and found it to consist of sandstones, siltstones, and shales. He noted that several conglomerate beds are present in the upper North Horn which are laterally very persistent. Lautenschlager notes minor lithologic types include pink, red, and purple siltstones, and a thin algal-ball limestone near the top of the formation.

**Flagstaff Formation**

The type section of the Flagstaff Formation (originally called the Flagstaff Limestone) is on the slopes of Flagstaff Mountain some 80 km to the southeast of the study area. Originally defined by Spieker and Reeside (1925, p. 448-49), the Flagstaff Formation at its type section consists of freshwater limestones and gray limey shales with minor amounts of sandstone and gypsum. At the type section only 61 m of the Flagstaff is exposed, although some 150 m of Flagstaff crops out in better exposures to the north. The Flagstaff is Paleocene-Eocene in age (LaRocque 1960, p. 73), and it is suggested that the Flagstaff is time transgressive and becomes younger from east to west.

At the type section, two separate lithologic units can be discerned; a lower unit of shales with thin limestones (unit 1 of LaRocque), and an upper unit of massive white limestone with minor shale, sandstone, chert, and much gypsum (unit 2 of LaRocque). Along the western front of the Wasatch Plateau, LaRocque (1960, p. 12) mentions the presence of another unit of thin tan shales and limestone with much chert.
overlying the massive white limestone (unit 3 of LaRocque). This new unit is, in turn, overlain by the Colton Formation.

In the vicinity of the study area, LaRocque (1960, p. 13) extended the three-unit Flagstaff subdivision into the Long Ridge, the Valley Mountains, and the Pavan Range. In Long Ridge, LaRocque suggested only units 2 and 3 are represented. Muessig (1951, p. 75) noted two distinct facies are represented, a northern piedmont facies and a southern lacustrine and fluviatile facies. The southern facies is composed of limestone, shales, sandstone, and pebble conglomerates. The northern piedmont facies consists of massive boulder conglomerates with an average clast diameter of 30 to 60 cm. Clast composition reflects the whole Precambrian and Paleozoic stratigraphic column. Lambert (1976) studied the Flagstaff in the southern end of Long Ridge in the West Hills and noted it was composed of algal microfacies, intraclastic algal limestone, wackestones, sandstone, mudstone, and conglomerate. Paleocurrents and thinning of units indicate a source to the north, with southward transportation of clastics. No oncolites were noted by either Lambert or Muessig. In the western Valley Mountains, Tucker (1951) found oncolites in the lower Flagstaff. Gilliland (1951, p. 22) found four distinct facies of the Flagstaff Formation in the Gunnison Quadrangle with the northern Valley Mountains section being typically yellow, gray, and red dense limestone. He noted in his measured sections (p. 89, 91, 92) oncolites in his basal Unit A. Lautenschlager (1952, p. 55) noted the Flagstaff in the central Pavan Range to be composed of brightly colored silstones, shales, and silty limestones with some white limestone and brown conglomerates.

Previous Stratigraphic Interpretations in the Canyon Range

A few individuals between the years 1890 and 1915 made reconnaissance studies in the Canyon Range and published a few observations and suggested correlations relating to the younger conglomeratic sequences, later called the Indianola or North Horn Formations (See Previous Work). The situation remained the same until Christiansen (1952) mapped the range and estimated some 5,245 m of conglomerate, sandstone, shale, and occasional limestone strata along the eastern half of the range. For the purposes of this study, Christiansen’s geological map of the Canyon Range proved to be sufficiently accurate, with minor changes, to serve as a base.

Christiansen (1952, p. 725) tentatively assigned 3,810 m of coarse clastics to the Cretaceous Indianola Group because of similarities to sections in the Gunnison Plateau. Some 1,067 m of section were assigned to the Cretaceous-Paleocene because of similarities with a section in the Long Ridge area immediately to the east of the Canyon Range (it should be remembered that these correlations were made without benefit of paleontologic evidence).

Christiansen (p. 726) subdivided his Indianola into three distinct units; A lower, 244-m unit consisted of pebble-sized conglomerates with clasts composed of lower Paleozoic carbonates, with Cambrian types predominating. Clast composition was 90 percent Paleozoic carbonates, with the remaining 10 percent being composed of quartzites from the Tintic or the Precambrian. The middle unit is a series of massive, quartzite-clast conglomerate beds approximately 550 m thick. Clasts are composed of the red, purple, and gray quartzites of the Precambrian and the Tintic Formation. As Christiansen noted (p. 726), the entral part of this middle unit is extremely coarse, with clasts up to 2.2 m in diameter. Higher in the middle unit limestone clasts increase to 15 percent of the composition. The massive conglomerate beds form extremely resistive ledges and cliffs. The upper unit of Christiansen’s Indianola Group consists of 2,745 m of interbedded conglomerate, sandstone, siltstones, and shales with occasional beds of lithographic limestone in the upper part. Texturally the conglomerates are smaller in clast size than the underlying middle unit, and according to Christiansen the conglomerate clasts range in composition from pure limestone clasts to varying mixtures of limestone and quartzite.

Within the Canyon Range, Christiansen (1952, p. 726) suggested that correlations within the Indianola are not possible because of the discontinuous nature of the strata.

Unconformably above the Indianola is a series of strata consisting of interbedded limestone, shale, and coarse clastics that total up to 1,067 m thick which Christiansen (p. 727) tentatively correlated to the North Horn Formation in the Gunnison Plateau. Shale and siltstone compose 50 percent of the formation and are generally light to dark red and tan, but commonly the siltstones are varicolored in shades of purple, red, and yellow. The limestone is described as predominantly arenaceous and dense and generally light gray to white. Conglomerate beds are generally less than 4.6 m thick, and range up to 9 m, and clast composition is noted to have varying mixtures of limestone and quartzite.

The Indianola is seen to rest unconformably on Cambrian strata in the vicinity of Yellowstone Canyon. Southward it progressively truncates older strata until it rests upon the Precambrian. Christiansen’s North Horn Formation is suggested to overlie the Indianola with a slight unconformable relationship as seen in the hills north of Wide Canyon.

Present Interpretations—Reference Sections

In the study area (fig. 2) all strata were previously mapped as the Indianola Formation by Christiansen with the exception of the Precambrian on the thrust sheet. While paleontologic and lithologic evidence found in this study was not age-precise, it nevertheless indicated that some, if not all, of the strata found in the study area are younger than the Indianola Formation.

FIGURE 2.—Topographic index map showing location of study area and measured sections.
As will be discussed in the next sections, difficulties exist providing precise correlations to other Upper Cretaceous-Lower Tertiary strata. As a result, it was decided to call all the strata the Canyon Range Formation (informal new name), and divide it into mappable units. At a later time, with more data, this informal nomenclature might be changed to the correct, formal stratigraphic nomenclature. Armstrong (1968, p. 443) called the "Indianola" strata in the Canyon Range, the Canyon Range Fanglomerate because of age discrepancies he felt existed with Christiansen's units. Fanglomerate, however, has a genetic denotation of an alluvial fan depositional environment which is correct for only part of the "Indianola" sequence. Thus the strata in the study area are referred to as the Canyon Range Formation with two mappable units, Unit A and Unit B. Locations of measured sections are indicated on figure 2, and photographs of section traverses are found in figures 3 and 4.

Distinguishing Characteristics

Unit A and Unit B are considerably different in conglomerate clast composition and size; in percentage of interbedded sandstone, shale, and limestone; and, as a result, in the topographic expression.

Unit A is essentially all conglomerate strata with rare occurrences of sandstone and silty limestone. Clast composition (fig. 5) is significantly different from Unit B in that clasts derived from Precambrian quartzite constitute a majority of the conglomerate composition. In the center of Unit A, conglomerate units have clasts of Paleozoic carbonate origin, but it is significant that these are mainly dolomite clasts, whereas those in Unit B are essentially all limestone clasts. Clast sizes are consistently much larger than those in Unit B, and in the upper third of the unit, clasts average 30 cm in diameter, with the maximum observed clast size being 2.5 m long. Topographically, Unit A is very resistant, and conglomerate units composed of quartzite clasts commonly form precipitous cliffs and ledges (fig. 6). Numerous covered slopes do occur, and they are littered with Precambrian boulder rubble.

Unit B is a completely interbedded sequence of conglomerate, sandstone, fine clastics, and limestone strata (fig. 5). Conglomerates in Unit B are composed of clasts almost exclusively pebble-size and essentially all of Paleozoic limestone origin. A maximum of 10-15 percent quartzite clasts of a basal Cambrian origin occur throughout the section. Maximum clast sizes average about 7.5 cm, with the largest clast measured being 18 cm across. The presence of interbedded sandstone, fine clastics, and limestone in Unit B distinguishes it from the massive conglomeratic sequence of Unit A. The interbedded limestone generally is micritic and rarely oncitic; it indicates a much quieter, lower-energy depositional environment than that represented by Unit A. Figure 4 shows the location of the measured section Unit B and also the typical subdued topographic expression.

Boundary Relationships

The reference section for Unit A starts at a quarry approximately 1.6 km south of Cow Canyon. Here the base is not exposed, and the section starts at the first outcrop above allu-
Figure 4.—Low-angle air photograph facing west at ridge with location of measured section of Unit B. Note topographic expression of Unit B compared to that of Unit A, figure 6.

Figure 5.—Detailed columnar sections showing variations in clast size, clast composition, presence of sedimentary structures, paleoecology, and paleocurrent direction indicators. Figure on facing page.
vium. The top of the measured section of Unit A is at the fault contact of the Canyon Range thrust. Most of Unit A dips only 5–10° east with some steepening along the thrust due to drag.

Unit A is seen to lap out against undifferentiated Paleozoic carbonates in Little Oak Creek Canyon (fig. 7) in an apparent depositional contact with up to 180 m relief. On the allochthonous plate, patches of Unit A are preserved. North of Oak Creek summit, Unit A (fig. 8) conglomerates which dip gently south (less than 10°) rest unconformably upon the allochthonous west-dipping Precambrian. Apparently only very minor movement along the thrust occurred after deposition of the upper Unit A, for similar units of Unit A juxtaposed on opposite sides of the thrust show only minor differences in structural attitudes.

The reference section for Unit B was measured west to east along a ridge with the base of the section starting at the base of a steep, covered slope (fig. 2). Dip attitudes are fairly constant at 20–30° east. Unit A is exposed at the top of the covered slope. The contact relationship at the base of Unit B is not clear because of a covered slope; however, a similar east dip in both units suggests the contact is either slightly angular or conformable. Christiansen (1952) considered this the relationship in his work. A second possibility and modification of the first is to project a normal fault through the covered slope between Unit A and Unit B. This possibility is in keeping with Christiansen’s mapped normal faults on his geologic map. Figure 9 is Christiansen’s geologic map with the present units applied. The upper contact of Unit B in the study area is at the east edge of the ridge where strata dip below alluvium (figs. 2 and 9). It seems likely that the eastward extent of this ridge and thus of the section is controlled by normal faults. On the ridge north of Wide Canyon (out of the study area), Unit B and younger strata are exposed in a more complete section than measured in the study area.
Extents

Units A and B of the Canyon Range Formation are useful, mappable units for study in the entire Canyon Range. Unit A is typically what is thought of as the classic "Canyon Range Conglomerate or Indianaola" of the Canyon Range. It is exposed widely throughout the entire "Indianaola" outcrop area. Unit A most certainly corresponds with Christiansen's lower and middle units (p. 725) of the "Indianaola." Unit B can easily be projected to the ridge north of Wide Canyon where a more complete section is present. This corresponds to Christiansen's (p. 725) upper unit of the Indianaola Formation.

Regional Correlations

Unit A of the Canyon Range Formation is most likely a Price River-North Horn equivalent and correlates well with lithologies in the Long Ridge and the Pavant Range. Unit B definitely correlates with the North Horn-Flagstaff Formations as seen in the Long Ridge, the Valley Mountains, and the Pavant Range, instead of the Indianaola as previously mapped.

Although the contact between Unit A and Unit B is covered, Unit B most likely conformably overlies Unit A. Assuming this relationship, reasonable correlations can be made. Beneath the sandstones, shales, and limestones (some oncotic) of the North Horn Formation in the Pavant Range are massive conglomerates of the Price River Formation. Lithologically the conglomerate clast composition and sizes are identical to those in Unit A of the Canyon Range Formation. Tectonic trends shown by Hickcox (1971) would suggest an identical source for both areas to be from the Wah Wah-Canyon Range allochthon. In Long Ridge, the basal 137 m of the exposed North Horn Formation (Muesig, p. 72) is a conglomerate unit composed of basal Cambrian and Precambrian quartzite clasts. Gilliland (1948, p. 38) had previously called those conglomerates the Price River Formation in a reconnaissance study of Long Ridge. Regardless, these conglomerates at the base of the North Horn Formation (?) are probable equivalents to the uppermost strata of Unit A. Unit A of the Canyon Range Formation most likely is equivalent to the Price River-lower North Horn Formations.

Unit B has certain diagnostic lithologic types (i.e., limestone/oncocitic limestone) which are restricted enough stratigraphically in the vicinity to provide correlation with the North Horn to basal Flagstaff Formations. These lacustrine-fluvial facies seen in Unit B, together with the unquestionable gastropod shape seen in an oncotic, provide evidence that Unit B is genetically related to early Tertiary lacustrine and fluvial deposition. Exact correlation of stratum cannot be yet made with those in Long Ridge and Valley Mountains, but future work in the Canyon Range will make it possible.

Lithology

The Canyon Range Formation in the study area is composed of interbedded conglomerate, sandstone, limestone, and minor amounts of mudstone and shale. Compositional and textural differences in conglomeratic strata provide for easy distinction into two mappable units. The nonconglomerate strata, while volumetrically quite important, are seldom noticed in most casual observations amid the more resistant and prominent conglomeratic strata.

Conglomerate

Unit A

Conglomeratic strata in Unit A account for 390 of the 499-m measured section. Covered intervals, which are most likely conglomerates, would increase the total conglomerate thickness to 437 m. Figure 5 shows the variations in clast size and composition versus section thickness. Clast composition in Unit A grades upward from Paleozoic carbonates (with high percentage of dolomite) to essentially pure Precambrian quartzite clasts in the upper third of the section. The upper half of the section is extremely resistant and prominent, and because of its large areal extent, it has become the classic Canyon Range "Indianaola or fanglomerate."

The largest clast observed was 2.5 m long. It is composed of Precambrian quartzite and is found in subunit 21. Maximum clast sizes average from 7.5 to 15 cm near the base of the section to 30 cm in the upper half of Unit A. Conglomerate beds composed of Precambrian clasts consistently demonstrate the larger clast sizes and suggest a close proximity to the source. Clast texture tends to be quite variable throughout the section. However, as a generalization, the clast angularity and also lack of sphericity seem to be much more common higher in the section. Larger Precambrian clasts (greater than 30 cm) are much more rounded than the smaller cobble-size clasts. Clasts in Unit A are generally more angular and blocky than those in Unit B, and suggestive that relatively minor abrasion and transportation has taken place in an initial deposition cycle. Most conglomerates in Unit A are a framework type demonstrating point contact of clasts. A few of the subunits in the upper half of the unit have very angular and blocky clasts in a chaotic framework, suggesting very rapid deposition with little or no reworking of clasts and sediments.

Unit B

Conglomeratic sediments in Unit B account for 212 of the 537 m of a measured section. Figure 5 shows the variations in clast size and composition versus section thickness. Lower Paleozoic carbonate lithologies (dominantly limestone) of pebble size comprise 90-95 percent of the conglomerate clasts. White quartzite clasts, probably derived from the Tintic Formation or possibly from the Eureka Quartzite, seldom amount to 10 percent of the clast composition but commonly represent the largest clasts observed. The red, maroon, and tan-orangish white quartzite lithologies characterizing the Precambrian are extremely rare as clasts.

Maximum clast size observed was 13-15 cm but this size was rare. Most often the maximum clast sizes average 7.5-9 cm.
Figure 9.—Geologic map of study area.
Coarse-grained sand, relatively free of clay-sized particles. The conglomerates all demonstrate point contact of clasts, and the presence of floating clasts in a finer matrix was not observed. Matrix of the conglomerate beds is generally a medium- to coarse-grained sand, relatively free of clay-sized particles.

Because of the dominance of carbonate clasts, the overall conglomerate color is commonly light gray (N7) to yellowish-gray (SY 8/1). The conglomerate strata in the upper half of Unit B are very sandy, and the presence of this yellowish-orange to reddish-brown sand causes the conglomerates to appear yellowish-orange (10YR 8/6) to pale reddish-brown (10R 5/4).

Individual beds generally range from 1.5 to 6 m in thickness and very commonly average 3 m in the upper third of the unit. Contact relationships with underlying strata are rarely exposed. In a few locations conglomerates were seen to overlie calcareous sandstone or mottled, intraclastic limestone with a sharp contact and little evidence of channeling (fig. 10). Contacts with overlying sandstones and limestones are gradational over 3 to 30 cm. Individual beds are laterally quite persistent, and can be traced for 400 m on either side of the line of section before dipping under Recent alluvium.

Individual conglomerate beds are resistant and generally form low ridges or ledges (less than 2.5 to 3 m relief). However, the relatively thin beds (compared to Unit A), the interbedded limestone and the finer clastics, and the structural dip create a subdued topographic expression compared to the resistant and prominent Unit A (fig. 4).

Sandstone

Sandstone strata make up less than 10 percent of Unit A and about 25 percent of Unit B. Texturally and compositionally sandstones from both units are similar and generally reflect short transportational distances and lack of reworking.

Sandstones in Units A and B range from predominantly lithic arenites to quartz arenites; however, the majority would fall in the lithic category. Lithic fragments consist dominantly of limestone and dolomite sand grains probably derived from Paleozoic strata. In subunit 75 of Unit B, limestone fragments are as high as 60 percent of the total. The majority are probably from Paleozoic formations, but some oolites and algal laminites formed during deposition of Unit B were incorporated. Nearly all sandstone studied from Units A and B has highly angular grains, with subrounded to rounded grains being unusual. Sandstones are typically poorly sorted and well cemented with calcium carbonate cement.

There are considerable gradations in many of the sandstone and micrite beds of Unit B. Many of the sandstones are so calcareous as to approach a wackestone, and, conversely, micrites grade from pure calcium carbonate to sandstone-wackestone proportions.

Mudstone-Siltstone-Shale

The finer clastic lithologies are interbedded with conglomerates, sandstones, and limestones. They are typically slope-forming units and difficult to observe and measure accurately. All are highly calcareous and grade into both sandstone and limestone lithologies. They are commonly pale red, but also yellowish gray, pink, and purplish gray.

Carbonate Rocks

Interbedded with more resistant conglomeratic rocks of Units A and B are numerous carbonate subunits ranging from pure, porcelaneous-looking micrites to sandy, oncolitic limestones. Unit A contains at best 10 m of carbonate strata, whereas Unit B contains approximately 107 m.

Fine-Grained Carbonates

Between 92 and 107 m of carbonate strata in Unit A and Unit B are a very fine-grained carbonate lithology. These range from pure, porcelaneous-looking micrite or limy mudstone through terrigenous wackestone and eventually to calcareous sandstone and siltstones. Figure 11 is a terrigenous wackestone from subunit 27 of Unit B. This sample is typical of many of the fine-grained carbonate subunits although many have no terrigenous constituents. Typically these micrites or wackestones are varicolored, ranging from light to dark gray, yellowish gray, pale red, purplish red, and finally dark yellowish brown.

The pale red to purplish red lithologies are commonly extremely mottled and burrowed. Many of the fine-grained carbonate units in Unit B have the upper 1.5 to 3 m composed of pale red, mottled wackestone, although the reddish zones do occur throughout many units. Often these reddish zones are overlain by conglomerate strata (fig. 10); and it seems likely that these zones represent carbonate mudflat conditions which were subject to drying-out periods or low water stands. Fluc-

**Figure 10.** Contact of subunits 23 and 24 of stratigraphic Unit B. Conglomerate clast size and composition are typical for all of Unit B. Underlying unit is red, mottled, silty wackestone.

**Figure 11.** Thin section of silty, mottled wackestone from subunit 27 of Unit B.
tuation in water level is suggested by root growth, burrowing, and intraclastic nature in the red, oxidized zones.

Intraclasts are common in the fine-grained carbonates. In fact, they are fine-grained carbonates which were ripped up and redeposited in quieter water. Figure 11 displays this limeclast texture. This intraclastic nature is in large part responsible for the mottled surface texture of many of the units.

Many of the fine-grained carbonates with high percentages of detrital grains weather to give a sandy rind and are easily mistaken for sandstones. In many of the clean micrites (limy mudstones), a glassy conchoidal fracture is displayed.

**Oncolite Limestone**

At least two subunits in Unit B, totaling 14 m in thickness, are composed of oncolitic limestone, a unique Early Tertiary lithofacies in central Utah. At present, both subunits are termed oncolitic, but the differentiation has not been made between oncolites and rhodolites.

The majority of the oncolites were apparently carbonate-algal rich fluvial and/or lacustrine transported after formation in a purely (or nearly so) depositional setting and were finally redeposited with varying mixtures of sand, algal laminite fragments, and lime mud. Bissel (1977 pers. comm.) observed thin sections of oncolites from Unit B and verified the presence of algal material within the laminations. He thus supports the algal-carbonate origin for these oncolites rather than seeing them as nodules built up by caliche layers that are sometimes observed in alluvial fan deposits. Figure 12 is a thin-section photograph from subunit 71 of Unit B and is a typical example of a sandy, oncolitic limestone. Individual oncolites in both oncolite subunits range from peased to about 5 cm and commonly average about 2.5 cm in diameter.

With only one noted exception, all oncolites were formed around either indigenous algal laminite fragments or small pebbles of Paleozoic carbonate or quartzite. Figure 13 shows the one exception found. The elongate oncolite in the lower center of the photograph was undoubtedly cored by a gastropod. Weiss (1977 pers. comm.) observed thin section and noted that, while no shell material was present, the thin section was likely cut tangential to the shell, and only the algal-carbonate laminae around the shell are observed. The oncolite in the left center of the same plate shows the more typical occurrence of algal laminate fragments as oncolite nuclei. This sample's matrix and those in figures 12, 14, and 15 show a majority of the oncolite's nuclei and rock matrix to be composed of algal laminate fragments.

Figure 16 is a photograph of a single oncolite from subunit 71 of Unit B. This sample shows the excellent internal structure and near lack of detrital material characteristic of the individual oncolites in both units. As is obvious from the numerous thin-section photographs, detrital grains are essentially limited to the oncolitic limestone matrix.

**Algal Laminite Hash/Intraclastic Limestone**

Figure 17 is an intraclastic limestone from subunit 77 of Unit B with intraclasts composed of algal laminate fragments. Numerous oolitic grains are present, mostly abraded. The subunit varies between a mud and a grain-supported texture. These algal laminate hash limestones, while not volumetrically important, occur occasionally in the upper half of Unit B.

**SEDIMENTARY STRUCTURES**

Sedimentary structures and/or features are occasionally observable in both units of the Canyon Range Formation. These
are: (1) clast imbrication, (2) channeling, and (3) cross-bedding.

Clast Imbrication

Clast imbrication is rare in both units and thus did not serve as an important criterion for studying conglomerate units and associated paleocurrent directions. Clasts tend to be highly spherical, even in the large boulders of Unit A, and possibly because of this, imbrication was not well developed nor noticeable when present.

Channeling

Channels were observed in both units, but of different magnitudes. In Unit A, large channels (up to 3 m in relief) were seen in the more massive Precambrian clast conglomerates. Figure 18 is typical of a subunit with channels and is seen at the base of subunit 9, Unit A. The massive conglomerates in the upper third of Unit B display similar channeling.

From the exposures present, it appears most of the channels trend roughly west to east and were probably developed near the apex to midfan position in an alluvial fan depositional environment.
In Unit B, possibly because of the covered nature of many of the finer clastics and limestone, large channels were not observed. The evidence of erosion is seen more as scoured uneven surfaces developed on finer clastics and limestones. Maximum relief observed was on the order of 15 to 60 cm with the low areas being normally filled and overlain by pebbly conglomerates.

Cross-beds

Ripple-sized cross-beds (Hays and Kana, p. 1-8) were the dominant cross-bedding type observed in both units.

In Unit A, only one unit with cross-beds was noticed, and a paleocurrent direction to the northeast was indicated. Figure 19 illustrates ripple-bedded sandstones from subunit 92 of Unit B. Interspersed throughout the ripples in that unit are horizontally stratified plane beds. Figure 20 shows a thin section of a ripple-bedded sandstone from subunit 69 of Unit B with vertical burrowing developed. Paleocurrent directions from ripple cross-beds are fairly unidirectional in Unit B and vary within 10-15° of east.

PALEONTOLOGY

Previous work on the Indiana-North Horn sequence in the Canyon Range by Christiansen (1952, p. 725) encountered sections barren of all fossil remains. Christiansen’s (p. 725) purely lithologic correlations have been the subject of criticism by Armstrong (1968, p. 488).

The present study essentially substantiates Christiansen’s claim of unfossiliferous sections. While the area was not entirely barren, preserved megafossils proved to be extremely rare. The paleontologic evidence found was plagued with nondiagnostic samples due to poor preservation. In the case of trace fossils, which were sparse in occurrence, the even sparser mention of them in the literature of research dealing with fluvial and lacustrine trace fossils proved to be an annoying hindrance.

Invertebrate

Common to the lower Tertiary of central Utah are numerous continental and lacustrine mollusks, particularly gastropods (LaRocque 1960). One sample of oncolitic limestone found in subunit 71 of Unit B (fig. 13) contains an oncolite unquestionably cored by a gastropod. The peculiar shape of the gastropod is at once observed; however, no shell material is recognized in the thin section. Weiss (1977 pers. comm.) observed the thin section and noted that it had been cut tangentially to the shell surface and only recorded the carbonate laminae that coated the shell.

The presence of a gastropod in an oncolitic limestone is quite significant. Weiss (1969) documents the unique occurrence of oncolite-bearing strata in the lower Tertiary strata of central Utah and suggests that while oncolites are found in the North Horn, Flagstaff, and Colton formations, the presence of gastropod-cored oncolites is a singular feature found only in the Flagstaff Formation (p. 1110).

Paleobotany

Upper subunits of Unit B contain rare remains of iron-replaced twigs or fucoids and unrecognizable carbonaceous plant fragments. In subunit 92, a poorly preserved leaf fragment of the ‘fan’ palm *Sabalites* sp. was recovered by the writer and tentatively identified by Dr. W. Tidwell (1975 pers. comm.) of the Brigham Young University Botany Department. To date, it represents the only megafossil recovered with-
Thomas (1960) have since assigned the portion of the South Flat Formation containing the plant fossils to the underlying Indianola Member IV. Hays (p. 98) concludes that the Indianola Member IV is no older than a middle-Blackhawk equivalent and thus probably middle Montanian in age. Parker (1968) recovered two genera of palms, Sabalites montanus and Geonomites imperialis from the Middle Campanian Blackhawk Formation. Schoff (1951, p. 630) found unidentifiable palm fragments in the North Horn Formation in the Cedar Hills. In Long Ridge, Muesig (1951, p. 98) discovered a fragment of Sabalites sp. in the Sage Valley Limestone Member of the Goldens Ranch Formation. The plant assemblage recovered indicated an Eocene age about the same as, or younger than, the Green River Formation (Middle Eocene).

Present knowledge of the genera Sabalites in central Utah has it ranging from Middle Campanian to Middle Eocene. At present, the lack of species identification precludes more detailed comparison and biostratigraphic correlation and unfortunately neither changes nor confirms previous or new stratigraphic correlations.

Although not indicative of age, Sabalites is a good indicator of general paleoclimatic conditions. Parker (1969, p. 13) notes that Sabalites in extant floras are usually tropical to subtropical and range into the warm-temperate lowlands.

Approximately 12 samples from Unit B of the Canyon Range Formation were processed by Gulf Research and Development Company for pollen and spore content and age determination. Samples from subunits 29, 38, 69, and 77 gave reason for optimism that they might prove to be useful samples for the recovery of palynomorphs. All were dark gray to brownish black and seemed to indicate that there was a possibility of recovering samples not thoroughly oxidized in a section characterized by bright red oxidized strata. All the samples proved to be barren of microfloral forms. Griesbach (1974 pers. comm.) warned of the problem of barren samples and samples with poorly preserved forms as being a characteristic problem of the nonmarine Tertiary section of central Utah. Although unsuccessful in this study, this writer is of the opinion that palynomorphs still provide the best possibility for future biostratigraphic correlation of the Canyon Range Formation.

Ichnofossils

Rare occurrences of burrowing and trails are present in both units of the Canyon Range Formation. Samples were collected and submitted to C. Kent Chamberlain for identification and interpretation. Unfortunately, to date, very little research has been completed on fluvial and lacustrine ichnofossils, and little can be said of them, either as to the paleoecology or the etiological fauna. Research on nonmarine traces has shown that identification of the type of burrowing organism is difficult as many organisms produce similar burrows.

Several good examples of horizontal back-filled burrows were collected. Surprisingly, the best examples were found in fine-grained sediments amid the resistive and massive conglomerates of Unit A. Chamberlain (1976 pers. comm.) commented that "the backfilled burrows are quite striking and are similar to the marine traces such as Muensteria or backfilled Thalassinoides; however, the nature of the backfilling is peculiar to the nonmarine forms in that it is a blunt transverse fill and made up of small platelike appendages rather than the posterior (or anterior) of some marine worm. Most trace fossils made in nonmarine environments are made by beetles or other insects. Numerous families burrow and make similar burrows." Several of the subunits in both units contained simple linear forms, 2-3 mm across that Chamberlain (1976 pers. comm.) refers to as Planolites sp. Burrows were observed to be oriented horizontally, vertically, and obliquely in the samples. Figure 20 is a ripple-bedded sandstone with an example of Planolites sp.

Oncolites

Oncolites are being cited as a trace fossil. Although they are commonly referred to as algal balls, definitive algal remains in fossil oncolites are rare. However, algal remains have been observed by Bissell (1977 pers. comm.) in oncolites from Unit B. Sufficient modern examples have been presented in the literature to show the importance of algae in the formation of oncolites and thus warrant their classification as trace fossils.

Oncolites, when found in strata in central Utah, provide a good lithologic marker for distinguishing Lower Tertiary strata from Cretaceous strata. Nowhere in central Utah have oncolites been observed in Cretaceous or Jurassic strata (Weiss 1976 pers. comm.). The occurrence of oncolites in central Utah seems definitely related to the lacustrine-fluvial environments of the Paleocene and Eocene. To the knowledge of the writer, the only occurrence of oncolites in central Utah is found in Lower
to Middle Cambrian strata; Christiansen (1952, p. 723) notes its occurrence in the Ophir Formation.

In the vicinity of the study area, oncolites appear to be restricted to the North Horn and Flagstaff Formations and the “tawny beds.” Muessig (1951) found no oncolites in the North Horn, Flagstaff, or Colton Formations, but he did record (p. 76) the occurrence of wavy, stromatolitic Chlorolepis beds in the upper Flagstaff Formation. Lambert (1976) studied the Flagstaff and Colton (2) in the southern Long Bridge and noted algal micrite and pelletal limestone, but no oncolite beds. He did note that red, sandy oncolites are a characteristic feature of the North Horn Formation in the Long Bridge. Vogel (1957, p. 55) noted the presence of oncolites up to 15 cm across in the “tawny beds” east of the Sevier Bridge Reservoir. Tucker (1951) mapped the Scipio Quadrangle, in which the Flagstaff occurs only along the eastern edge in the western Valley Mountains, and there he found oncolites in the uppermost North Horn and lower Flagstaff formations. Gilliland (1951, p. 22), in the eastern Valley Mountains, found oncolites throughout the North Horn and in his basal Unit B of the Flagstaff (p. 89, 91, and 92). Lautenschlager (1952, p. 177) notes the presence of an oncolitic limestone bed near the top of the North Horn in the Pavant Range.

The occurrence of oncolitic strata restricted to the Lower Tertiary in central Utah provides a good marker for general correlation. Thus, Unit B of the Canyon Range Formation can be equated with the Lower Tertiary North Horn–Flagstaff Formations, and not to the Indianola Group as previously mapped.

INTERPRETATION OF CLIMATIC CONDITIONS AND SEDIMENTARY ENVIRONMENTS

Climatic Conditions

Few conclusions can be drawn from direct climatic indicators, and most conclusions are inferred from lithologies. The best direct indicator of climatic conditions during deposition of the Canyon Range Formation comes from the presence of the “fan” palm Sabalites found in subunit 92 of Unit B. Parker (1968, p. 13) indicates that extant floras of Sabalites live in tropical-subtropical to warm temperate conditions. These climatic zones are generally quite humid and warm.

From the carbonate strata observed in Unit B it seems apparent that abundant water was present to form the lacustrine or playa conditions. The presence of algal mat debris and oncolites seems to suggest that warm-water conditions existed. The presence of curved intraclasts of algal laminit fragments apparently suggests that desiccation of algal mats was common. Finally, the red, mottled zones within micrite and wackestone subunits are also suggestive that mudflats were periodically subjected to drying-out periods or low water levels.

Most of the conclusions are inferred, but it seems likely that, during deposition of the Canyon Range Formation, warm, humid conditions prevailed with abundant rainfall and occasional periods of drying out.

Sedimentary Environments

Unit A and Unit B of the Canyon Range Formation were deposited by processes characteristic of alluvial fans, braided streams, and fluvial and lacustrine environments.

Unit A

The massive conglomerates of Unit A display very few sedimentary structures that would be of help in interpreting the sedimentary environment, with the exception of channeling. However, from the essentially pure conglomerate nature of Unit A, its large clasts sizes, common clast angularity, and rare occurrences of floating clasts, and chaotic clast arrangement, it seems likely Unit A was deposited by alluvial fan processes very near the source (fig. 21). The source for a majority of the subunits in Unit A is the Precambrian of the Canyon Range allochthon. The source during formation of Unit A is essentially at its present exposures. Many beds of Unit A rest directly on the strata from which they were derived. Maximum clast sizes of 2.5 to 3 m in subunit 21 attest to the fact that clasts were not transported far to their present locations.

Large-scale channels, 2.5 to 3 m high, are present in many of the coarse conglomerate subunits and suggest that exposures of Unit A were deposited as alluvial fan deposits near the apex of the fan structures.

Unit B

Depositional environments and processes inferred to have been operative during deposition of Unit B were fluvial braided streams, coarse-grained meander belts, and lacustrine and/or playa conditions. Figure 5 indicates a general fining upward toward the upper half of Unit B. Although this change occurs in the measured section, it is somewhat synthetic and probably not representative of a true vertical section in any one place. Unit B was measured along a ridge (fig. 2) from west to east over a distance of 1.8 km. Paleocurrents also indicate clastic material was being shed from west to east. The writer suggests that as the section was measured toward the east going progressively higher stratigraphically, a facies change was also occurring from west to east. Coarse clastics predominated toward the west nearer the source and graded eastward into lacustrine deposition giving the interbedded conglomerate, sandstone, and limestone sequence seen in the measured section.

Conglomerates.—Conglomerates strata were probably deposited in the form of coalescing longitudinal bars in braided streams flowing toward the east. Individual conglomerate beds are fairly uniform in thickness and laterally very persistent. Pebble-sized clast in Unit B are characteristically well rounded and suggest continued abrasion. Most conglomerates in the lower half of the unit are remarkably free of sandstone lenses and have a minimum of sandstone matrix. Higher in the section (and farther toward the east), sand lenses are more frequent and conglomerates become very sandy. Many conglomerate subunits in Unit B overlie and are overlain by lacustrine carbonate strata (fig. 10). These conglomerates might well fit a fan-delta depositional model.

FIGURE 21.—Typical conglomerate unit (subunit 25) from stratigraphic Unit A. Clasts are composed of quartzite and Precambrian or basal Cambrian.
Sandstones.—Sandstones in Unit B were most likely deposited in a braided fluvial or coarse-grained meander belt and also in nearshore and/or beach environments on the western boundary of lacustrine deposition. Of the sandstones studied in thin sections, nearly all are lithic arenites, extremely angular and poorly sorted (fig. 22). Some of the subunits higher in the section (example: subunit 75) displayed better rounding and sorting and also included indigenous oolites and algal laminite fragments (example: subunit 75). These were interpreted as nearshore and/or lacustrine beach deposits.

Micrites and Wackestones.—Fine-grained carbonates are common in the upper part of Unit B and are interpreted as forming in a still-water, carbonate mudflat and/or playa depositional setting. Rivers and streams draining highlands to the west were undoubtedly charged with dissolved and suspended carbonate material being eroded from the Paleozoic sequence. These fine-grained carbonates vary greatly from pure lithographic-like micrite to detrital wackestone and hence to calcareous sandstones and siltstones; they reflect nearness to a fluvial or nearshore environment. Many of these fine-grained carbonates are intraclastic and reflect ripping up and redeposition of intraclasts by fluvial and/or nearshore processes. Numerous red, mottled zones are present at the top of fine-grained carbonate subunits and seem to reflect periods of aridity or drying up and subsequent burrowing and root growth.

Oncolitic Limestone.—Significant paleoecologic and paleo-geographic conclusions can be construed from the presence of oncolites. Weiss (1969) discussed the presence of oncolites in the North Horn, Flagstaff, and Green River formations and suggested their occurrence in association with rising tectonic elements. Citing previous work, Weiss (1969, p. 1115) concluded oncolites formed in agitated water less than 4 m deep. He also concluded that Paleozoic limestone strata were exposed in the surrounding hills of the Lower Tertiary lakes. Erosional processes provide the fine carbonate material used by algae in the construction of carbonate-algae framework in oncolites.

Whereas many of the oncolitic limestone samples collected in Unit B were observed to have sandy matrices, this was rarely the case with the individual oncolite. They seem to have formed in quiet water, free from the influx of detrital grains. Their spherical nature suggests that agitation and continual rolling occurred during their formation. Oncolites were formed either in isolated bodies of water, in slow-moving, carbonate-rich streams, or in an open lacustrine environment free from the influences of fluvial and nearshore processes. After formation, the oncolites were disturbed, subjected to varying degrees of abrasion and transportation, and redeposited with sand, algal laminite fragments, and lime mud.

The overall depositional setting of Unit A in the study area places it on the western margins of early Tertiary lacustrine environments. Clastics were derived from highlands a few kilometers to the west and transported by rivers to the carbonate-rich lacustrine waters eastward. The source for clastics was a Paleozoic carbonate terrain.

GEOLOGIC HISTORY AND STRUCTURAL DEVELOPMENT

During the Late Mesozoic, extensive orogenic activity was taking place in western Utah and Nevada, finally culminating in regional eastward thrusting of the Cordilleran geosynclinal strata over younger strata to the east. This activity is known as the Sevier orogeny (Armstrong 1968). In the Canyon Range, an allochthonous sheet of Precambrian quartzite is exposed over a Middle to Lower Paleozoic carbonate sequence. This allochthonous plate is called the Canyon Range thrust (fig. 24). It has been linked through different thrusts to the south of the Wah Wah thrust (Armstrong 1968, p. 437), and is called the Wah Wah-Canyon Range plate by Hickcox (1971, p. 59). The Canyon Range thrust rests on a sequence of Middle to Lower Paleozoic carbonates and basal Cambrian and Precambrian quartzite, which can be correlated structurally and stratigraphically to the Pavan Range allochthon to the south. Thus the Canyon Range thrust lies on top of the Pavan Range allochthon, which lies in thrust contact over the Jurassic Navajo Sandstone.

Clast lithologies in the Canyon Range Formation would suggest the possibility of correlating units to the structural de-
development of the range. Unit A is a sequence of massive conglomerates. Clast lithologies indicate in part a Paleozoic dolomite provenance, but the striking feature is the massive boulder conglomerates with Precambrian clasts. Unit A in places rests directly upon the allochthonous plate. There is no question that the conglomerates in Unit A were derived from the Precambrian-composed allochthonous plate. The large clast sizes (maximum 2.5 to 3 m) indicate that most of Unit A was transported for only short distances, less than 1 or 2 km.

With Unit B overlying Unit A, and Unit B is a good North Horn-Flagstaff Formation equivalent, Unit A must be North Horn or older. In the Pavant Range, lying unconformably above the Pavant Range thrust and conformably below the North Horn, are the massive conglomerates of the Price River Formation (?). The clast composition of the Price River in the Pavant Range displays clasts derived from the Cambrian Tintic and Precambrian quartzite formations (Lautenschlager 1952, p. 39), the same as Unit A of the Canyon Range Formation. The only likely source for the Precambrian clasts in the Price River of the Pavant Range was from Precambrian strata being unroofed on the Wah Wah-Canyon Range plate. Little doubt exists that Unit A and the Price River are genetically related and lithostratigraphically the same unit.

WEST

EARLY-LATE CRETACEOUS
Major Thrusting
Canyon Range Thrust
PALEOZOICS

LATE CRETACEOUS
Price River Deposition
P.R.

PALEOCENE-EOCENE
North Horn-Flagstaff Deposition

EAST

FIGURE 24.—Block diagram of study area showing paleoenvironmental and structural development of Canyon Range.
In the Canyon Range after major movement along the Canyon Range thrust had ceased, Unit A buried the trace of the Canyon Range thrust. Thus major thrusting in the Canyon Range can be said to have ended by Price River (?) time. Major folding of the allochthonous and autochthonous plates into the present synclinal structure occurred in the very last stages of major thrusting or after it had ended. This determination can be made from conglomerate bed attitudes in Unit A (fig. 25). Two km north of Oak Creek summit, the upper strata of Unit A are seen juxtaposed on opposite sides of the Canyon Range thrust with opposite, but gentle dips (less than 10°). To the north, at the head of Yellowstone Canyon (extreme upper left corner of fig. 9), beds equivalent to Unit A, the lower and middle "Indianola" units of Christiansen, are present in a tight syncline and are folded into a vertical position. These conglomerates lie with a gentle angular discordance on Cambrian-age strata. These vertical beds are not just a localized phenomenon, but are present in the entire north half of the range. Major folding occurred after Unit B was deposited and after it had covered the Canyon Range thrust.

Late folding and associated minor thrust movement along part of the Canyon Range thrust explains the problematic contact of the " Indianola" (Unit A) with the Canyon Range allochthon. Along the eastern flank of the range from the summit east of Dry Fork Canyon to the south end of the range, the thrust contact can be observed (figs. 26, 27, 28, 29). Between Dry Fork summit and the head of Wide Canyon, Christiansen was uncertain of the relationship and displayed it on his map as dashed. Christiansen notes (p. 731) the displacement along the thrust decreases from Cow Canyon to the summit east of Dry Fork Canyon where it is terminated by tear faults. North of Wide Canyon, Unit A (Christiansen's "Indianola") lies unconformably upon a lower Paleozoic sequence and is vertically folded. Folding is far more severe in the northern half of the range than it is in the southern half where the thrust is exposed. During the folding phase of the Canyon Range, the northern half of the range responded by tight overturning. Southward this compression folded the allochthon into a relatively gentle syncline and also caused minor movement along a reactivated thrust zone.

The amount of late-phase movement along the thrust can be estimated with a fair degree of certainty. By matching up apparently equivalent conglomerate beds on opposite sides of the thrust, measuring their vertical displacement, and assuming a 45° dip for the thrust plane (Christiansen, p. 730), an approximate horizontal displacement can be calculated. This was done for strata which are juxtaposed on opposite sides of the thrust just south of Cow Canyon. A minimum horizontal displacement along the thrust would be approximately 250 m (185 m vertical displacement of beds and 45° dip on thrust plane). Even if the dip of the fault is only 10°, maximum horizontal displacement would be on the order of 900 m.

Unit B, in this interpretation, covered Unit A with a sequence which changes facies from conglomerates at the west to...
FIGURE 26.—Thrust contact of Precambrian sequence with underlying Unit A. View facing north from Oak Creek summit.

FIGURE 27.—Thrust contact north of Cow Canyon; photograph facing north.
Figure 28.—Photograph facing southwest toward study area. Ridge in foreground is east-dipping strata of Unit B north of Wide Canyon. Unit A in the upper left-hand corner is gently east dipping.

Figure 29.—Photograph facing west at gently east-dipping strata of Unit A. Right center of photograph is same as upper left-hand corner of figure 28. Cow Canyon, right center.
interbedded conglomerates, sandstones, and limestones to the east. Unit B was deposited on the western fringes of North Horn-Flagstaff lacustrine deposition. The highlands to the west were much more subdued during deposition of Unit B, and this is reflected in small pebble clast sizes (fig. 5). The source for Unit B was now almost exclusively Paleozoic carbonates. Probable sources for clasts in Unit B were the vicinity around the present Gibson Mountains, the area west of the Canyon Range, or possibly erosion of exposed Paleozoic under the eroded alluvial conglomerate plate.

Stratigraphically below Unit A a very thick conglomerate sequence should exist composed of Paleozoic and Mesozoic clasts. These would have been unroofed from the allochthonous plate prior to exposure of Precambrian strata. Such a thick sequence representing the erosional debris of the whole Paleozoic-Mesozoic column is not represented in the Canyon Range. However, the uppermost portion of this suggested sequence may be represented by the lower half of Unit A, or Christiansen's lower unit of the "Indianola," as seen in Yellowstone Canyon. This sequence would be pre-Price River in age, and is probably represented to the east of the Canyon Range by the carbonate-clast conglomerates of the Indianola in the Gunnison Plateau.

The timing of folding in the Canyon Range and deposition of Unit B is at present uncertain. Later block-faulting during the Middle to Late Tertiary uplifted the buried Canyon Range allochthon, and subsequent erosion has dissected and exposed the Precambrian and thrust fault relationships.

CONCLUSIONS

The Canyon Range Formation (informal new name), formerly referred to as the Indianola Group, represents a Late Cretaceous-Paleocene alluvial fan sequence and an overlying sequence of interfingering fluvial and lacustrine strata deposited near the western margin of early Tertiary lacustrine deposition.

The Canyon Range Formation is divisible into two distinct mappable units, A and B. Unit A is nearly all conglomerate strata, and conglomerate texture and sedimentary structures suggest an alluvial fan depositional environment. Precambrian and basal Cambrian quartzite clasts represent the erosional debris from the allochthonous Canyon Range thrust. Unit B is composed of interbedded fluvial sandstones and conglomerates with lacustrine limestones, commonly micritic and/or oncotic. Conglomerate clasts indicate a Paleozoic carbonate provenance.

Unit A, also previously mapped as the Indianola, most likely underlies Unit B and correlates with the Price River Formation (?) of the Pavant Range. Marginal paleontologic and stratigraphic indicators suggest Unit B to be a Paleocene-Eocene North Horn or Flagstaff Formation equivalent, rather than the Cretaceous Indianola group (fig. 30). Stratigraphic and structural relationships indicate the last major phase of Sevier thrusting ended by Price River (?) time.

The Canyon Range offers many possibilities for future research work. Important areas that might be considered are (1) in the tight fold in the north half of the range where a possible unmapped thrust fault occurs; (2) the contact between Unit A and Unit B on the ridge north of Wide Canyon; (3) the questionable contact between Unit A ("Indianola") and the thrust sheet between Dry Fork Canyon and the head of Wide Canyon; (4) the Unit B section north of Wide Canyon with more emphasis on basin analysis; and (5) at the extreme north tip of the range, the contact relationships of conglomerates with the underlying allochthonous plate and the overlying, yet unstudied, volcanics.

The appendix to this paper, manuscript pages 49-62, measured stratigraphic sections of units A and B, is on open file in the Geology Department, Brigham Young University, Provo, Utah 84602, where a Xerox copy may be obtained.

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APPENDIX

Measured Section of Unit A of the Canyon Range Formation

Beginning at the basal conglomerate outcrops 15 m downhill (east) from a flagstone quarry located 1.2 km south of Cow Canyon. The section is measured westward up the steep eastern flank of the Canyon Range to the contact with the Canyon Range Thrust (Plate 1, Fig. 1). Red and maroon quartzites and shales are exposed at the base of the allochthonous plate.

<table>
<thead>
<tr>
<th>Unit</th>
<th>Description</th>
<th>Subunit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Description</td>
<td>Metres</td>
<td>Metres</td>
</tr>
<tr>
<td>CANYON RANGE THRUST (Precambrian quartzites and shale)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Conglomerate, cobble and boulder clasts, average 15 - 20 cm., larger</td>
<td>47.3</td>
<td>499.3</td>
</tr>
<tr>
<td></td>
<td>clast size are rounded while smaller clast size are subangular to subrounded.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clast composition: 80-90% Precambrian-basal Cambrian quartzites (probably</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mutual Formation predominantly), 10-20% Paleozoic limestone clasts. Quartzite</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>are purple, striped red or purple and white, dark red, predominantly.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Some of the Paleozoic limestones are fettled and occasionally contain</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>lenticular black chert. Maximum clast size is 91 cm. (quartzite).</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Conglomerate contains very little sand matrix. Unit is very massive bedded</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>and is exposed as cliffs.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Conglomerate, very coarse pebble to small cobble clast size, average clast</td>
<td>15.3</td>
<td>452.0</td>
</tr>
<tr>
<td></td>
<td>size is 6.4 cm., maximum clast size is 30 cm. Color is predominately grayish</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>orange pink (10R 8/2) resulting from the fine to coarse grained, sandstone</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>matrix is only slightly calcareous. Clast composition: 60% siltstone, dark</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>yellowish brown (10YR 4/2) to light olive gray (5Y 5/2); 40% quartzite,</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>grayish orange pink (10R 8/2); (probably basal Cambrian or upper Precambrian).</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Most clasts are subangular to subrounded, blocky to rectangular.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unit 24 is mainly a covered slope interval with rare outcrops.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Conglomerate, cobble and boulder clasts, average clast size is 25-30 cm.</td>
<td>35.1</td>
<td>436.7</td>
</tr>
<tr>
<td></td>
<td>Maximum clast size ranges from 1 m. in the lower half of the unit, to 75 cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>in the upper half of the unit. Clast composition: 95% quartzite clasts</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(probably predominantly Precambrian Mutual Formation).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Sandstone, medium to coarse grained, very hard, quartzitic to very</td>
<td>1.5</td>
<td>401.6</td>
</tr>
<tr>
<td></td>
<td>slightly calcareous, pale reddish brown (10R 5/4) to pale yellowish orange</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(10YR 8/6). Contacts with upper unit is sharp and lower unit grades into Unit 22. Unit 22 is a very good marker bed, and can be traced on air photographs for 3.2 to 5 km.

Conglomerate, cobble and boulder clasts, average clast size is 30 cm. Maximum clast size is 25m (0 399m - rounded, oblong Precambrian quartzite). Upper 3m of unit is composed 30-50% of quartzite boulders 1.2-1.5m long. Clasts composition 95% quartzite, varicolored (Precambrian and basal upper massive conglomerates are channeled into lower conglomeratic mudstone. Mudstone has pale reddish brown (10R 5/4) clayey matrix.

Covered Interval - slope littered with Precambrian boulders, and cobbles.

Conglomerate, pebbles, very sandy and silty. Clast composition at base: 35% Paleozoic limestones (commonly black, fetid), 35% white quartzite, 15% black chert, 15-20% calcareous sandstone to sandy limestone, clast composition grades upward until top third of unit averages 95% limestone clasts (black, fetid, some containing fusulinids), 5% white quartzite. Clast size is bimodal, near base, 30% of clasts are 10-12.5 cm diameter. 70% average about 1.9 cm diameter. Top third of unit 20% of clast range from 5-13 cm diameter. Maximum clast size at base and top is 20 cm and 30 cm respectively. Matrix throughout unit is medium to coarse sandstone, moderate red (5R 4/6) to moderate reddish brown (10R 4/6), occasional 7.5-10cm sandstone stringers, medium grained, color same as matrix, throughout unit.

Covered Interval - probably same as Unit 19

Limestone, very silty, mottled appearance due to burrowing, predominant color is grayish orange pink (5YR 7/2). Burrows infilled with fine to medium sand, pale red (5R 6/2). Unit is laterally discontinuous. In part, unit is pebbly, with clasts averaging 6mm diameter. Clasts are Paleozoic limestones. Burrows are highest noted in section.

Conglomerate, pebbly, average clast size is 1.3 cm diameter, maximum clast size is 10 cm, bimodal with small fraction 6-12mm in diameter, and large fraction averaging 1.9-10 cm diameter. Clast composition: 50% dolomite, 15% limestone, 35%
Precambrian and basal Cambrian quartzite. Matrix average 20-40% of sample, and is very poorly sorted, fine sand to grit. Sandy matrix is pale red (10R 6/2) and appear derived from Precambrian quartzite. Sandstone lenses, 7.5-10 cm thick of pale red (10R 6/2), medium to coarse sand are common throughout the unit. Unit 16 is generally poorly exposed with rare scattered outcrops.

15 Sandstone, fine to coarse grained, poorly sorted yellowish gray (5Y 7/2) to pale red (10R 6/2), mottled in places, pebbly sandstone lenses with limestone-dolomite clasts.

14 Covered Interval

13 Conglomerate, pebbly, generally bimodal with 75-80% clasts average 3-12 mm, 20-25% clasts 2.5-15 cm in diameter. Maximum clast sizes are 41 cm, 15 cm, 25 cm at the base, middle and top of the unit, respectively. Clast composition is 85-100% Paleozoic dolomite, 0-15% Precambrian quartzite. Precambrian clasts seem to average 9-12 mm diameter, whereas the dolomite clasts account for most of the larger 2.5-10 cm fraction. Six meters above base of unit is 30 cm sandstone stringer, burrows 2.5 cm across. Clasts are generally very tightly packed with less than 10% matrix. Matrix is pale red (5R 6/2) sandstone composed dominantly of sand and quartzite grains from Precambrian quartzite. At 201 m, matrix seem to be all yellowish gray (5Y 7/2) micrite with little sand.

12 Limestone, slightly sandy with very fine sand finely crystalline, very firm, pinkish gray (5YR 8/1). Upper contact is sharp, lower contact was minor 12-15 cm channels or depressions cut into underlying conglomerate. Unit 12 is discontinuous and lenses out 30 m south from line of section.

11 Conglomerate, pebbly, clasts coarsens upward from 6 mm average at base to 1.9 cm average at top, clasts are angular Paleozoic limestones and dolomites. Maximum clast size is 10 cm (white quartzite). Numerous thin 7.5-12 cm lenses of pinkish gray (5YR 8/1) to light brownish gray (5Y 6/1), very fine grained, calcareous sandstone occur throughout unit.
10 Sandstone, fine to coarse grained, moderate red (5R 5/4), rough paleocurrent direction at 151 m from low angle cross beds is N 25° E. Occasional horizontal and vertical burrowing noted at 151 meters.

9 Sandstone, coarse to grit grain size with some siltstone to fine sandstone streaks, grayish orange pink (5YR 7/2) to grayish red purple (5RP 4/2) common lenses of pebbly conglomerate, clasts are essentially all Precambrian quartzite at base ranging to nearly pure limestone-dolomite at the top of the unit. Unit represents transition from Precambrian clast conglomerates below to dolomite - limestone clast conglomerates above. Horizontal burrowing noted at top of unit.

8 Conglomerate, cobble and boulder clasts, composed entirely of Precambrian quartzite clasts, majority clasts greater than 10 cm, maximum clast size is 1.4 m diameter. Unit is poorly exposed.

7 Sandstone, fine to coarse grain, poorly sorted, moderate red (5R 5/4) to pale reddish brown (10R 5/4), calcareous, occasional thin lenses 5-12 cm of pebbly sandstone and conglomerate, small pebble clasts of Paleozoic limestone and dolomite averaging 9-12 mm diameter. Maximum clast size is 1.9 cm. Unit is predominantly a slope former.

6 Conglomerate, pebbly, bimodal clast size, 9 mm and 1.9 cm, maximum clast size is 3.8 cm, clasts are Paleozoic limestone, matrix is moderate red (5R 4/6), silt to very coarse sandstone, over-all color is light gray (N-6) to moderate red (5R 5/4).

5 Sandstone, very fine to fine grain, moderate red (5R 5/4), calcareous, grades into shale below, upper contact with Unit 6 is gradational over 10-15 cm.

4 Shale, flaggy, thinly laminated, very hard, moderate red (5R 5/4) to pale red (10R 6/2), thin interbeds of moderate red (5R 5/4) fine sandstone, unit becomes sandier at base, occasional interbeds of micrite, pale red (10R 6/2) to grayish red purple (5RP 4/2), very hard, horizontal worm-like trails 2 mm wide on micrite bed. (Unit 4 located at quarry).

3 Conglomerate, pebble to boulder, clast composition is 95% limestone and 5% quartzite, maximum clast size is 20 cm, generally bimodal with 2.5 cm and 7.5-10 cm average clast sizes. Over-all color
is grayish yellow, 7.5-10 cm sandstone lenses, yellowish gray (5Y 7/2). Matrix is medium to coarse sandstone, with color as lenses. Unit is poorly exposed.

2 Shale and limestone, interbedded flaggy, thinly laminated, very hard, shale is moderate red (5R 5/4) to pale red (10R 6/2), limestone is pinkish gray (5YR 8/1) with pale red (10R 6/2), streaks, very finely crystalline to micritic, varve-like laminations.

1 Conglomerate, pebble and cobble clasts, bimodal with sizes averaging 2.5 cm and 7.5-10 cm, respectively, clast composition is 95% dolomite and limestone, 5% white quartzite, over-all color is grayish yellow (5Y 8/4), unit is poorly exposed.

Alluvium - Base of section
Measured Stratigraphic Section of Unit B of the Canyon Range Formation

This section was measured on a west-east trending ridge located 1600 m north of Cow Canyon. The section begins at the base of a steep slope where the ridge projects out from the mountain front (Fig. 2). Unit 1 is the base of the section.

<table>
<thead>
<tr>
<th>Subunit</th>
<th>Description</th>
<th>Subunit Metres</th>
<th>Total Metres</th>
</tr>
</thead>
<tbody>
<tr>
<td>95</td>
<td>Oncolitic limestone, light olive gray (5Y 6/1) to medium gray (N5), average oncolite size is 6 mm, maximum size is 3.2 cm diameter, slightly sandy matrix.</td>
<td>7.6</td>
<td>536.8</td>
</tr>
<tr>
<td>94</td>
<td>Conglomerate, pebbly, bimodal with 1.3 cm and 5.0-6.5 cm average clast sizes, maximum clast size 7.5 cm. Clast composition: 95% Paleozoic limestone, 5% white quartzite (probably Tintic). Matrix is medium to coarse, moderate red (5R 5/4) sand. Contact gradational with overlying unit.</td>
<td>3.05</td>
<td>529.1</td>
</tr>
<tr>
<td>93</td>
<td>Sandstone and siltstone, thin interbedded, slightly calcareous, pale, reddish brown (10R 5/4), abundant root impressions in siltstone, 1.3 cm diameter vertical burrows.</td>
<td>4.6</td>
<td>526.1</td>
</tr>
<tr>
<td>92</td>
<td>Sandstone, very fine to medium grain, moderate red (5R 5/4) to pale reddish brown (10R 5/4). Low-angle ripple cross-bedding common, direction of transportation approximately N90°E. Palm leaf fragment Sabalites Sp. found at 517 m.</td>
<td>6.1</td>
<td>521.5</td>
</tr>
<tr>
<td>91</td>
<td>Sandy micrite to calcareous mudstone, grayish orange (10YR 7/2) to yellowish gray (5Y 7/2), poorly exposed. Rare micrite intraclasts in sandier lithology.</td>
<td>4.6</td>
<td>515.4</td>
</tr>
<tr>
<td>90</td>
<td>Conglomerate, pebbly, bimodal with average clast sizes of 1.3 cm and 5-6.5 cm. Maximum clast size is 7.5 cm (Paleozoic limestone). Matrix is medium gray, moderate red (5R 5/4) sand. Clasts are essentially all Paleozoic limestone.</td>
<td>3.05</td>
<td>510.8</td>
</tr>
<tr>
<td>89</td>
<td>Sandstone, medium to coarse grain, calcareous, yellowish gray (5Y 7/2) to pale red purple (5RP 6/2).</td>
<td>1.5</td>
<td>507.8</td>
</tr>
<tr>
<td>88</td>
<td>Conglomerate, pebbly, average clast size 1.3-1.9 cm maximum clast size is 6.5 cm 95-98% of clasts are Paleozoic limestone, Pale reddish brown (10R 5/4) coarse sand matrix.</td>
<td>2.4</td>
<td>506.3</td>
</tr>
</tbody>
</table>
Sandstone, medium to coarse grain, calcareous, yellowish gray (5Y 7/2).

Conglomerate, pebbly, bimodal with 1.3 cm and 4-7.5 cm average clast sizes. Matrix is coarse, yellowish gray (5Y 7/2) sand. Clast composition 90-95% Paleozoic limestone and 5-10% white quartzite (Tintic).

Sandstone, medium to coarse grain, yellowish gray (5Y 7/2), calcareous.

Conglomerate, pebbly, average clast size is 1.3-1.9 cm essentially all Paleozoic limestone clasts, basal contact with limestone sharp.

Micrite and sandstone, base and top of unit are terrigenous micrite, pale red (5R 6/2) with minor yellowish gray (5Y 7/2) mottling, intraclastic. Middle 4.6 m of unit is yellowish gray (5Y 7/2), fine to medium grain, calcareous, sandstone.

Conglomerate, pebbly, average clast size is 1.3-1.7 cm, maximum clast size is 5 cm, 85-95% of clasts are Paleozoic limestone, quartzite clasts are white, Tintic looking.

Sandy micrite, occasional very fine sandstone beds, unit color is yellowish gray (5Y 7/2), unit poorly exposed.

Sandstone, fine to medium grain, calcareous, grayish pink (5R 8/2) to pale reddish brown (10R 5/4).

Sandy Micrite, predominantly yellowish gray (5Y 7/2), weathered surface has etched appearance and in places weathers to sandy external rind.

Conglomerate, pebbly, average clast size at base is 3.05 cm, clast size upward to 6 mm average at top of unit. Maximum clast size 6.5 cm (white quartzite). Matrix is moderate reddish orange (10R 6/6), coarse sand.

Interbedded micrite, intraclastic limestone and sandstone; micrite is pure to silty, yellowish gray (5Y 7/2) to olive black (5Y 2/1); sandstone, fine to medium grain, very calcareous, light olive gray (5Y 5/2); intraclastic limestone, ALgal (?) laminite intraclasts, 1/2 - 2 mm diameter, medium olive gray (5Y 5/1) to olive gray (5Y 4/1).

Covered interval - very poor exposures. From rare outcrops interval lithology is probably dominantly sandstone like underlying unit, with occasional mottled reddish micrite patches.
75 Sandstone, medium grain, very calcareous, yellowish gray (5Y 8/1) to light olive gray (5Y 6/1). Some of quartz grains have rounded frosted surface texture.

74 Conglomerate, very sandy, pebbly, average clast size is 1.3-1.9 cm. Maximum clast size is 4.5 cm (white quartzite), 90-95% of clasts are Paleozoic limestones.

73 Sandstone, fine to medium grain, calcareous, pale reddish brown (10R 5/4) to yellowish gray (5Y 7/2).

72 Micrite, sandy, yellowish gray (5Y 7/2) to light olive gray (5Y 5/2) basal 60 cm is mottled pale red (5R 6/2) to moderate red (5R 5/4).

71 Oncolitic limestone, average oncolite size 1.9 cm diameter, maximum size 4 cm micrite texture, occasional small pebble nuclei of quartzite or limestone, generally most oncolites have algal (?) laminate fragments as nuclei.

70 Conglomerate, very sandy, pebbly, clast composition predominantly Paleozoic limestone clasts, less than 10% quartzite clasts, grades into overlying oncolitic limestone over 15 cm.

69 Sandstone, very fine to medium grain, silty, clayey, 14.6 laminations, 15 cm carbonaceous sand is with poorly preserved plant fragments in center of unit. Unit color grayish orange pink (5YR 7/2) to pale red (10R 6/2), horizontal stratification on top of carbonaceous sandstone, occasional biogenic and burrowing structures, small scale ripple crossbedding, common giving rough paleocurrent direction of 110-120°.

68 Conglomerate, pebbly, clast composition: 90% Paleozoic limestone, 10% quartzite, clast size at base averages 6-12 mm diameter, bimodal in middle and upper portion of unit with 2.5-4 cm and 6-12 mm clast sizes. Abundant coarse sand to grit matrix. Maximum clast size: 7.5 cm (white, vitreous quartzite), unit grades into overlying unit over 7.5-10 cm.

67 Sandstone, coarse to very coarse grained, good sorting, grains subangular to subrounded, color is pale red (5R 6/2) weathered to grayish orange pink (5YR 7/2)-fresh calcareous.

66 Conglomerate, pebbly, clast composition: 90-95% Paleozoic limestone clasts, 5-10% quartzite, average clast size is 2.5 cm maximum clast size is 7.5-10 cm (quartzite), thin stringers of sandstone in upper half of unit, medium to very coarse grained, pale red (5R 6/2), basal contact with underlying unit is sharp.
Interbedded micrite, mudstone, and sandstone, dusky yellow (5Y 6/4) to grayish orange (10YR 7/4)-fresh, pale yellow orange (10YR 8/6) to yellow gray (5Y 7/2) weathered, micrite and mudstone samples have etched surface texture, micrite is silty, pale red purple (5RP 6/2) mottled micrite bottom 1.5 cm of unit.

Conglomerate, pebbly, average clast size is 2.5 cm 3.05 maximum clast size is 10 cm (white quartzite, orange stained), clast composition: 90-95% limestone, 5-10% quartzite.

Limestone, micritic to finely crystalline, silty, etched surface texture, moderate yellowish brown (10YR 5/4)-micrite to yellowish gray (5Y 7/2)-finely crystalline limestone, samples dissolve leaving small residue of silt.

Conglomerate, pebbly, average clast size 1.3-1.9 cm 2.4 D., maximum clast size is 7.5-10 cm (white quartzite). Clasts are rounded and spherical. Unit is very sandy yellow-orange matrix, coarse grained sand. Clasts are essentially all Paleozoic limestone.

Sandstone, medium to very coarse grained, horizontal 2.7 lamination due to grain size gradation, well-sorted, color pale reddish brown (10R 5/4)-weathered to grayish pink (5R 8/2)-fresh.

Conglomerate, pebbly, average clast size is 1.3-1.9 3.4 cm, maximum clast size is 7.5 cm (quartzite), conglomerate is very sandy, occasional thin lenses of sandstone, medium to very coarse, pale reddish brown (10R 5/4), essentially all Paleozoic limestone clasts.

Sandstone and micrite, grades from very fine grained 8.2 sandstone, very calcareous, at base up into micrite, slightly sandy. Sandstone is grayish orange (10YR 7/4) to moderate yellowish brown (10YR 5/4) with some pale reddish brown (10R 5/4) patches grading upward into medium gray (N5) slightly carbonaceous sandstone Micrite is light olive gray (5Y 6/1).

Conglomerate, pebbly, average clast size is 1.3-1.8 2.4 cm, maximum clast size is 7.5 cm (white quartzite), very sandy.

Sandstone, fine to very crs. grained, horizontal lamination due to grain size gradations, light brown (5YR 5/6) to pale reddish brown (10R 5/4) weathered, fresh-pale grayish pink (5R 8/2).

Mudstone to fine sandstone, predominantly grayish orange (10YR 7/4) to pale yellowish orange (10YR 8/6), slightly calcareous, unit poorly exposed, top 1.5-3 m.
mottled pale red purple (5RP 6/2) to pale red (5R 6/2). National Forest fence crosses at saddle in ridge in middle of unit.

55 Conglomerate, pebbly, bimodal, average clast size 3.05 282.2
is 1.3-1.9 cm, maximum clast size is 10 cm (lime-
stone), clast composition, 85% Paleozoic limestone,
15% quartzite (white), quartzite clasts average
2.5-5 cm, unit is fairly sandy.

54 Micrite, mottled, slightly sandy, yellowish gray
(5Y 7/2) to pale reddish brown(10R 5/4)

53 Conglomerate, sandy, pebbly, bimodal, 80% clasts
2.5-5 cm, 20% clasts 6-12 mm, clast composition:
85-90% Paleozoic limestone, 10-15% quartzite (white
with few rare red precambrian clasts); matrix is me-
dium to coarse grained sand, grayish orange (10YR
7/4), thin sandstone lenses throughout unit.

52 Sandstone, coarse grained, grayish orange (10YR
7/4), smallscale ripple cross-beds, approximate
direction of transportation is S 75 E.

51 Conglomerate, same as conglomerate unit above.

50 Mudstone, very calcareous, yellowish gray (5Y
7/2)-weathered, slightly darker on fresh surface,
contact between overlying conglomerate and calcar-
eous mudstone is fairly sharp with only minor chan-
neling.

49 Micrite, mottled, intraclastic, slightly terrigenous 3.05 258.8
with silt and fine sand, dusky yellow (5Y 6/4) with
minor grayish red (5R 4/2) staining on fresh surface,
mottled pale red (10R 6/2) and grayish yellow (5Y 8/2)
on weathered surfaces.

48 Mudstone, same as mudstone unit above.

47 Sandstone, coarse grained, pale reddish brown
(10R 5/4), poorly sorted, calcareous.

46 Conglomerate, pebbly, clast size grades from 2 cm
average at base to 1.3 cm average at top of unit
clast composition: 85-95% Paleozoic limestone, 5-
10% white quartzite; possible large megaripples pre-
sent at base of unit oriented west-east.

45 Micrite, slightly terrigenous with sand and silt,
dusky yellow (5Y 6/4), top 1.5 m of unit is mottled
with pale red (10R 6/2).

44 Conglomerate, pebbly, clast size averages 2 cm
1.5 239.6
maximum clast size is 5-6 cm (white quartzite), nearly all clasts are Paleozoic limestone.

43 Mudstone to sandstone, yellowish gray (5Y 7/2), very calcareous, sandstone is fine grained.

42 Conglomerate, pebbly, 7.5-12 cm sandstone lenses at base, top 15cm grades into medium to coarse grained sandstone, essentially all clasts are Paleozoic limestone.

41 Mudstone to sandstone, as in unit above, apparent massive bedding.

40 Covered Interval - probably mudstone lithology.

39 Conglomerate, pebbly, average clast size 1.3-1.9 cm, maximum clast size 6.5 cm (white quartzite), clast composition: 95% Paleozoic limestone, 5% white quartzite, matrix is medium grained sandstone, calcareous, yellowish gray (5Y 7/2).

38 Micrite, traces of terrigenous material at base grading up into slightly silty and sandy micrite, color at base is patchy ranging from yellowish gray (5Y 8/1) to medium olive gray (5Y 5/1); yellowish gray at top of unit. Micrite is dense and hard.

37 Conglomerate, pebbly, sandy, clast size averages 1.3-1.9 cm, maximum clast size is 7.5 cm (limestone); clast composition: 85% limestone, 5% red-purple siltstone, 10% white quartzite, trace limestone with chert. Matrix makes up 30% of sample, medium to coarse grained sandstone, very calcareous, poorly sorted, high in lithic (limestone) grains, overall color of unit is light brownish gray (5Y 6/1).

36 Sandstone, fine grained, calcareous, yellowish gray (5Y 7/2)

35 Micrite, mottle, slightly silty and sandy, pale red (10R 6/2) predominantly covered interval.

34 Conglomerate, pebbly, 1.3-1.9 cm average clast size, maximum clast size is 5 cm (white quartzite), clast composition: 90% Paleozoic limestone, 10% quartzite.

33 Micrite, mottled, slightly sandy and silty, pale red (10R 6/2), predominantly slope covered.

32 Conglomerate, pebbly, occasional 7.5-12 cm sandstone lenses, average clast size: 1.9-2.5 cm, maximum clast size: 12 cm (white quartzite), clast composition: 90% Paleozoic limestone, 10%...
white quartzite, matrix is medium to coarse grained sand, calcareous, poorly sorted, lithic, pale reddish purple (5RP 6/2)

31 Interbedded siltstone, and micrite, siltstone is very calcareous, grades into a micrite, easily diaggerated in HIC leaving small silty residue; yellowish gray (5Y 7/2), micrite is silty, extremely mottled, color fresh is grayish red (5R 7/2) with minor amounts of yellowish gray (5Y 7/2); color weathered is dominantly pale red (10R 6/2) with patches of dusky yellow (5Y 6/4).

30 Conglomerate, pebbly, average clast size is 1.3-1.9 cm, maximum clast size is 10 cm (white quartzite), occasional 2.5-7.5 cm reddish sandstone lenses throughout unit, clast composition: 95% Paleozoic limestone, 5% quartzite.

29 Micrite, terrigenous, top 1.5 m is mottled pale red (5R 6/2), grades down into cleaner, pure micrite, dark yellowish brown (10YR 4/2) to brownish gray (5YR 4/1) on fresh surface, yellowish gray (5Y 7/2) on weathered surface, bottom of subunit interbedded with fine-grained sandstone.

28 Conglomerate, pebbly, average clast size is 1.3-1.9 cm, maximum clast size is 10 cm (white quartzite), overall color is grayish orange (10YR 7/4).

27 Micrite, slightly silty and sandy, upper third of unit is mottled pale red (5R 6/2), middle 1.5-3 m of subunit grades into fine-grained sandstone, very calcareous, yellowish gray (5Y 7/2), basal third of unit is mottled micrite as top third of subunit, intraclastic, apparently extensively bioturbated.

26 Conglomerate, pebbly, average clast size is 1.3-1.9 cm, bimodal with 1.3-1.9 cm and 1.3 cm average clast sizes, maximum clast size is 7.5 cm (limestone); clast composition: 100% Paleozoic limestone, conglomerate grades into sandstone in top 60 cm of unit, basal contact is sharp where exposed.

25 Interbedded siltstone, sandstone and micrite, siltstone very calcareous, grades into a micrite, yellowish gray (5Y 7/2); sandstone, very fine grained, yellowish gray (5Y 7/2); top 1.5 m is mottled, pale red (5R 6/2) micrite, clean of terrigenous material, apparently bioturbated.

24 Conglomerate, pebbly, average clast size is 1.9-2.5 cm, maximum clast size is 6.5 cm (white quartzite), clast composition: 95% Paleozoic limestone, 5% quartzite.
Siltstone and micrite, siltstone is calcareous, yellowish gray (5Y 7/2), fluctuates from very sandy to very calyey; micrite is silty and sandy, top 3 m of unit is mottled pale red (5R 6/2). See Plate 3 Figure 3 for picture of contact between overlying conglomerate and micrite.

Conglomerate, pebbly, very sandy, almost a pebbly sandstone, average clast size is 1.3-1.9 cm, maximum clast size is 5 cm (white quartzite), clast composition: 98% Paleozoic limestone; matrix is medium to coarse grained sandstone, calcareous, grayish yellow (5Y 8/4), upper half of unit has occasional 7.5-12 cm thick sandstone lenses.

Covered Interval, probably a sandstone and siltstone lithology, soil color pale red.

Conglomerate, pebbly, average 1.3-2.5 cm, maximum clast size is 18 cm, (white quartzite), clast composition: 90-95% Paleozoic limestone, 10% quartzite.

Micrite, silty, mottled, pale red (5R 6/2), unit predominantly a covered interval.

Conglomerate, pebbly, average clast size is 1.3 cm, maximum clast size is 18 cm (white quartzite), occasional sand lenses 18-30 cm thick, medium to coarse grained sandstone.

Covered interval-probably interbedded sandstone and silty micrite.

Conglomerate, pebbly, bimodal with average clast size of 1.3-2.5 cm and 5-7.5 cm, maximum clast size is 14 cm (limestone clast with chert lenses); clast composition: 90-95% Paleozoic limestone, few with chert lenses, 5-10% white quartzite; occasional sandstone lenses and beds 18 to 60 cm thick, light gray (N7) to yellowish gray (5Y 7/2), calcareous, some ripple cross-bedding.

Sandstone, fine to very fine grained, very pale orange (10YR 8/2) to pale yellowish brown (10YR 6/2), calcareous, platy splitting.

Conglomerate, pebbly, average clast size is 30-60 cm, clast composition: 95% Paleozoic limestone, 5% quartzite; upper part of unit has 60-90 cm thick sandstone beds interbedded in conglomerate.

Sandstone, grayish orange (10YR 7/4) to yellowish gray (5Y 7/2), fine to medium grained, calcareous.

Conglomerate, pebbly, predominantly a slope forming
unit, average clast size is 0.9-2.5 cm, clast composition: all Paleozoic limestone.

11 Sandstone, grayish orange (10YR 7/4) to yellowish gray (5Y 7/2), fine to medium grained, very calcareous, platy splitting. 4.0 53.9

10 Conglomerate, pebbly, clast size and composition as in above unit. 4.0 50.0

9 Sandstone, silty, grayish orange (10YR 7/4), fine grained, generally a slope forming unit, some minor small scale ripple cross-bedding, questionable direction of transportation N 70-80 E. 2.1 46.0

8 Conglomerate, pebbly, clast size and composition as unit 12. .9 43.9

7 Sandstone and micrite, interbedded, basal part is silty micrite, mottled, pale red (5R 6/2), grades upward into fine grained, sandstone, grayish orange (10YR 7/4) to very pale orange (10YR 8/2). 4.9 43.0

6 Conglomerate, pebbly, maximum clast size is 10 cm (white quartzite) clast composition: 95% Paleozoic limestone, 5% quartzite, trace Precambrian quartzite (small pebble size), contacts above and below unit are sharp. 7.6 38.1

5 Sandstone, very fine grained, mottled, pale red (5R 6/2), calcareous. 2.1 30.5

4 Conglomerate, pebbly, average clast size is 1.3-2.5 cm, unit is ledge former, numerous thin 7.5-12 cm sandstone lenses occur throughout unit. 12.2 28.3

3 Sandstone, fine grained, calcareous, grayish orange (10YR 7/4) to moderate red (5R 5/4), predominantly a slope former. 4.9 16.2

2 Conglomerate, pebbly and sandy, maximum clast size is 30 cm (white quartzite), clast composition: 95% Paleozoic limestone, 5% quartzite, trace mottled reddish siltstone clasts; matrix is fine to medium grained sandstone, reddish, thin 2.5 cm sandstone lenses in upper half of unit. 7.9 11.3

1 Sandstone, fine to medium grained, calcareous, grayish orange (10YR 7/4), platy splitting, predominantly a slope former. 3.4 3.4

COVERED INTERVAL  Base of section
REFERENCES CITED


Loughlin, G. F., 1912, Reconnaissance in the South Wasatch Mountains, Utah, Jour. Geol., vol. 21, p. 448.


Figure 1  Index map of central Utah.

Figure 2  Topographic index map showing location of study area and measured sections.

Figure 3  Generalized correlation chart.

Figure 4  Geologic map of study area.

Figure 5  Detailed columnar sections showing variations in clast size, clast composition, and presence of sedimentary structures, paleoecology and paleocurrent direction indicators.

Figure 6  Block diagram of study area showing paleoenvironmental and structural development of Canyon Range.
<table>
<thead>
<tr>
<th>LOCAL FORMATIONS</th>
<th>SUGGESTED CORRELATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>GREEN RIVER</td>
<td>UNIT B</td>
</tr>
<tr>
<td>FLAGSTAFF</td>
<td></td>
</tr>
<tr>
<td>NORTH HORN</td>
<td>UNIT A</td>
</tr>
<tr>
<td>PRICE RIVER</td>
<td></td>
</tr>
</tbody>
</table>
LEGEND-Figure 5

- CONGLOMERATE
- SANDSTONE
- SILTSTONE, SHALE
  or MUDSTONE
- LIMESTONE

- ONCOLITES
- ROOTS
- LEAF IMPRINTS
- GASTROPOD

- BURROWING
- RIPPLES
- MEGARIPPLES
- CROSS-BEDS
- CHANNELING
- INTRACLASTIC

+ Vertical bars denote calcareous nature. ++ Bars denote silty nature

PALEOCURRENT DIRECTION

Arrow points in current direction
WEST

EARLY-LATE CRETACEOUS
Major Thrusting

PALEOZOICS

LATE CRETACEOUS
Price River Deposition

PALEOCENE-EOCENE
North Horn-Flagstaff Deposition

EAST
Plates

Plate 1 - Figure 1  View facing west at the east side of the Canyon Range with location of measured section Unit A.

Figure 2  Low angle air photograph facing west at ridge with location of measured section of Unit B. Note topographic expression of Unit B compared to that of Unit A, Pl. 1, Fig. 3.

Figure 3  Typical topographic expression of Unit A as seen on the north side of Cow Canyon.

Figure 4  Contact of Unit A with undifferentiated Cambrian limestone on the east side of Oak Creek summit.
Plate 2 - Figure 1  Thrust contact of Precambrian sequence with underlying Unit A. View facing north from Oak Creek summit.

Figure 2  Contact of thrust between Unit A and Precambrian sequence between Oak Creek summit and Cow Canyon.

Figure 3  Thrust contact north of Cow Canyon; photograph facing north.

Figure 4  Gentle dipping Unit A unconformably resting on Precambrian quartzite strata of the allochthonous plate north of Oak Creek summit.
Plate 3 - Figure 1
Photograph facing southwest towards study area. Ridge in the foreground is east-dipping strata of Unit B located north of Wide Canyon. Unit A in the upper left hand corner is gently east dipping.

Figure 2
Photograph facing west at gently east dipping strata of Unit A. Right center of photograph is same as upper left hand corner of Figure 1. Cow Canyon is located in the right center of the picture.

Figure 3
Contact of subunits 23 and 24 of stratigraphic Unit B. Conglomerate clast size and composition is typical for all of Unit B. Underlying unit is red, mottled silty wackestone.

Figure 4
Typical conglomerate unit (subunit 25) from stratigraphic Unit A. Clasts are composed of quartzite from the Precambrian or basal Cambrian.
<table>
<thead>
<tr>
<th>Plate 4 - Figure 1</th>
<th>Thin section of sandstone from subunit 57 of stratigraphic Unit B.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 2</td>
<td>Thin section of sandstone from subunit 75, Unit B.</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Thin section of silty, mottled wackestone from subunit 27 of Unit B.</td>
</tr>
<tr>
<td>Figure 4</td>
<td>Thin section of algal laminite hash-limestone from subunit 77 of Unit B.</td>
</tr>
</tbody>
</table>
Plate 5 - Figure 1
Thin section of oncolitic limestone from subunit 71, stratigraphic Unit B.

Figure 2
Thin section of oncolitic limestone from subunit 71, stratigraphic Unit B. Note gastropod-like form in elongate oncolite.

Figure 3
Thin section of sandy, oncolitic limestone from subunit 95, stratigraphic Unit B.

Figure 4
Thin section of oncolitic limestone from subunit 71, stratigraphic Unit B. Note algal mat fragment which has been ripped up and reincorporated in oncolite in lower left corner of photograph.
Plate 6 - Figure 1
Thin section of large oncolite showing internal structure from subunit 71 of Unit B.

Figure 2
Large channel at base of subunit 9 of stratigraphic Unit A.

Figure 3
Photograph of ripple, cross-beds observed in subunit 92 of stratigraphic Unit B.

Figure 4
Thin section of ripple, cross-bedded sandstone from subunit 69, Unit B with vertical burrow of Planolites sp. Note V-shaped backfilling above transverse crack in section.